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Industrial Engineering and Environmental Protection

IIZS conference

PROCEEDINGS

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Zrenjanin, 11-12th October 2018.

University of Novi Sad
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INTRODUCTION

Departments of Mechanical engineering at Technical Faculty "Mihajlo Pupin", Zrenjanin, organized seven international conferences «Industrial Engineering and Environmental Protection - IIZS».

Since 2017, Department of Industrial engineering in exploitation of oil and gas has been joined to the Conference organization, and since 2018, Department of Environmental protection has been joined for the first time.

Industrial engineering is a field of technique, which includes the processes and procedures, plants, machinery and equipment used in manufacturing final products in different industries. The task of industrial engineers is that on the basis of theoretical and practical knowledge, solve specific problems in engineering practice, and the development of technology in the field of industrial production process.

The theme of scientific conference «IIZS 2018», covers the fields of Industrial engineering and Environmental protection, which are defined in the program of the conference, such as: Mechanical engineering, Energetics and process technique, Designing and maintenance, Oil and gas engineering, Health and environmental protection, Environmental management, Occupational safety.

The main goals of the conference can be identified here: innovation and expansion of knowledge engineers in industry and environmental protection; support to researchers in presenting the actual results of research projects, establishing new contacts with leading national and international institutions and universities; popularization of the faculty and its leading role in our society and the immediate environment, in order to attract quality young population for studying at our faculty, cooperation with other organizations, public companies and industry; initiative for collecting ideas in solving specific practical problems; interconnection and business contacts; introducing professional and business organizations with results of scientific and technical research; presentation of scientific knowledge and exchange of experiences in the field of industrial engineering.

We express gratitude to:

- The partners of the conference – „Aurel Vlaicu" University of Arad, Faculty of engineering, Arad, Romania; University «St. Kliment Ohridski«, Technical faculty, Bitola, Macedonia; University Politehnica Timisoara, Faculty of engineering, Hunedoara, Romania; University of East Sarajevo, Faculty of mechanical engineering East Sarajevo, B&H, Republic of Srpska; University of Giresun, Faculty of engineering, Giresun, Turkey.
- The management of Technical Faculty «Mihajlo Pupin», University of Novi Sad,

for supporting the organization of the conference «IIZS 2018». We are also grateful to all the authors who have contributed with their works to the organization of the scientific meeting «IIZS 2018».

We would like our Conference to become a traditional meeting of researchers, every year. We are open and thankful for all useful suggestions which could contribute that the next, International Conference - Industrial Engineering and Environmental Protection, become better in organizational and program sense.

President of the Organizing Committee
Prof. Ph.D Slavica Prvulović

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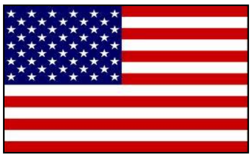

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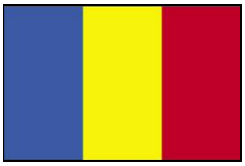

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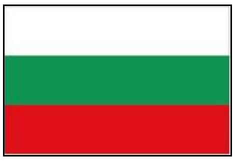

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ANTAGONISTIC ACTIVITY BETWEEN RHIZOBACTERIA AND PHYTOPATHOGENIC FUNGI UNDER ECOLOGICAL FACTORS

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Abstract: The objective of the present work is to show the ability of different plant root colonizing bacteria isolated from wastewater sludge treated soil to antagonise some phytopathogenic fungi under different ecological factors such as NaCl, $CdCl_2$, $ZnCl_2$, pH 8.3 and 35°C incubation temperature. All antagonists assigned to show different patterns of antagonistic activity against different phytopathogens like *Alternaria* sp., *Fusarium oxysporum, F. solani, Pythium* sp., *Rhizoctonia solani* and *Sclerotinia* sp. Application of *Pseudomonas, Burkholderia cepacia, Enterobacter* sp. and *Bacillus* cells showed a significant reduction in the growth of phytopathogens *in vitro* experiments. However, *P. fluorescens* strongly inhibited the growth of phytopathogens more than the action of other antagonists due to production rates of allelochemicals that include metabolites, siderophores, antibiotics, volatile metabolites, cyanide and hydrolytic enzymes. This study will help to optimize the application strategies of *P. fluorescens*, *Burkholderia cepacia* and *B. subtilis* as biocontrolling agents or their metabolites as biopesticides. Finally, biocontrolling is an alternative, environmentally friendly and relatively cost-effective to conventional biological soil treatment technique.

Key words: Biocontrol agent, PGPR, Phytopathogens, Ecological factors, Hydrolytic enzymes

INTRODUCTION

Increasing the global human population needs more food and the world population will rise to about 9.5 billion by 2050. Implementing safe and environmental friendly technology would be viable solution for achieving sustainable restoration of degraded soils. Worldwide, phytopathogenic fungi constitute a big problem because they affect a large number of crop species of economic importance causing multiple damages and diseases in agroecosystems.

Plant diseases cause economic losses by reducing crop production and contaminating plant crops with chemical toxicants. Disease is a dynamic interaction between a pathogen, a host and the environment, which causes physiological and morphological abnormal changes in the host. Therefore, disease is not a property of the host, but a product of the interrelationship of host and pathogen under a specific environment. The endless variety and complexity of the many diseases of plants caused by fungi have led to develop of large new fungicides; unfortunately several phytopathogens have developed resistance to certain fungicides for e.g., resistant to benomyl. Success rate of microbial inoculation under field conditions depends on their antagonistic or synergistic interaction with indigenous microbiotas or their inoculation with organic fertilizers [1].

Allelochemistry is the science of the production and release of toxic chemicals produced by one species that affect a receiving sensitive species, has been the subject of diverse groups of scientific community. Allelopathy defined as chemically elicited interactions between plants or pathogens is mediated by secondary metabolites type of compounds [2]. Allelopathy involves the synthesis of bioactive compounds known as “allelochemicals” which play a vital role as natural pesticides and can resolve problems like pest biotypes, health defects, soil and environment pollution resulting in climate change caused by the indiscriminate use of synthetic agrochemicals [3]. The allelopathic effect is highly dependent on environmental conditions such as water, nutrition, bacterial density, soil structure, and texture [4]. Biocontrol is a desirable technique for controlling pathogens, due to its minimal environmental impact and preventing the development of resistance in vectors. Biocontrol has been defined a number of times. A recent definition by Eilenberg et al. [5] is the use of living organisms to suppress the population density or impact of a specific pest organism, making it less abundant or less damaging than it would otherwise be. Biocontrol can be divided into four complementary strategies: classical, inoculation, inundation and conservation.

Rhizobacteria are the most widely studied as plant growth-promoting bacteria, associated with plant rhizosphere and are present in all agroecosystems. Antagonistic rhizobacteria are considered as biological control [biocontrol] agents because of the rapid growth, easy handling, and aggressive

colonization of the rhizosphere. The use of Plant growth promoting rhizobacteria (PGPR) as biocontrol agents of soil borne phytopathogens is an alternative or complementary strategy to physical and chemical disease management have been investigated for over a century.
PGPR support plant growth by improving growth restricting conditions via production of antibiotics; depletion of iron from the rhizosphere; production of fungal cell wall lysing enzymes β-(1,3)-glucanase and chitinase; synthesis of antifungal metabolites such as cyanide; competition for infection sites on roots; induction of systemic resistance [6]. PGPR include Gram-positive bacterial taxa that include e.g., *B. subtilis* and Gram-negative bacteria like fluorescent and non-fluorescent pseudomonads as well as different members of the family Enterobacteriaceae e.g., *Enterobacter*. In particular, strains of *Pseudomonas, Stenotrophomonas*, and *Bacillus* have been successfully used to control phytopathogens and increase plant growth [7]. The fungal antagonists *Pseudomonas stutzeri, B. subtilis, B. amyloliquefaciens*, and *S. maltophilia* have been shown to be effective biocontrol agents in prior studies [8, 9, 10].
Various *Pseudomonas* species produce several metabolites with antimicrobial activity towards other bacteria and fungi. Indeed, the first clear-cut experimental demonstration that a bacteria-produced antibiotic could suppress plant disease in an ecosystem was made by Thomashow & Weller [11].
The objectives of this study were to identify and characterize PGPR indigenous and to evaluate their ability to suppress the growth of some phytopathogenic fungi. The role of PGPR in adaptation of plants in extreme environments is not yet completely understood. For this reason, isolation of native rhizobacteria was done from rhizospheric soils treated with 30% wastewater sludge and evaluation of their antagonistic potential against different phytopathogenic fungi under different ecological conditions such as temperature, pH, alkaline and heavy metal ions was investigated.

MATERIAL AND METHODS

Rhizospheres of two commercial cultivars of sunflower and maize were grown under nursery conditions for 5 weeks were used to isolate the following rhizomicrobial strains and study their antagonistic potential. The soil type of the rhizosphere was sandy brown forest soil (Gödöllő, Hungary) treated with 30% wastewater sludge (originated from Nyíregyháza, Hungary). The plants were grown in plastic pots containing one kilogram non-sterile wastewater sludge treated soil for 5 weeks under greenhouse conditions to be consisted of a 16 h day light at temperature 25±3°C. The plant cultures were watered as necessary to maintain the soil moisture at approximately 60%.
The selected potent rhizobacterial antagonists were: *Pseudomonas fluorescens, P. aureofaciens, P. putida, P. aeruginosa, Stenotrophomonas maltophilia, Burkholderia cepacia, Enterobacter* sp., *Bacillus subtilis, B. cereus, B. mycoides* and *Streptomyces* sp. The selected phytopathogenic fungi used were: *Alternaria* sp., *Fusarium solani, Fusarium oxysporum, Pythium* sp., *Rhizoctonia solani* and *Sclerotinia* sp.

Detection of hydrolytic enzyme produced by rhizobacteria

The selected colonies of antagonists were investigated in agar plate assay for chitinase and protease activity. The chitinase activity was assessed using a soil minimal medium containing (gl^{-1}): 0.8 K_2HPO_4, 0.2 KH_2PO_4, 0.5 $(NH_4)_2SO_4$, 0.2 $MgSO_4.7H_2O$, 2 Casamino acids, 15 purified agar and an equal volume of 1% (w-v) of colloidal chitin suspension (Sigma), as well as containing (mgl^{-1}): 10 $CaCl_2.2H_2O$, 10 $FeCl_3.6H_2O$, 1 $ZnSO_4.7H_2O$, and distilled water. The protease activity was investigated on plates containing (gl^{-1}): 100 skim milk, 1.5 yeast extract, and 15 technical agar, and distilled water. Using the procedure described by Dunne et al. [12], the isolates were spotted onto the agar surfaces. The plates were incubated for 1 or 3 and 2 or 5 days at 28°C. The assays were repeated three times. Both chitin- and skim milk- containing plates are opaque and enzyme activity was identified by the development of a clear zone around the colonies and spots.

In vitro Screening for Antagonism

To test antagonism of *Alternaria* sp., *F. oxysporum, F. solani, Pythium* sp., *Sclerotinia* sp. and *Rhizoctonia solani* by each strain of rhizobacteria *P. fluorescens, P. aureofaciens, P. putida, P.*

aeruginosa, *Stenotrophomonas maltophilia*, *Burkholderia cepacia*, *Enterobacter* sp., *B. subtilis*, *B. cereus*, *B. mycoides* and *Streptomyces* sp., the pathogen and bacteria were inoculated 3 cm a part on the same a garplate. Fungal growth on each plate was observed, and the zone of inhibition, if present, was determined as following:

$$\% \text{ Inhibition of mycelial growth} = [(X-Y)/X]\times 100 \quad (1)$$

Where, X is mycelial growth of pathogen in absence of antagonists and Y is mycelial growth of pathogen in presence of antagonists.

***In vitro* antagonistic activity at different environmental conditions**

The investigation of the antagonistic effect was carried out by the same procedure mentioned above. Under the variations of the ecological factors, the six selected rhizobacterial strains were screened for their antagonistic activity towards *Alternaria* sp., *F. oxysporum*, *F. solani*, *Pythium* sp., *Sclerotinia* sp. and *Rhizoctonia solani* onto potato dextrose agar (PDA) medium. Zones of inhibition were recorded after 2 and 5 days of incubation at 35°C or with different concentrations of 25 mM of NaCl or under the stress of 25 µM of $CdCl_2$ and $ZnCl_2$ or under pH 8.3 values. Fungal growth on each plate was observed, and the zone of inhibition, if present, was determined as described above.

RESULTS AND DISCUSSION

The antagonistic study showed that the inoculation of PGPR biocontrol agents significantly increased the plant growth in nursery conditions (data not show). Thus this study underlines the commercial potential of the selected PGPR biocontrol agents for sustainable plant cultivation.

Detection of hydrolytic enzyme produced by rhizobacteria

The investigation of the chitinase and protease activities of the selected antagonistic rhizobacteria is illustrated in Figure 1. It was found that *P. fluorescens* was the most enzyme producing strains, while the *Stenotrophomonas* was the lowest producer.

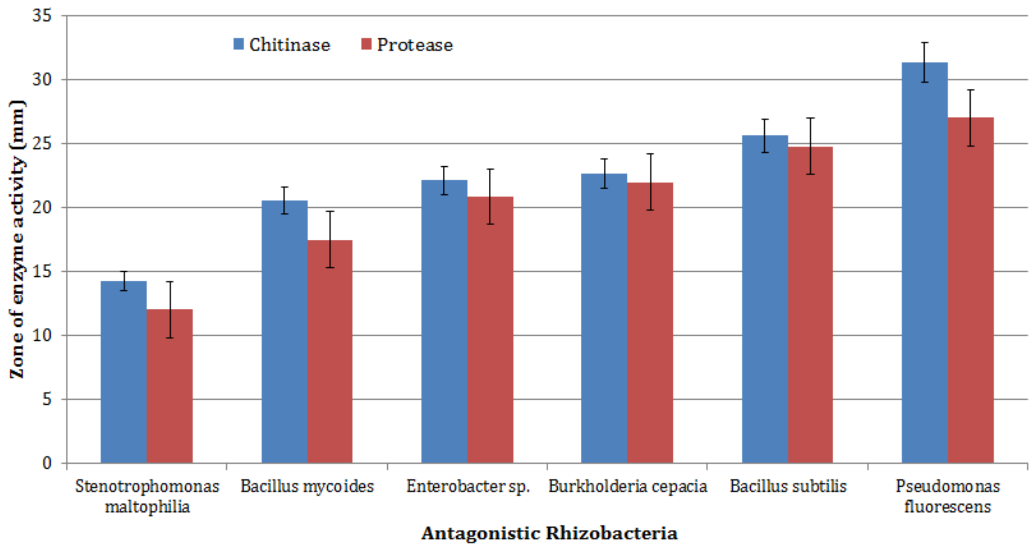

Figure 1. Enzymatic activities of antagonistic rhizobacteria

***In vitro* Screening for antagonism**

The results of the antagonistic potential of the rhizobacterial strains are demonstrated in Figures 2-7. Figures 2, 3, 5, 6 and 7 show that the strains *P. fluorescens* had the highest inhibiting potent on the growth of *Rhizoctonia solani*, *Alternaria* sp., *F. oxysporum*, *F. solani*, and *Sclerotinia* sp., respectively. Also these figures demonstrate that the *Streptomyces* sp. had the lowest inhibitor and produce low antagonistic metabolites to reduce the growth of these phytopathogens. Figure 4. shows that *Enterobacter* sp. strain had the highest potent to reduce the growth of *Pythium* sp.

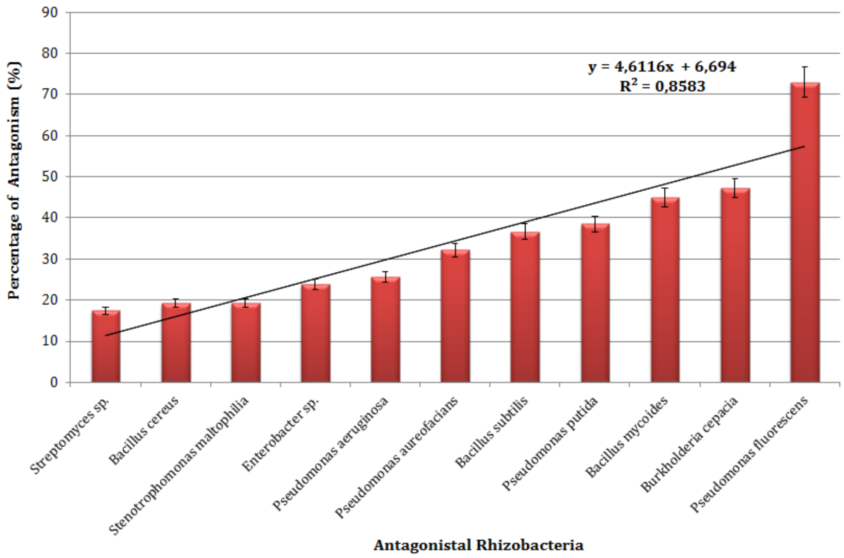

Figure 2. Effect of different antagonists on the growth of *Rhizoctonia solani*

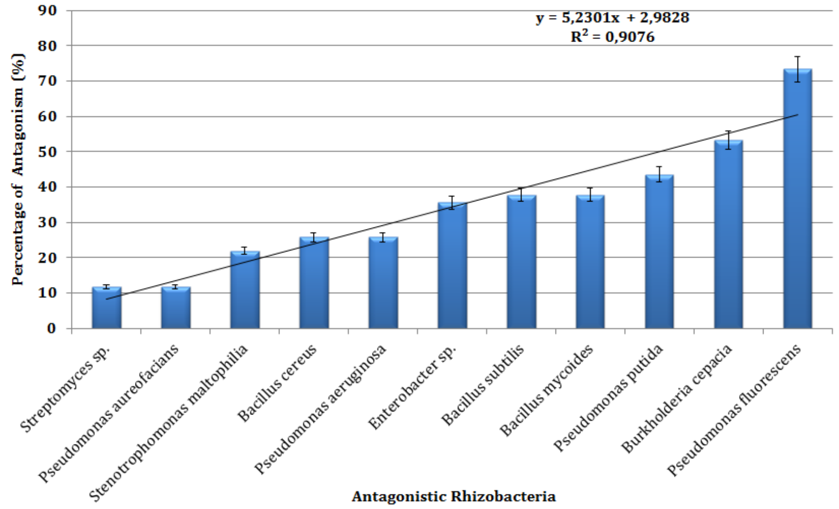

Figure 3. Effect of different antagonists on the growth of *Alternaria* sp.

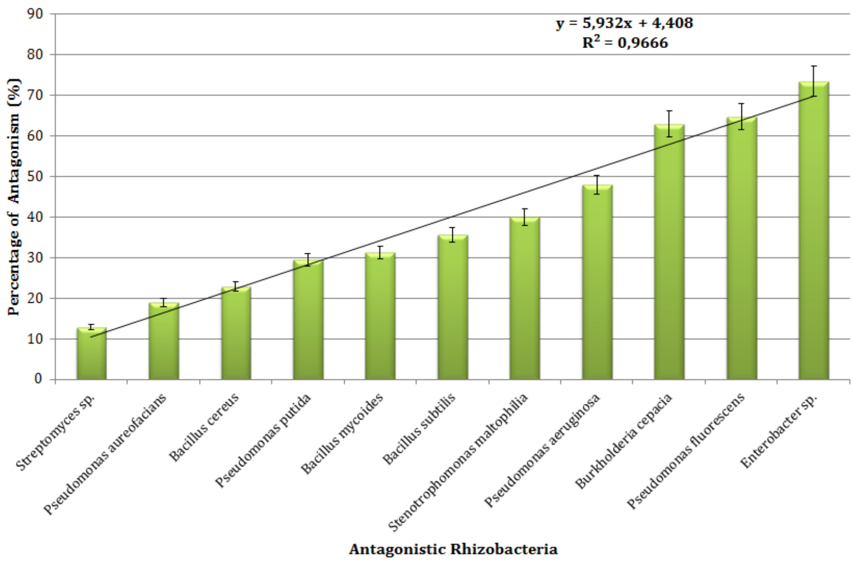

Figure 4. Effect of different antagonists on the growth of *Pythium* sp

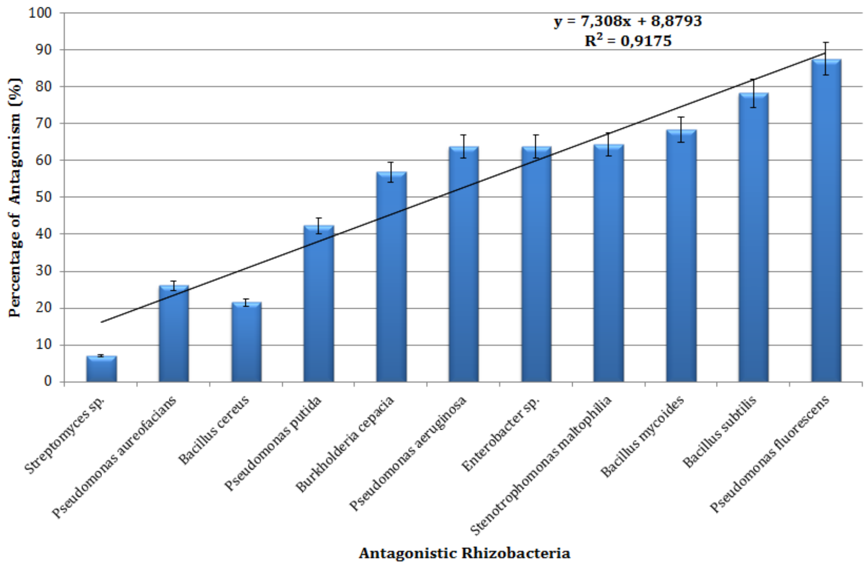

Figure 5. Effect of different antagonists on the growth of *Fusarium oxysporum*

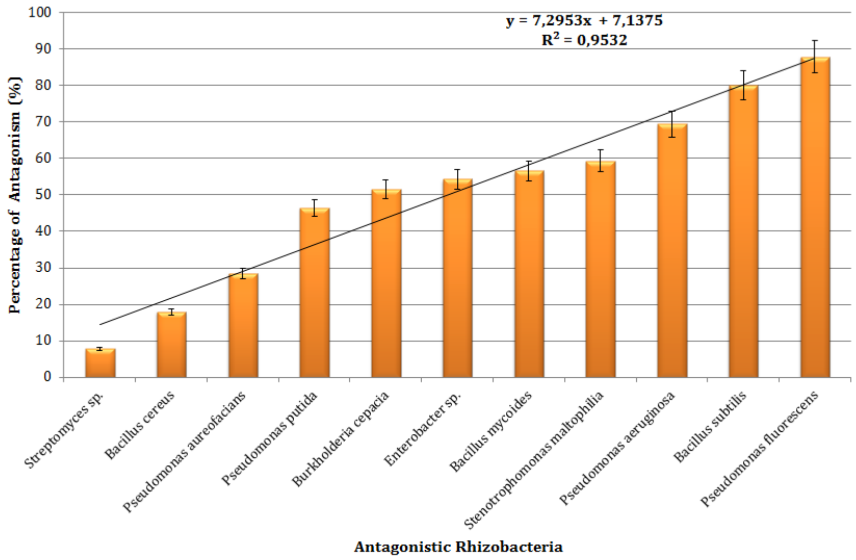

Figure 6. Effect of different antagonists on the growth of *Fusarium solani*

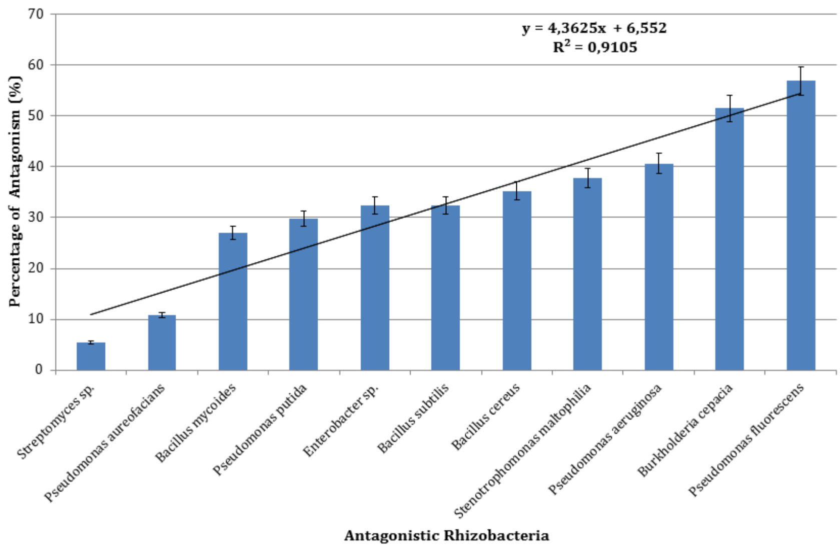

Figure 7. Effect of different antagonists on the growth of *Sclerotinia* sp

In vitro antagonistic activity at different environmental conditions

Under the effect of 25 mM of NaCl, *B. mycoides* was the most inhibitor to the all investigated phytopathogenic fungi (Figure 8) and the strain Enterobacter had the lowest inhibition potent to reduce the growth of the tested fungi.

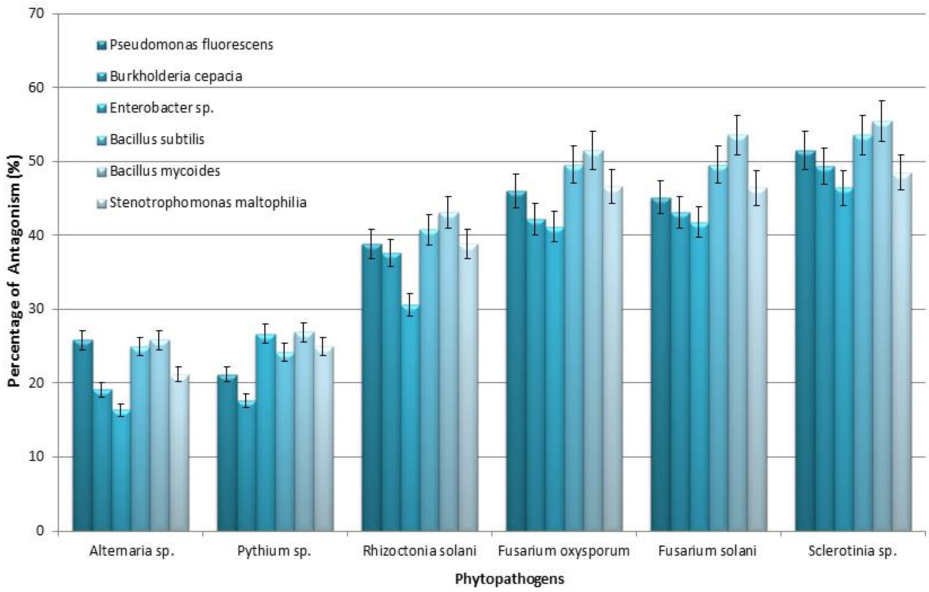

Figure 8. Effect of different antagonists on the growth of phytopathogens under the stress of NaCl salt

Figure 9 shows that under the stress of 25 µM of $CdCl_2$, the strain *B. mycoides* was the most significant antagonist to reduce the growth of *Alternaria* sp., *Pythium* sp. and *Sclerotinia* sp., it was able to reduce the growth of *Alternaria* sp. and *Pythium* sp. more than the other antagonists (Figure 10) and *P. fluorescens* was significant inhibitor to reduce the growth of *Alternaria* sp. and *F. oxysporum* under the stress of $ZnCl_2$. The strain *Burkholderia cepacia* had the antagonistic potent to reduce the growth of *R. solani* and *F. oxysporum*.

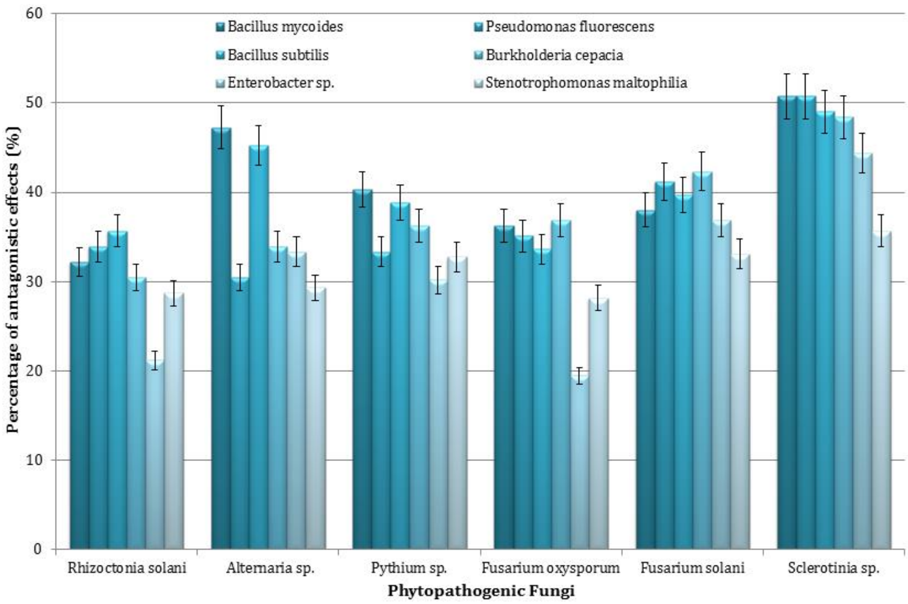

Figure 9. Effect of different antagonists on the growth of phytopathogens under the stress of $CdCl_2$

Figure 11 demonstrates the effect of incubation temperature at 35°C on the antagonistic activity of the antagonists on the phytopathogenic fungi. It was found that at this temperature *Enterobacter* sp. strain had the lowest potent to reduce the growth of the tested fungi except at the case of *Sclerotinia* sp. which was inhibited more by the antagonist *B. mycoides*.

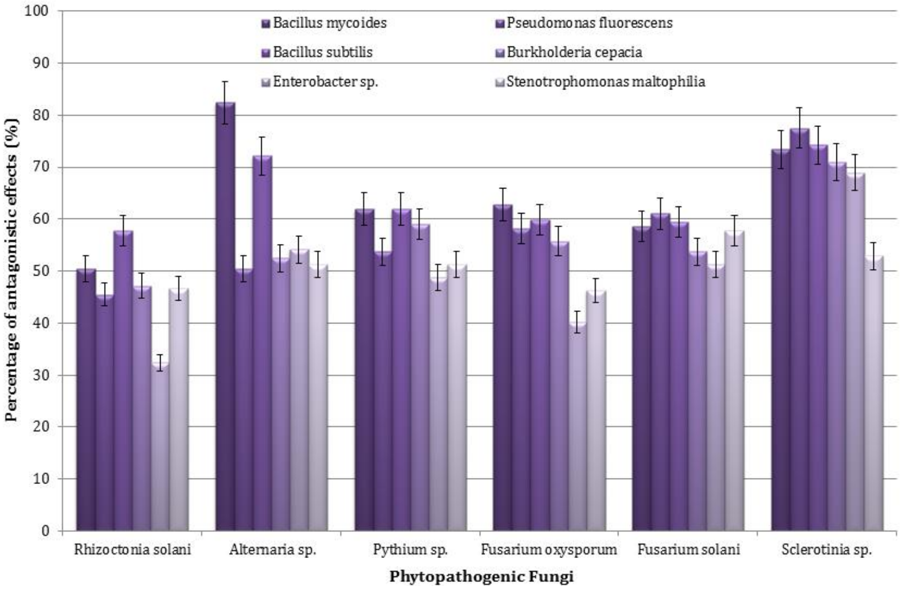

Figure 10. Effect of different antagonists on the growth of phytopathogens under the stress of $ZnCl_2$ salt

Also, it was found that *B. mycoides* inhibits significantly the growth of *F. solani* and *Alternaria* sp. *S. maltophilia* was the most inhibitor and growth reducer of *R. solani* and *F. oxysporum*. Figure 12 demonstrates the effect of alkaline pH on the antagonistic potent of different antagonists on the phytopathogenic fungi. It was found that pH 8.3 stimulates the antagonistic effects of the strain *Burkholderia cepacia* to reduce the growth of *R. solani*, *Alternaria* sp., *F. solani* and *Sclerotinia* sp., while *B. subtilis* was able to reduce the growth of *F. oxysporum* significantly.

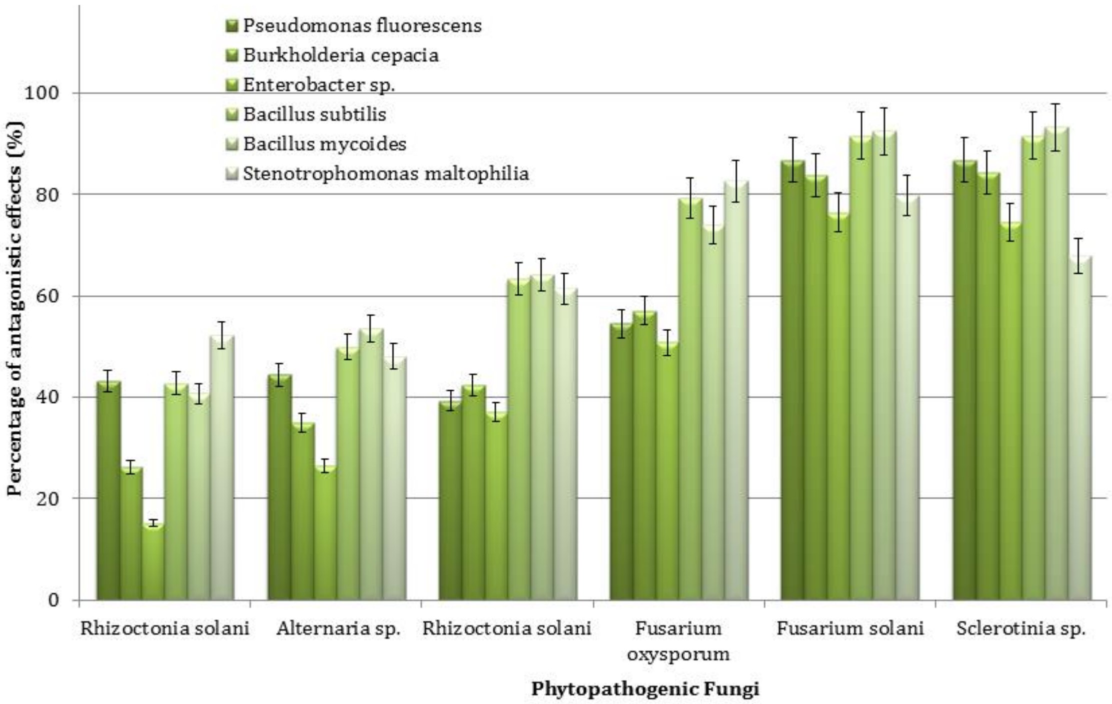

Figure 11. Effect of different antagonists on the growth of phytopathogens under 35°C

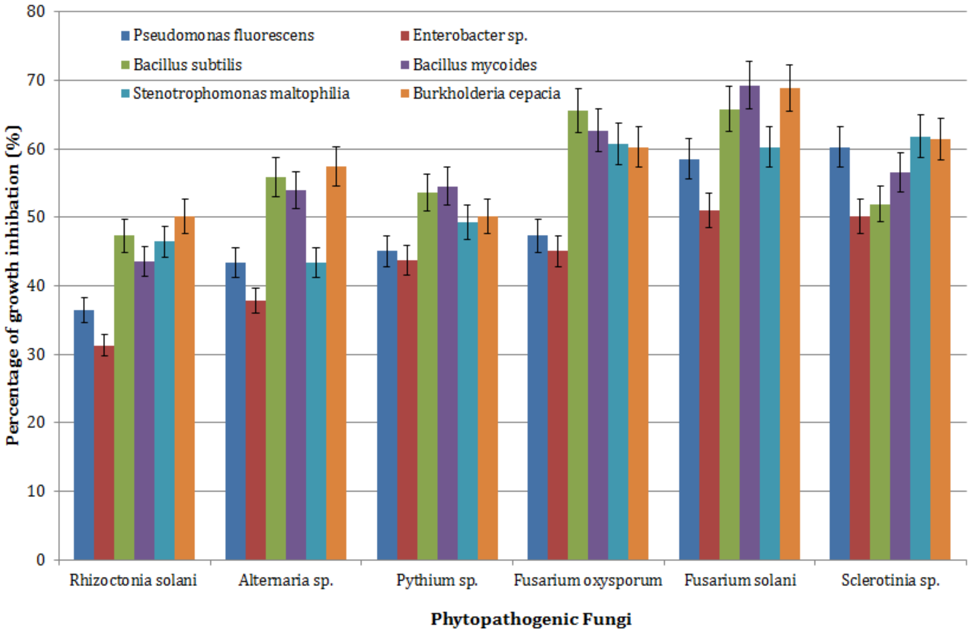

Figure 12. Effect of different antagonists on the growth of phytopathogens under pH 8.3

Bayoumi Hamuda and Kecskés [13] showed that in the antagonistic experiments there was no antagonistic effect among the tested microorganisms. Antagonistic relationships are the keys in the biocontrol of many soil borne phytopathogens and in the successful introduction and survival of soil microbes and rhizosphere. Soil is a dynamic living matrix and an important resource for agricultural products. Soil is also a store-house of microbial activity, which is confined to aggregates with accumulated organic matter, the rhizosphere. The rhizosphere both contacts plant roots and supports high populations of active microorganisms and it has attracted much interest [14].

Siderophores chelate available iron from the soil; antibiotics discourage bacterial colonization; lytic enzymes degrade many organic compounds including chitin (main component of fungal cell walls); detoxification enzymes prevent damage from pathogenic toxins. Production of volatiles such as hydrogen cyanide, suppress the growth of fungal phytopathogens; the ability to successfully compete with phytopathogens for nutrients or specific niches on the root; and the ability to induce systemic resistance (ISR) [15]. So, PGPR was found to be mainly involved in enhancing plant nutrition, stress tolerance or health [16]. Since these PGPR inoculants exhibited multiple characters benefit to the host plants, they may be applied in the development of new, safe, and effective seed treatments as an alternative to chemical fungicides.

A considerable worldwide research has focused on the exploration of varied agro-ecological niches for the existence of native beneficial microorganisms. In the current study, rhizobacteria with in vitro PGPR traits were isolated from sewage sludge treated rhizospheric soil of 2 different plant species. These potential PGPR isolates were enumerated and screened in vitro for a broad spectrum for antagonistic potential against phytopathogenic fungi. Selected strains scoring high rank as PGPR were identified and their phylogenetic affiliations were determined. Antagonistic potential against phytopathogenic fungi was selected as criteria to have a preliminary judgment for the isolates whether they possess PGP traits or not. Isolates having antagonist potentials were considered as good candidates for being PGPR because of their indirect effect for promoting plant growth via inhibition of various plant phytopathogens.

Lytic enzymes is another trait associated with PGPR enabling them to limit fungal phytopathogens growth, as in vitro studies showed that the exposure of selected plant pathogenic fungi to lytic enzymes such as chitinase and protease for example can result in degradation of the structural matrix of fungal cell wall [17]. In our study, it was observed that all selected antagonists were chitinase- and protease-producers.

Bacillus spp. is known for their wide distribution in many soil types. Among all *Bacillus* spp. that have been isolated and characterized as PGPR, spore-forming bacilli have received much attention for commercial purposes due to their stability in the environment. Mirza et al. [17] reported the isolation of strains of *Enterobacter* spp. from rhizosphere of sugarcane and illustrated their ability to function as PGPR. *Enterobacter* spp. strains were also found in diversity of PGPR isolated from sugarcane cultivated in South of Brazil [18]. In an effort to study the diversity of PGPR associated with rhizospheric soil and roots of canola, Farina et al. [19] found that *Pseudomonas* and *Enterobacter* were among the most abundant rhizospheric bacteria showing several PGPR traits. It has also been reported that *Pseudomonas* spp. is one of the most important bacteria inhabiting the rhizosphere of a diverse group of plants [20]. It has been shown that, in comparison to other plant microenvironments, the rhizosphere is one of the main reservoirs of antagonistic bacteria [21] with pseudomonads as being most dominant bacteria showing antagonistic properties and therefore potential PGPR [22]. However, in contrast to these reports, our results suggest that rhizoplane of wild plants in arid soil is a potential source for pseudomonades with PGP properties rather than rhizosphere.

CONCLUSIONS

Rhizobacteria isolated from plants rhizosphere of 30% sewage sludge treated soil were found to harbour antagonistic activity against the investigated phytopathogenic fungi. These antagonistic rhizobacterial strains have broad spectrum of in vitro PGP abilities and antagonistic potentials in such environment. The results of in vitro studies should be considered at the time when the in vivo and field experiment studies will be done.

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USING SHERPA SCREENING TOOL FOR DESIGN AND ASSESSMENT OF LOCAL AND REGIONAL AIR QUALITY MANAGEMENT

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Abstract: As atmospheric pollution continue to be a significant issue on global level, but with a particular importance at European Union level, the air pollution reduction policies will continue to be enforced in the next decades. At EU level, especially on most developed countries, NO_2 and Particulate Matter (fine and coarse fractions) remain an acute problem. To help decision factors to have a better view on entire EU region the SHERPA (Screening for High Emission Reduction Potentials on Air quality) was developed, a tool that was proven helpful in addressing source allocation, governance and the assessment of scenario impacts.
Key words: SHERPA, air quality policy, air pollution, air quality assessment

INTRODUCTION

Good air quality is still a challenge in Europe. In 2015, 16 Member States out of 28 failed to comply with the European Union air quality limit values. The situation is more challenging in cities, where a high percentage of the population – up to 90%, according to the World Health Organization (WHO) limit values – is still exposed to pollution levels detrimental to health, both in terms of morbidity and mortality. From European to local level, policy-makers strive to improve air quality in urban areas. Although there are many possible interventions that can be made at the city scale through measures such as congestion charges, investment in public transport, or higher share of renewables in the energy used in district heating and cooling, it is difficult for policy-makers to quickly assess the consequences of policies on local air quality. The efficacy of those policies often depends on a combination of specific factors such as meteorology or topography, only to name some. The JRC-developed tool can help fill this gap. [1]
Many European cities suffer from poor air quality and regularly exceed both the European standards prescribed by the Air Quality Directive and the guidelines recommended by the World Health Organization. This is particularly the case for fine particulate matter (PM10) for which both the daily and yearly average limit values are regularly exceeded in many cities and several regions in Europe. Similar conclusions hold for PM2.5 where few cities manage to keep concentrations below the levels recommended by the WHO. Actions have been proposed and taken at the international, national and urban scales to reduce air pollution. While they have undoubtedly resulted in an overall improvement of the air quality over the years, there are still problems which are localized in specific regions and many cities. A key issue is thus to determine at which scale to act in order to abate these remaining air pollution problems most effectively. [2]
It is a continuous need to provide information to improve air quality policy governance, to support authorities in choosing the most efficient actions at the appropriate administrative level and scale. Actions at the local level can only focus on urban scale and are more immediate and easy to enforce. However, at national and international levels the decision making process is more difficult and needs more time and debate to reach final conclusions, SHERPA tool is design specially to bring air quality information's at EU level in order to support authorities in actions.
The impact of a given abatement measure on air quality differs from city to city, even for cities that are located in the same country. Actions taken at different scales or in different activity sectors

therefore lead to impacts on air quality that are city-specific. Consequently, it is important to take into account these city-specific circumstances when designing air quality plans. Actions that are efficient in one city might not be efficient in others. [2]

MATERIAL AND METHODS

Chemistry transport models can account for these complex transport, diffusion and chemical transformation processes and can therefore be used to quantify the impact of cities on their pollution levels by performing simulations where emissions are switched on or off in a city. Because these models require intensive computational resources they are generally used to perform this detailed analysis for one city or region at the time. To cope with this limitation, the "Screening for High Emission Reduction Potentials for Air quality" tool (SHERPA) has been developed by the Joint Research Centre. [3] This simplified screening tool mimics a chemical transport model, but with a much faster time response.
In the latest air quality study for major EU cities [2] several interesting key points arise regarding the sectorial contribution to air pollution, on the 150's analyzed EU cities:

- The average contribution from the ***residential sector*** was 13%, with a largely local contributions in Poland mining areas, and with an observation that in general, the residential sector (heating) has a greater impact in Eastern European countries
- The average contributions from the ***road transport*** was 14%, with larger contributions in Western Europe cities. As expected, transport emissions represent an important contribution in some of the largest cities (Paris, Madrid, London). However, they are also a key contributor in densely populated areas like Belgium and the Netherlands. [2]
- The average contribution from ***agriculture*** was 23%, with larger contribution in German and Czech cities.
- The average contribution of ***industry*** was 20%, with larger contribution in German, French and Austrian cities.
- The average contribution of natural sources was 19%, with PM2.5 peaks in cities in Mediterranean area, associated with episodic atmospheric dust events.

This variability in terms of sectoral impact, even within a single country, illustrates the scope for targeting air quality plans on a city-by-city basis, and the need to supply to local policy makers the tools to support them in better air quality assessments.
SHERPA is a modelling tool, developed for the exploration of potential air quality improvements resulting from national/regional/local emission reduction measures. It is based on source-receptor relationships. These source-receptor relationships are a simplified version of a chemistry transport model, used to simulate the contribution to concentration levels due to all precursor emissions (NOx, NMVOC, PPM, SO_2 and NH_3) from one particular area of the domain. They are used to estimate the effect of changes in precursor emissions on pollutant concentrations [4]
In SHERPA, concentration changes due to an emission reduction scenario are computed on a cell by cell basis according to the following equation:

$$\Delta C_n = \sum_{p}^{Nprec} \sum_{m}^{Ncell} a_{n,p,m} \Delta E_{p,m}\,, \forall n \in [1, N_{cell}] \tag{1}$$

where the delta concentration ΔC_n (change of concentration in comparison to the base case) in a receptor grid cell n is expressed as a linear combination of the emissions delta $\Delta E_{p,m}$ (variation in emission when compared to the base case), for each source cell m and pollutant (i.e. precursor) p. The $a_{n,p,m}$ coefficients act as weighting factors which apportion the amount of emission variation $\Delta E_{p,m}$ of precursor p stemming from cell m and reaching cell n. As the correlation between ΔC_n at receptor cell n and $\Delta E_{p,m}$ at sources cell m decreases with the distance between the cells, it has been assumed that the coefficients $a_{n,p,m}$ in the previous equation can be approximated by the following distance-function [5]:

$$a_{n,p,m} = \alpha_{n,p}\left(1 + d_{n,m}\right)^{\omega^{n,p}} \quad (2)$$

where $d_{n,m}$ is the distance between cells n and m and the two unknowns α and ω for each precursor p and each grid cell n were estimated from chemical transport model simulation results. [5]
The SHERPA tool is distributed with EU-wide data on emissions and source-receptor models (spatial resolution of roughly 7x7 km2), so that it is very easy to start working on any region/local domain in Europe. More specifically, SHERPA logical pathway is implemented through the following steps:

- Source allocation: to understand how the air quality in a given area is influenced by different sources;
- Governance: to analyze how one should coordinate with the surrounding regions to optimally improve air quality;
- Scenario analysis: to simulate the impact on air quality of a specific emission reduction scenario (defined also through the previous two steps)

In this particular study the Romanian Region was taken into account and 3 SHERPA sections were used, Source allocation, Governance and Scenario.

RESULTS AND DISCUSSION

Emission reduction rates in SHERPA are defined to definite regions, which in Romania correspond to the different counties in the country. Investigation in higher resolution, such as for cities, is not possible, except for the capital, Bucharest, which itself represents an individual region. Therefore, we chose West Region of Romania (where Timisoara is located) to be the target area in the analysis of the effects of emission reduction. Figure 1 represents the expected effects of a 8.37% emission reduction of particulate matter concerning all sources in western Romania.

Figure 1. Western Romania area, PPM-all sectors scenario, governance

One can observe that the maximum range where the local/regional decision makers can work is at maximum 8.37%, suggesting that a large amount of airborne particles in the region are not locally generated.
A better view is given by Figure 2, where the “No control” chart is emphases in Governance module of SHERPA. However, even if the target area was specifically defined by the GPS coordinates of Timisoara, as SSHERPA is not defined at low geographical level in Romania, the uncertainties in this particular study can be significant.

On the larger scale, at country level (entire Romania), the estimations are better due to higher number of data available from national air quality monitoring stations. In Figure 2 one can observe the result of a two-step scenario, one (in the left side) with no emission reduction strategies and second with emission reduction strategies applied at all emission sources.

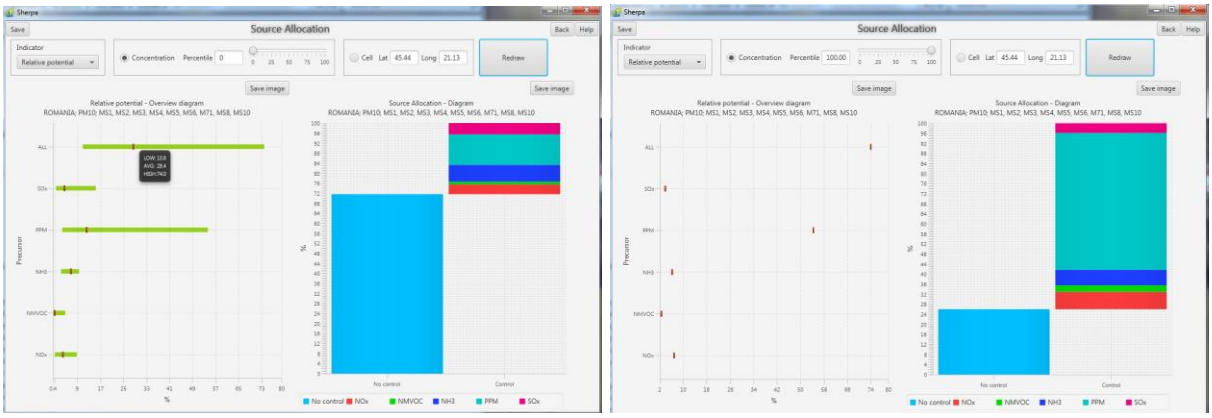

Figure 2. Romania area, all sectors scenario, governance, reduction potential

Obviously the scenario with emission control enforced at 100% is an utopia, but the results shows an interesting fact for Romanian case, that gaseous pollutants emitted are already controlled (as minimum reduction is shown in Figure 2) but PPM (mostly PM10) emissions can be significantly reduced at country level.

Other, more source focused scenarios can be analyzed in SHERPA, as the one shown in figure 3 to 5, where only transportation source was taken into account, at entire Europe level.

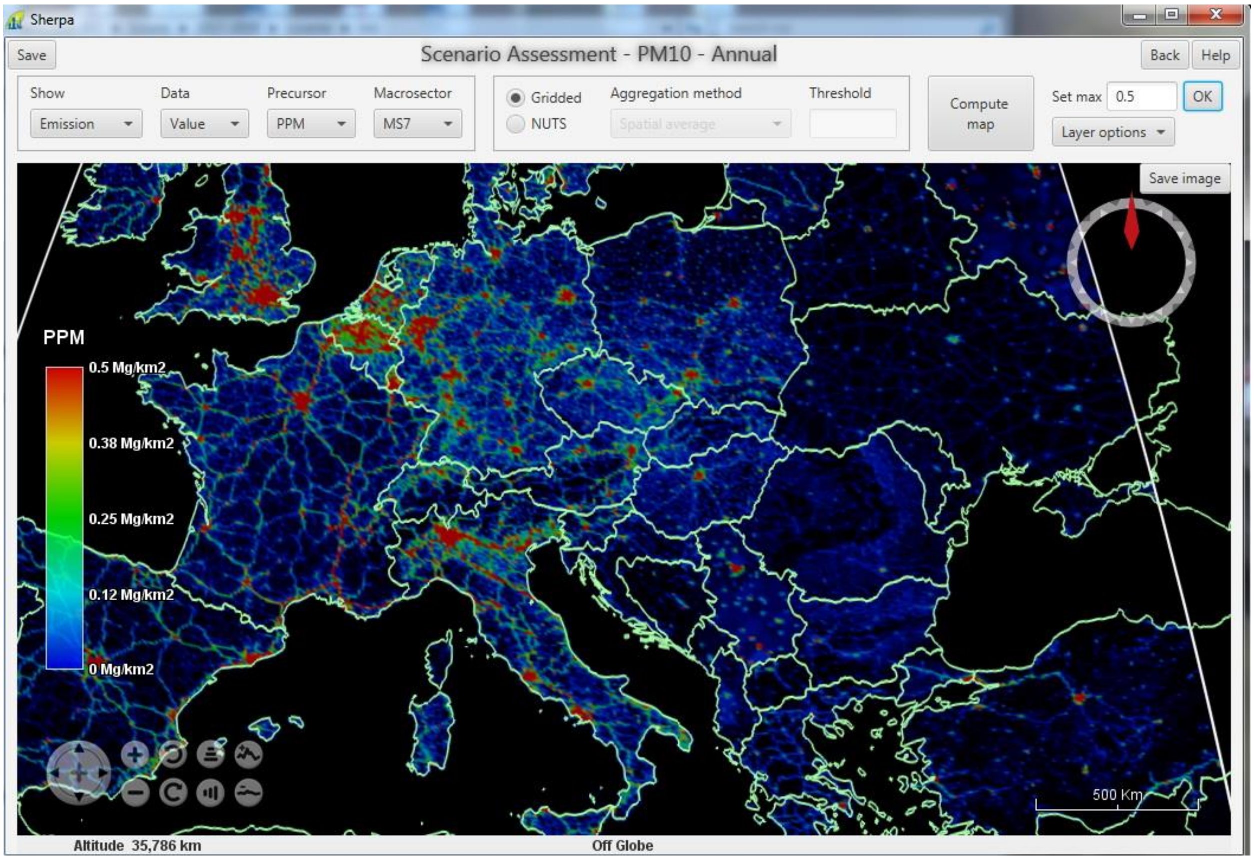

Figure 3. Europe-city level, PM10 emission factors, exclusively road transport sector.

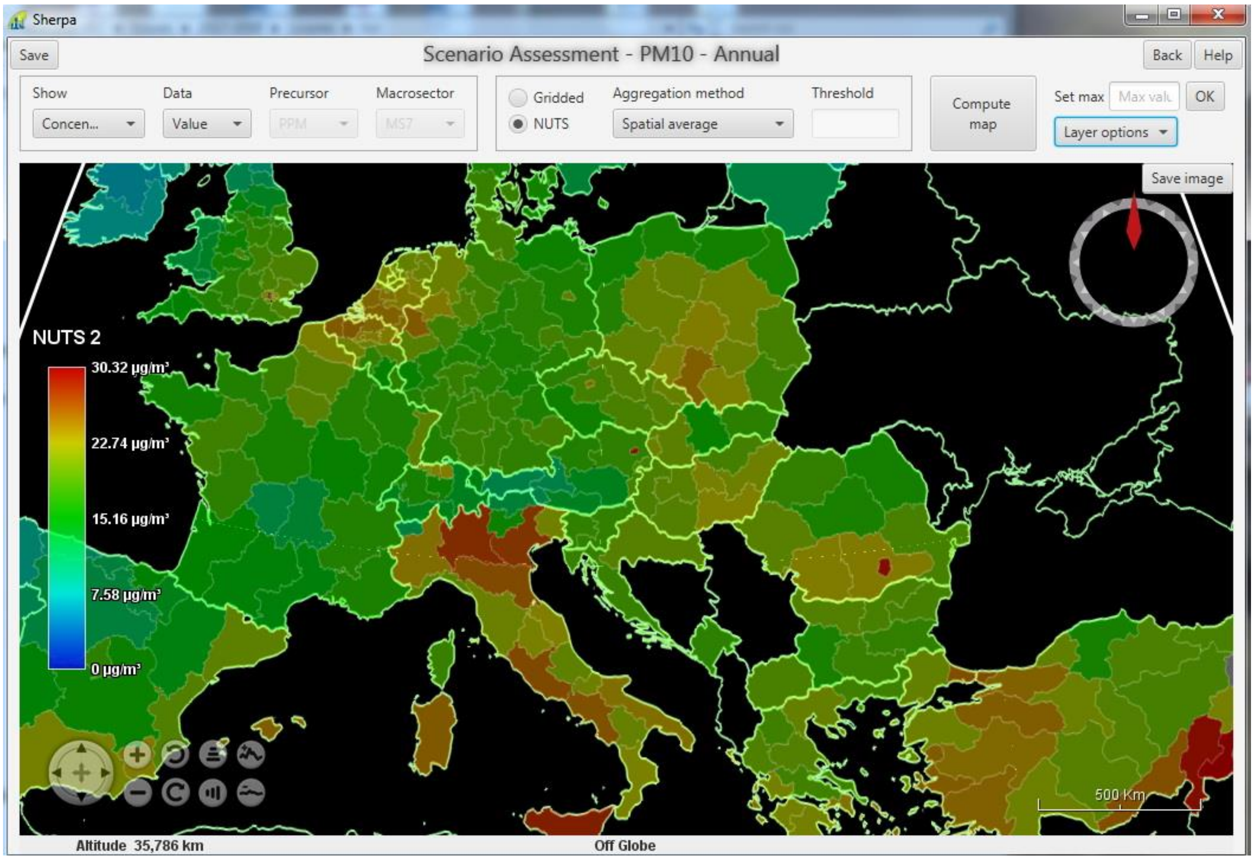

Figure 4. Europe-region level, PM10 annual average concentration, exclusively road transport sector.

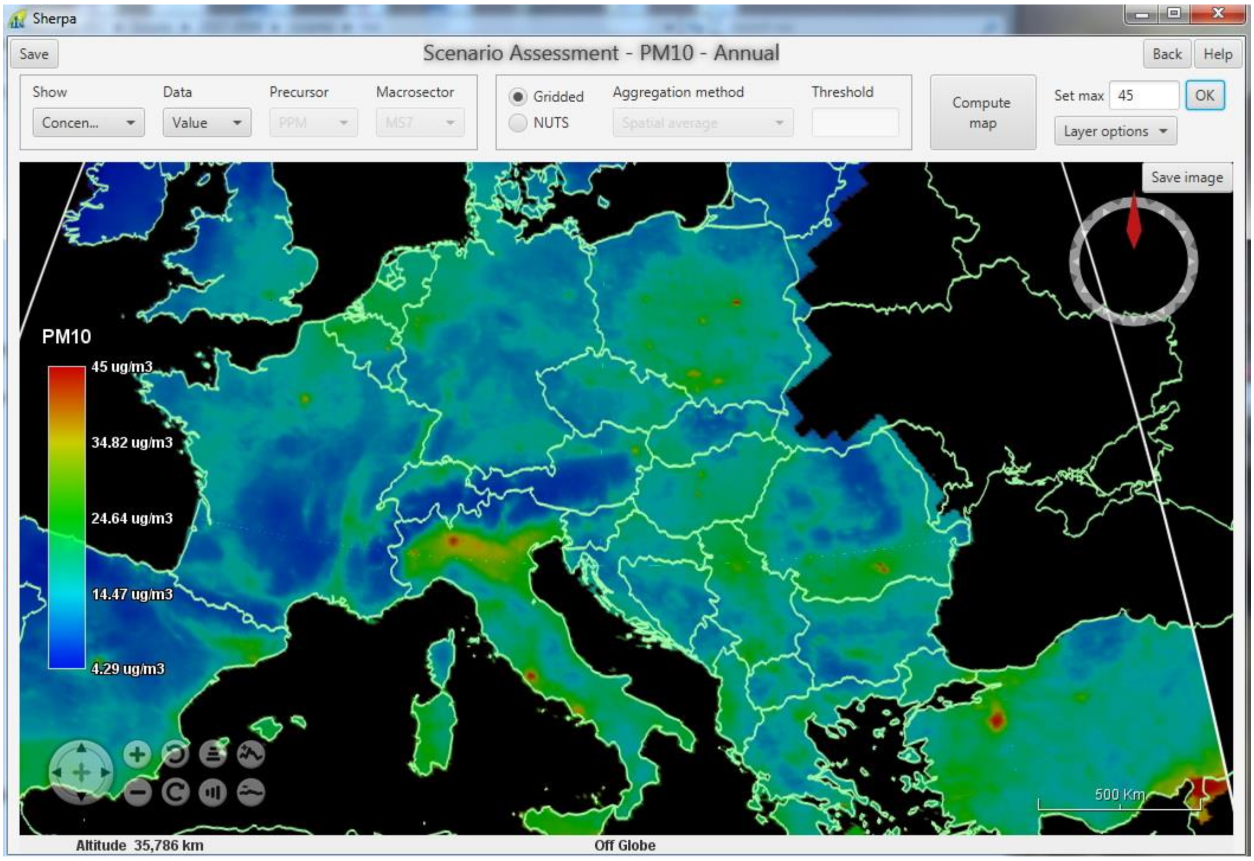

Figure 5. Europe-country level, PM10 annual average concentration, exclusiv road transport sector.

Analyzing the results presented in Figures 3 to 5 one can easily notice the major contributors to air pollution in urban levels are the western countries/cities, in respect to PM10 levels, like Nederland, Belgium, Germany and northern (developed) parts of Italy.

CONCLUSION

There is an obvious need to provide information to improve air quality policy governance, to support authorities in choosing the most efficient actions at the appropriate administrative level and scale. In particular, an appropriate balance between local actions focusing on the urban scale and actions requiring national/international efforts needs to be found. The purpose of this study was to provide information on the potential of SHERPA tool to support researchers and decision making officials on the local, regional and country level to develop and implement better air quality improvement strategies.

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THE IMPACT OF THE ADSORBENT HYDRATION ON THE CADMIUM ADSORPTION FROM WATER SOLUTIONS

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Abstract: In this paper, adsorption of cadmium ions from aqueous solutions was investigated, using Ca-alginate particles and biocomposites made from Ca-alginate and hemp fiber with differently pretreatment to determine the kinetics and adsorption isotherms for these processes. The concentrations of cadmium were monitored using atomic absorption spectrophotometry (AAS). Based on the experimental results, the coefficients for Langmuir and Freundlich adsorption isotherms were determined. For the adsorption kinetics study pseudo-first order, pseudo-second order, and the Weber Morris model were used. The obtained results proved that pretreatment had large impact on cadmium absorption and that investigated materials may help to reduce the cadmium concentration in a cost-effective and efficient manner.
Key words: cadmium, adsorption, alginate-hemp fiber composite, alginate beads

INTRODUCTION

For the preservation of life and the normal functioning of all living beings, water must have a natural chemical composition and characteristics. When, due to some natural processes or most recent, human activities, water is contaminated it must be somehow cleaned. Intensive technological and industrial development has led to over-exploitation of water resources, as well as increased pollution of ground and surface waters [1]. Among the most common pollutants heavy metals are the most dangerous inorganic pollutants of the environment since they are highly toxic even at low concentrations, non biodegradable and bioccumulative, and hence they must be removed [2]. There are a large number of different processes/technologies for the contaminated water treatment, starting with traditional techniques such as chemical precipitation, coagulation, flotation and or oxido reduction, but also the very expensive ones such as ion exchange, membrane filtration and electrolysis. However, despite the numerous advantages the above methods also have certain shortcomings like the high energy consumption, the generation of secondary waste and low selectivity [3]. In order to effectively address those problems, numerous researches focused on finding and/or improving methods and materials that can lead to the removal of heavy metals from water. Among other removal methods used today adsorption is most promising because of the high efficiency, low cost and abundance of different natural and synthetic adsorbents [4]. Environmental pollution by heavy metals is mostly due to the release of untreated or insufficiently purified industrial wastewaters, mining or surface treatment of metal objects, dissolution of minerals, agricultural activities and industrial processes.
Toxicity of heavy metals is different and some of them (like copper, zinc, iron, manganese and molybdenum) are considered essential for the functioning of living organisms and toxic only at higher concentrations, but others (like mercury, cadmium, lead, arsenic and selenium) are toxic even at very low concentrations [5]. Cadmium is one of the most toxic heavy metals and does not belong to a group of essential elements for living organisms. Due to its extreme toxicity in relatively small doses, it is designated as a priority pollutant by the United States Environmental Protection Agency (US EPA). Table 1 shows the maximum permitted concentrations of cadmium in drinking water.
When introduced into the body, cadmium that is not excreted is immediately accumulated in the kidneys and causes their damage, as well as damage to the immune, skeletal, urinary, reproductive, cardiovascular, central and peripheral nervous, and respiratory systems, and cancer in the case of long exposure [6]. Cadmium in nature comes from phosphorus fertilizers, through solid waste and waste water from the battery, paint, ceramics and plastics industries [7].

Table 1. MDK values of the cadmium

Document	Drinking water standards, [mg/L]
Pravilnik[1] (1999)	0,003
WHO[2] (2011)	0,003
EU[3] (Directive 98/83/EC)	0,005
US EPA[4] (2008)	0,005

Remarks: [1]Pravilnik o higijenskoj ispravnosti vode za piće Republike Srbije; [2] WHO –World Health Organization; [3]EU – European Commission, drinking water directive; [4]US EPA – United States Environmental Protection Agency.

MATERIALS AND METHODS

Methods for the removal of cadmium

In the last decades, a number of physicochemical methods have been developed that can be used to purify wastewater from heavy metals. Conventional methods for removing ions of heavy metals from water include chemical precipitation, coagulation and flocculation, ion exchange, membrane filtration, electrochemical methods, and adsorption [4]. The biosorption process implies an adsorption process with application of some material with organic origin called biosorbent. A large variety of different biomaterials may be used as biosorbents like: dead or live micro-organisms (algae, bacteria, fungi, yeasts); natural macromolecules (cellulose, lignin, starch, chitosan, alginate, carrageenan, etc.); residues of plant and animal origin (seaweed, wool, moss, peat, etc.); industrial and agro-industrial waste [8, 9].

As the most common adsorbent, activated carbon, has high production cost, the biosorbents represents abundant, extremely cheap, highly effective alternative, with the large variety of functional groups for metal removal (carboxyl, hydroxyl, phenolic, amidic, amino, carbonyl, etc.) [10]. Those groups may be further modified by different physical, chemical, or combined methods in order to improve adsorption abilities. In addition, some of the biosorption materials may be very effective even at very low concentrations of various pollutants [3].

Alginates as a biosorbents

The alginates are natural, water-soluble, linear anionic polymers of large molecular masses present in the cell wall of brown algae (*Phaeophycae*) in the form of calcium, magnesium or sodium salt of alginic acid, from which they are extracted for commercial use. Alginates represent a group of compounds with a complex structure, which is defined primarily by the composition and organization of its subunits. Namely, in the chemical structure of the alginates itself, there are blocks composed of the residues of β-D-manuronic (M-blocks) and α-L-guluronic acid (G-blocks), which are interconnected by 1,4-glycosidic bonds, and whose number and arrangement has a major influence on alginate and alginate gels properties [11]. Alginate gels belong to the group of the chelating ion exchange sorbents (like monofunctional ion-exchange resins), but these biosorbent materials are preferred since they have different functional groups (carboxylic and hydroxyl) in their three-dimensional structure, which are active sites for metal ion binding. In addition, their price is up to ten times lower than the price of ion-exchange resins and other commercial sorbents, and their lifetime is only slightly shorter [12]. They could be used for immobilization technology, in order to improve the biosorption process and regeneration/reuse of so formed biosorbent. These biosorbents have metal-sequestering property and thus can successfully and quickly sequester dissolved metal ions even from dilute complex solutions with high efficiency. Hence alginates are ideal candidates for the treatment of high volume and low concentration complex wastewaters [11]. However, although alginates are biosorbents with high efficiency their mechanical stability is extremely low [9].

Hemp fibers as a biosorbents

Hemp as biosorbent is widely used for phytoremediation where its green plants are used in order to remove pollutants from the environment since they possess large biomass into which large amounts of heavy metals from the substrate can be accumulated. In addition, hemp grows very quickly (it takes about 180 days to mature), the costs of planting are low and it could be cultivated in different climatic conditions. However, beside this use it could be also used as quick and effective biosorbent for heavy metal removal from drinking and wastewaters [13, 14]. Short and entangled hemp fibers, which can be obtained as waste in the textile industry, are a cheap lignocellulosic biosorbent for efficient removal of heavy metals from aqueous solutions. Cannabis fibers have an extremely complex structure and a heterogeneous chemical composition, which includes cellulose, hemicellulose and lignin, while pectin, fats and waxes are somewhat less represented in their structure. It should be noted that the structure of this biosorbent is extremely complex and, in combination with the chemical composition of its components, significantly affects the sorption capacity of hemp fibers. Heavy metal primarily bind to carboxyl groups (present in hemicellulose, lignin and pectin) and phenol groups (present in lignin, grease and wax), and to a lesser extent they bind to hydroxyl (from cellulose, hemicellulose, lignin, pectin and waxes and fats), and carbonyl (from lignin) groups [13]. The content and position of certain components of the chemical composition, (primarily cellulose, hemicellulose and lignin) in the structure of hemp fibers, significantly affect the adsorption capacity of hemp fibers as a biosorbent. The adsorption capacity of hemp fibers is closely related not only to the content of active heavy metal ion binding groups, but also to their availability, which depends mainly on the structural characteristics of the fiber. In order to improve the adsorption capacity of lignocellulosic fibers as well as the functionalization of their surface for heavy metal binding, chemical modification is most often applied. In this way, while preserving the exceptional physical and mechanical characteristics of cannabis fibers, they become an adequate carrier for the immobilization of various sorbents, which in their initial form are rather unstable [9].

Experimental

Materials used in this work were: alginic acid in a powder form (low viscosity, Sigma-Aldrich), cadmium chloride $CdCl_2*2H_2O$ (Sigma-Aldrich), calcium chloride $CaCl_2*6H_2O$ (Sigma-Aldrich), industrial hemp fibers and distilled water.

The standard solution of cadmium chloride 500 ppm concentration was prepared by dissolving 0.255 g of $CdCl_2*2H_2O$ in 250 ml of distilled water. A working solution of 75 ppm starting concentrations was made using the appropriate volume of standard solution of cadmium chloride in 50 ml of distilled water. The alginate solution was obtained by diluting 1 g of brown algae powder in 50 ml of distilled water. After dissolving of alginate in water (by agitation at 250 rpm for 2h) it was used either for particle formation or for formation of alginate-hemp fiber composite.

The alginate particles were made by syringe dropping 2% Na-alginate into a 2% calcium chloride solution in distilled water, and then allowed to stand for 24h in the same, after which they were washed with distilled water and allowed to stand for 24h in distilled water. After forming of particles three sets of particles with different degrees of hydration were made. The first set of particles was dried for 24 hours in the hot oven at 60ºC, and it represented dry particles. The second set of particles after drying for 24 hours was left to rehydrate in distilled water for 24 hours before it was applied as biosorbent and it was named as rehydrated particles. The third set of particles was not dried and it was inserted into the cadmium solution in the form it was prepared, representing fresh particles.

Composites were also like particles made in three states of hydration. The fiber of the cannabis was first submerged in the alginate solution, and then placed to dry for 24h. After drying fibers were immersed in a 2% calcium chloride solution and allowed to stand for 24h in the same, and after washing with distilled water allowed to stand for 24h in distilled water. One set of composites was obtained by using thus obtained composite as adsorbent, and this set represents a fresh composite. The second set of composites was obtained by drying it in the oven for 24 hours at 60ºC, and it represents a dry composite. The third set of composites was obtained by immersed a part of the dry composite in distilled water to rehydrate for 24h before the use and this one was called a rehydrated composite.

The amount of biosorbents used in all experiments, given as the mass of the dry biosorbent, was 0.125 g. For determination of the adsorption kinetics on different biosorbents following time intervals were used: 3, 5, 7, 10, 15, 30, 60, 120, 300 min, and 24 h. Analysis were performed on atomic absorption spectrometer (Pye Unicam SP9, Ltd., UK) was used.
The aims of to investigate the adsorption of cadmium ions from aqueous solutions using Ca-alginate particles and a biocomposites made from Ca-alginate and hemp in various hydration states, in order to determine the kinetics and adsorption isotherms for these processes. Based on the experimental results, the coefficients for Langmuir and Freundlich adsorption isotherms will be determined. Adsorption kinetics will be processed by pseudo-first and pseudo-second order models, as well as by Weber Morris model.

RESULTS AND DISCUSSION

Sorption capacity and removal efficiency

Effect of the hydration on sorption capacity, $q_{e,\,exp}$, is given in the Table 2, while the effects of contact time on removal efficiency are shown in Figure 1.

Table 2. The equilibrium sorption capacity, for c_0 = 75 ppm Cd(II) ions, at 250 rpm, and 25 ºC

Adsorbent	Dry particles	Dry composite	Rehydrated particles	Rehydrated composite	Fresh particles	Fresh composite
$q_{e,\,exp}$ (mg/g)	27.74	20.05	27.69	19.98	24.68	20.88

As it could be seen from Table 2 fresh composite, and dry and rehydrated particles have highest sorption capacity while dry and rehydrated composite have the lowest. This may indicate that once dried composite lose part of its adsorption capacity.

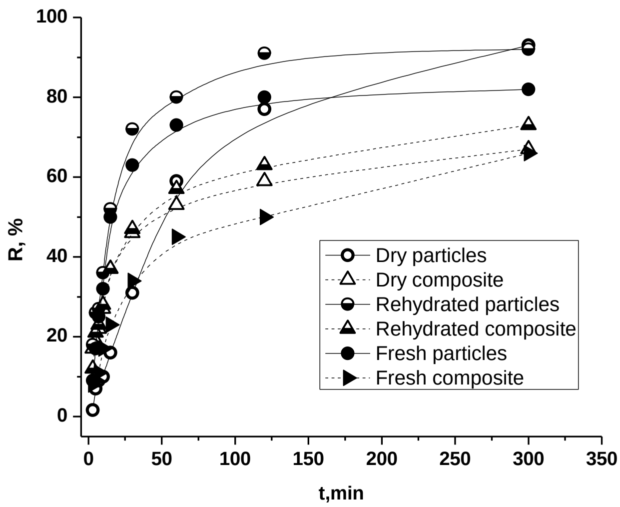
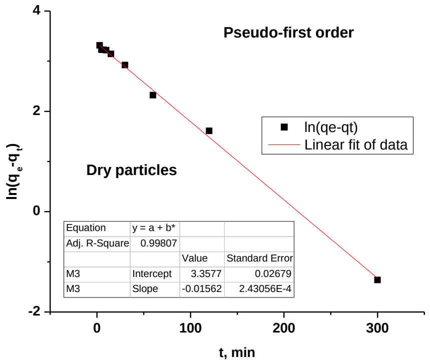


Figure 1. The removal efficiency vs. time, for c_0=75 ppm Cd(II) ions, at 250 rpm, and 25 ºC.

As it could be seen from the Figure 1 the biosorption of cadmium ions on all used sorbents is relatively quick process, because in the first 50 minutes there is adsorption of about 80-90% cadmium ions for alginate particles, while for alginate-hemp fiber composite there is a slightly slower and lower adsorption. This is not surprising since the alginate have up to ten times larger adsorption capacity compared to the hemp fibers and percentage of alginate in composite is only 12%. However, although dry particles have larger adsorption capacity they have much slower kinetic in the first 50 minutes than it has the composite.

Kinetic study

In order to investigate the kinetics of adsorption of the Cd(II) on different biosorbents, various kinetic models, like pseudo-first-order [15], pseudo-second-order [16] and intra-particle diffusion [17] models have been used. In the Figure 2 are shown examples of obtained results while obtained kinetic data for all biosorbents are summarized in Table 3.



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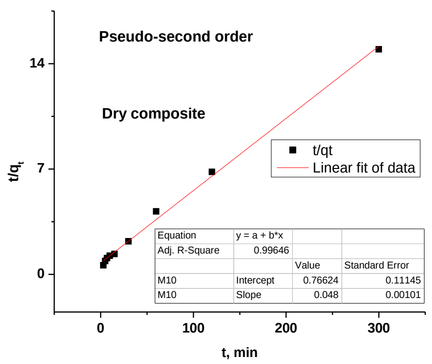

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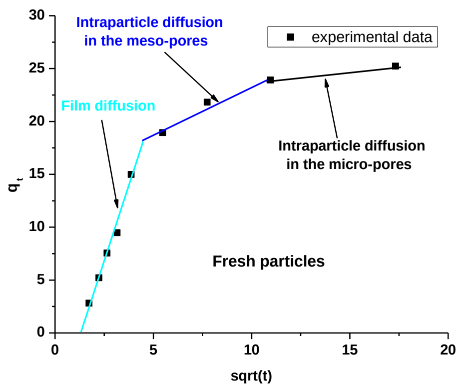


c)

Figure 2. The kinetics of Cd(II) adsorption for c_0=75 ppm at 250 rpm, and 25 ºC; a) pseudo-first-order, b) pseudo-second-order c) and intra-particle diffusion.

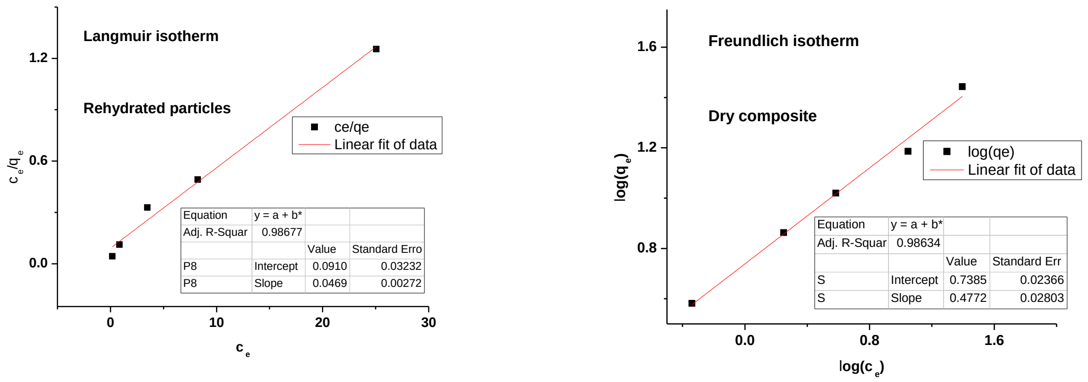
Table 3. The obtained parameters for pseudo-first-order, pseudo-second-order and intra-particle diffusion models

Kinetic model		Dry particles	Dry composite	Rehydr. particles	Rehydr. composite	Fresh particles	Fresh composite
Pseudo-first-order	**K_1 (min^{-1})**	0.0156	0.0093	0.169	0.0184	0.0144	0.0096
	q_e (mg/g)	28.72	13.12	30.48	12.02	15.17	17.04
	R^2	0.998	0.944	0.930	0.949	0.913	0.976
Pseudo-second-order	**K_2 (min^{-1})**	0.0002	0.0030	0.0025	0.0036	0.0022	0.0013
	q_e (mg/g)	40.27	20.83	29.27	20.90	26.85	21.89
	R^2	0.748	0.996	0.998	0.999	0.998	0.992
Intra-particle diffusion model	**K_{id1} (mg/g $min^{1/2}$)**	2.77	2.84	4.45	3.31	5.52	2.70
	K_{id2} (mg/g $min^{1/2}$)	1.62	0.857	1.11	1.14	0.889	1.74
	K_{id3} (mg/g $min^{1/2}$)	0.745	0.381	0.008	0.079	0.207	0.678

As it could be seen from Table 3 all adsorbents except dry particles may be better modeled by pseudo second order kinetics. The $q_{e,exp}$ and the $q_{e,cal}$ values from the pseudo-second-order kinetic model are close to each other except for the dry particles. The calculated correlation coefficients are closer to unity for pseudo-second-order kinetics than that for the pseudo first-order kinetic model, indicating that the adsorption of Cd (II) onto different sorbents can be better approximated by the pseudo-second-order kinetic model than the pseudo-first-order kinetic model. In addition results obtained for Weber-Morris kinetic parameters for all investigated systems with Co=75 ppm clearly shows that data points are represent by multi-linear plots. The first linear region is attributed to the film diffusion where mass transfer is governed by boundary layer effects. Second linear region describes the intraparticle diffusion stage (in the meso-pores), while the third is connected to the diffusion in the micro-pores. In all cases straight lines in the film diffusion region didn't started from the origin most possibly due to the difference in the rate of mass transfer in the initial and final stages of adsorption. Further, obtained values of k_{id} for Co=75 ppm listed in Table 3 indicate that particles generally have larger diffusion coefficients in the in the film diffusion region. For particles coefficients in the film diffusion region increased with hydration while for composite situation was similar. However, in the meso-pores diffusion region diffusion coefficients for particles decreased with hydration, while for composite there were increase with the hydration. Generally, fresh particles have highest mass transfer rates in the boundary layer, fresh composite in the meso-pores, and dry particles in micro-pores.

Equilibrium study

The obtained equilibrium adsorption data of Cd (II) adsorption onto investigated biosorbents have been tested by using Freundlich [18], and Langmuir [19] isotherm equations. The Freundlich isotherm is valid for a heterogeneous adsorbent surface with a non-uniform distribution of heat of adsorption over the surface. The Langmuir isotherm, however, assumes that the sorption takes place at specific homogeneous sites within the adsorbent. Figure 3 represents an example of experimentally obtained results while kinetic data obtained for all biosorbents are summarized in Table 4.



a) b)

Figure 3. The adsorption isotherm for Cd(II) adsorption for c_0=75 ppm at 250 rpm, and 25 ºC; a) Langmuir, b) Freundlich

The parameters of the isotherms, and the correlation coefficients, R^2 obtained by the fitting of the experimental data are listed in Table 4. By comparing the values for the correlation coefficients, it was found that the Freundlich isotherm generally better represents the equilibrium sorptions of Cd(II) onto investigated adsorbents. Those results are not surprising for composite since this isothermal model indicates the heterogeneity of the surface and that adsorption is multilayered, the same facts that were confirmed by the kinetic study.

Table 4. The obtained parameters for Langmuir and Freundlich isotherm

Adsorption isotherm		Dry particles	Dry composite	Rehydr. particles	Rehydr. composite	Fresh particles	Fresh composite
Langmuir	K_l (min^{-1})	16.98	4.71	13.79	10.99	9.75	/
	q_m (mg/g)	38.31	32.57	42.55	21.32	28.09	/
	R^2	0.938	0.848	0.809	0.987	0.877	/
Freundlich	K_f (mg g^{-1}) (dm^3 mg^{-1})$^{1/n}$	10.59	5.48	9.98	7.44	7.86	0.72
	n [g/dm^3]	1.68	2.09	1.53	3.02	2.44	0.81
	R^2	0.918	0.986	0.827	0.975	0.974	0.659

CONCLUSION

Based on the performed experiments and the obtained results and presented discussion, the following conclusions may be derived:

• The hydration state of used adsorbents have high influence on the adsorption process and it may be concluded that dry adsorbents generally have somewhat slower adsorption kinetic for Cd(II) removal for c_0 = 75 ppm and that particles have higher adsorption capacities which is expected.

• The sorption kinetics of Cd(II) onto tested adsorbents could be represented by the pseudo-second-order kinetic model. Since for the pseudo-first-order kinetics the rate-limiting step is diffusion (physical process), while for the pseudo-second-order the rate-limiting step is the chemical reaction (chemical process) it may be concluded that those adsorbents have good mass transfer properties, or in other words that they have easily available surface for adsorption.

• The adsorption processes could be well described by a multi-stage diffusion model proving complex structure of the composite.

• Freundlich isotherms generally better represented the equilibrium adsorption of Cd(Ii) onto investigated biosorbents indicating the heterogeneity of the surface and that adsorption is multilayered.

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PEDELEC LI-ION BATTERY PACK LIFETIME

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Abstract: Energy policy of EU promotes electro-mobility, especially the use of bicycles and electric bicycles. PEDELEC is a form of an electric bicycle that does not require a registry plate, and with a battery power 250 W electric motor helps the driver to overcome the altitude differences and influence of the wind. Batteries for electric bicycles are based on Li-Ion technology. Battery packs are made of standard cells that have a lifecycle of 1000 cycles. In realistic exploration conditions, the lifecycle is four years and up to a third of the declared cycle of use. The reason for this is the climatic conditions which lead to increased temperatures in usage and charging temperatures, which significantly reduce their life cycle. Paper on a practical example shows the dynamics of PEDELEC usage, energy needs for specific route characteristics, as well as changes in the thermal pattern of the battery and its condition after 4 years of use. The analysis was performed with Non-Destructive Testing (NDT) using infrared thermography, which confirmed the inhomogeneity of thermal patterns and the moment of final battery failure.
Key words: Li-Ion, 18650, battery pack, PEDELEC, thermography

INTRODUCTION

Energy policy of the European Union promotes the use of electric vehicles. In order to reduce import of crude oil, CO_2 emissions and congestion in large cities. The aim of the European Union's land transport policy is to promote mobility that is efficient, safe, secure and environmentally friendly. London is the first city to introduce Congestion charging zone in 2003. The charge covers a 21 km^2 area in London. If you enter the zone between 7am and 6pm on a weekday, you pay a flat daily rate. The charge has risen from 5 £ in 2003, 7.50 £ in 2006 to 11.50 £ in 2018. Residents receive a 90 % discount and registered disabled people can travel for free. Emergency services, motorcycles, taxis and minicabs are exempt. Fully electric vehicles and hydrogen fuel cell cars are exempt from this charge, along with a number of efficient hybrids. With the aim of reducing traffic congestion, the use of bicycles and electric bicycles is promoted. 40000 vehicles drive into it per hour in the morning peak. Since implementation, vehicle delays have reduced by 26 % inside the charging zone and the bus fleet and ridership have increased significantly, [1].
Aim of this paper is to present case study of four years usage of electric bicycle PEDELEC on city area with special reference to the weakest element of the electrical mobility, battery. PEDELEC (pedal electric cycle) is name for bicycle with an electric motor supporting the ride. Electric motor with maximum power of 250 W helps the driver until reach the speed of 25 km/h. It is the only form of electric vehicle in EU countries that does not require registration.

PRACTICAL USAGE OF PEDELEC IN THE AREA OF CITY OSIJEK

Basic information on daily transport needs

Cycling in Osijek represents a way of life and a favorite recreation on 40 kilometers of cycling trails. The city is located on an international bicycle route along the Danube that stretches from Germany across Austria, Hungary, Serbia, Romania and Bulgaria. The European bicycle route Euro Velo 6 connects Osijek with Budapest and Novi Sad. The second route nearby is the Euro Velo 13, the so-called Iron Curtain Route [2]. For daily traffic needs, in this research, was used Kalkhoff's electric bicycle. This bicycle has 8FUN drive engine on the front axle, power 250 W and Li-Ion 36 V, 9 Ah battery (Fig. 1).

Figure 1. Kalkhoff PEDELEC used for research

A typical day-trip on the way from home to work (Faculty of Electrical Engineering, Computer Science and Information Technology Osijek) as well as the speeds in (km/h) on individual parts of route can be seen in Fig. 2.

Figure 2. The basic daily route of PEDELEC and the driving dynamics of the daily route, source [2]

Average traffic speeds of PEDELEC goes from 20 to 22.8 km/h, [3]. Average traffic speeds in EU cities: London (19 km/h), Berlin (24 km/h), Warsaw (26 km/h), Edinburgh (30 km/h), Rome (30 km/h), Glasgow (30 km/h), Bristol (31 km/h), Paris (31 km/h), Belfast (32 km/h), Munich (32 km/h), Amsterdam (34 km/h), Barcelona (35 km/h). Conducted measurements during May 2015 indicate that the average speed of traffic in Osijek by car (38.4 - 39.7 km/h) and bicycle (12.5 - 14.6 km/h). Average traffic speed with PEDELEC and car in the populated area of high traffic density is similar [3]. The experiences from the literature, calculations by ExtraEnergy based on market values. As a basis for calculation, the lifecycle of PEDELEC including batteries was taken as 4 years or 19200 km, alongside a kWh price of 0.2 €, plus annual repair and spares cost of 150 €. Alternatively, the figure of € 40 per month for motivational leasing via an employer could be used, in which a PEDELEC to a value of € 1,800 would be leased over a period of three years for 38,01 € per month, [4].

Practical experiences of authors are presented in Table 1. Battery analyzed in this paper provided, during 4 years, 2543 km, while the experiences of other users of a similar bicycle that used only the lowest amount of engine power tell about 7000 km before the battery is dead. In the first years of use, the rechargeable battery of the test bicycle was allowing a movement radius of 30 - 40 km. In the fourth year, autonomy fell up to 15 km. Then in just a few recharges, on the radius of 7 km and then the battery has died. The price of the new battery is 351 €. This makes the price of the mileage, on the test model, higher than the cost of fuel in a car (0.08 €/km).

Table 1. The mileage of the battery over the lifetime

Year	Test bike Kalkhoff PEDELEC	Similar bike with same battery
2014	20 km	1000 km
2015	1093 km	2500 km
2016	950 km	1500 km
2017	300 km	2000 km
2018	180 km	0 km
Sum	2543 km	7000 km

PEDELEC energy needs on daily route

When driving a bicycle, the driver often invests extra energy in overcoming air resistance in the case of wind and potential differences in the case of a hill. The average recreational cyclist developing a power of 100 W, when in good form it can go even up to 200 W. Professional cyclist develop from 200 W up to 300 W. In races, 400 W was recorded in continuity at a distance of 14 km [3]. Needs of driving power are best described in Figure 3 left [5]. Figure 3 right presents speed and proportional energy demand from 75 kg driver with a bike by primary resistance forces during a state of 300 W constant power cycling, source professional training systems, scientific training for cyclist and multisport athletes.

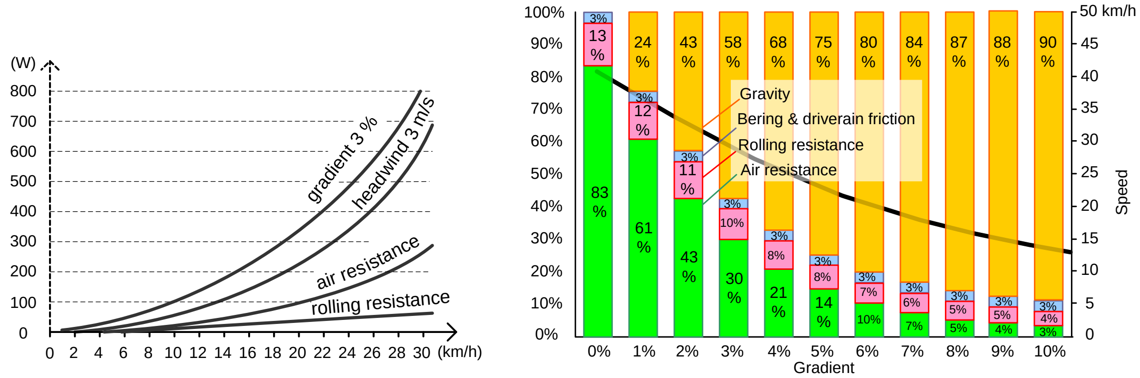

Figure 3. Required driving force for different speeds and proportional energy demand by primary resistance forces during steady-state cycling

The mathematical description of the needed power in relation to the variables as bike speed, wind speed, mass and resistance is defined by the expression (1). Trajectory dependency of particular variables are detail described in [6].

$$W = \left\lfloor K_a (V + V_w)^2 + g(m_r + m_b)(s + C_r) \right\rfloor \cdot V \tag{1}$$

where:						
W	- shaft power	s	- gradient (%) (5 % = 0.05)	m_r	- driver mass
K_a	- drag factor	Cr	- rolling resist. coefficient 0.003	m_b	- bike mass
V	- bike speed	V_w	- headwind speed	g	- 9.81 m/s^2

LI-ION BATTERY

The demand for PEDALEC started in 2005 mainly thanks to the widespread use of Li-Ion batteries [3]. Li-Ion batteries, thanks to a higher energy density, are currently the best solution for electrical mobility (Fig. 4).

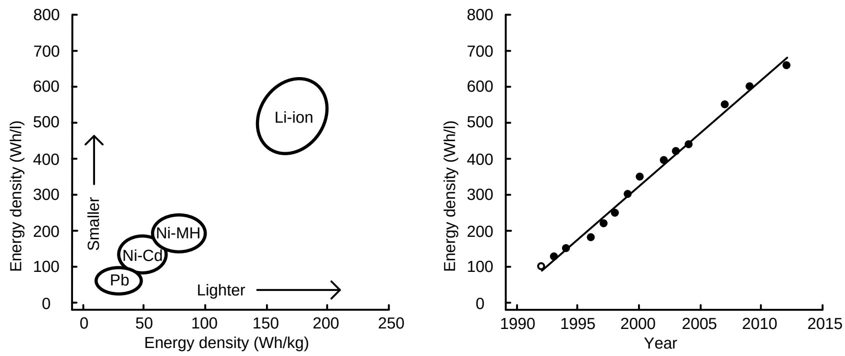

Figure 4. Energy density trend and increase in performances of 18650 Li-Ion cell [7]

In Li-Ion batteries (LiBs), Li+ ions move from the positive electrode to the negative electrode upon charging, and reversely upon discharge, as shown in Fig. 5. The negative electrode is usually carbon-graphite (LiC6). There are different kinds of positive electrodes: the lamellar compounds (archetype LiCoO2), the spinel compounds (archetype LiMn2O4) and the olivine compounds (LiFePO4). The electrolyte is either liquid, made of carbonates plus a Li salt, or a solid (a conductive polymer). Liquid electrolyte allows for much greater power density because the carbonates are good ionic conductors. Liquid electrolyte major problem is that boil at about 90 °C, and in practice, these batteries can be operated in the temperature range of 20 to +60 °C. At higher temperatures, the electrolyte deteriorates; at lower temperatures, the conductivity is too small. With a solid-state battery, the conductivity of the electrolyte is small so that the battery need to heat to the 90 °C. Battery pack mainly are make from standardized Li-Ion cells, Fig. 5, [8]. The first LIB generation (Sony Corporation, 1991) was produced in a standardized format, the well-known 18650 cylindrical cell [9].

Figure 5. Construction and interior design of a 18650 cylindrical battery

Lithium-ion chemistries tend to operate best between about 10 and 35 °C; this is referred to as the optimal temperature range. This is where you want the batteries to be at most of the time. However, most all lithium-ion chemistries will still operate down to about −20 °C and up to about 45 °C; this is known as the operational range. In this temperature range, no reduction in battery life would be expected to be experienced during normal operation. Between −20 and −40 °C the electrolytes may begin to freeze and the cold temperatures increase the impedance within the cell thereby resisting the flow of ions and reducing capacity and performance, and above 60 °C many lithium-ion cell chemistries begin to get more unstable; this is known as the survival temperature range, [7].

BATTERY PACK

Battery pack for PEDELEC is usually 36V. To get this voltage, it is necessary to connect 10 batteries in the series. In order to provide sufficient energy, certain elements may contain multiple parallel cells. The analyzed pack contains 40 CGR18650CG Li-Ion MH12210 cells. Cell nominal voltage is 3.6 V and with capacity 2250 mAh gives a pack capacity of 9 Ah.

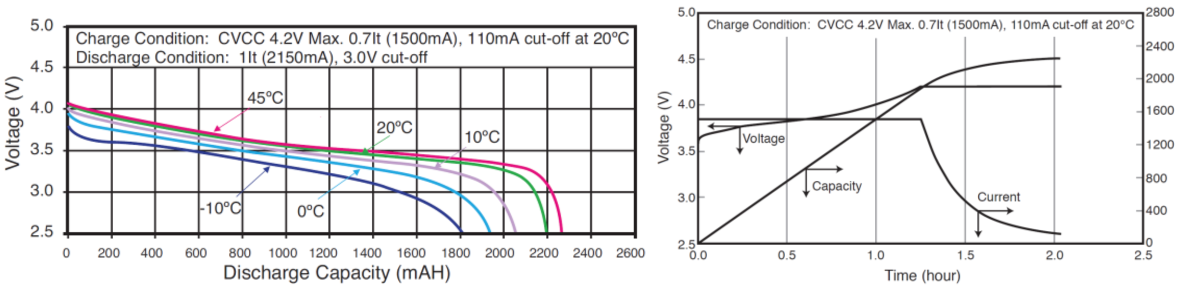

Figure 6. Panasonic CGR18650CG characteristic from data sheet

It is important that all cells, inside battery pack, are similar characteristics (inner resistance) because it depends on lifecycle of battery pack [10]. As some of the batteries in the same series differ in one another, it is necessary to monitor the charging cycles because Li-Ion batteries are sensitive to

overflow which can lead to ignition. Battery Management System (BMS) is the basic component of each battery pack. Electric bicycles do not have a Thermal Management System (TMS) which can cause a temperature difference of about 2 – 3 °C from the coolest cell to the warmest cell. In the case of cars and larger battery packs the difference can be as much as 6 – 8 °C. The reason why this is important is that a large temperature gradient between the cells will cause the cells to age at different rates, more information in [11]. Hotter cells will age faster than the cooler cells, and if there is a large gradient, this could mean that the battery's calendar life will be reduced prematurely [7].
BMS serves to balance energy of individual cells because the behavior of the group is complex [12]. Balancing can be active and passive. In practice, it is most passive because the price of active balancers is not justified by energy savings. The passive cells balancer that fill individual cell in the charging process before the other, i.e. achieve the 4.2 V voltage slowly empties over the resistor that is connected in parallel with the cell. Fig. 7 shows the location of BMS and individual cells in the analyzed battery pack as well as the sematic layout of the BMS compound.

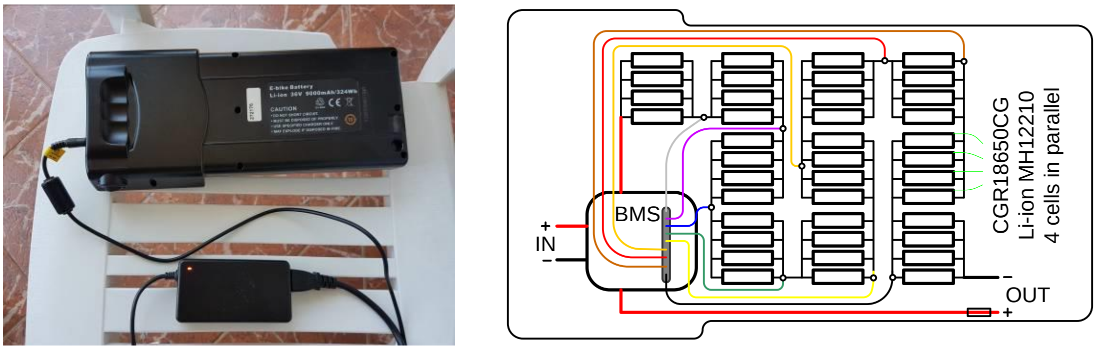

Figure 7. Battery photo with charger and schematic representation of the BMS in the battery pack (bottom view)

The premature destruction of the battery led to the use of charging immediately after the run, which was mainly during high outdoor temperatures. The lack of thermal management and the unequal distribution of dissipation led to a different aging of the cells, which can be seen from the thermal form in Fig. 8.

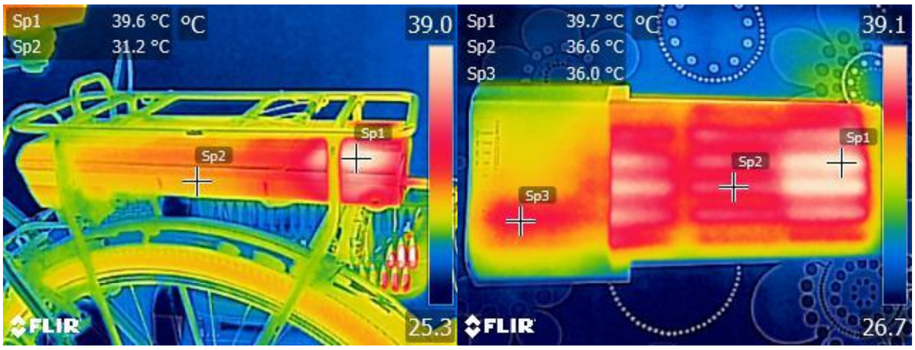

Figure 8. Uneven thermal pattern in operation (top view)

The temperature values in Fig. 8 show a difference in the battery temperature of 3.7 °C, while the difference to the housing takes up to 8.4 °C. Older cells with lower capacity have higher internal resistance. Because of this, good cells take over most of the current on themselves. This leads to their heating and aging. Batteries in the battery pack are set in two levels, so you need to analyze both sides of the battery pack. Fig. 9 (left) shows the upper side of the battery and the lower side (right). Fig. 9 can clearly estimate the location of individual cells as well as assume their qualitative status.

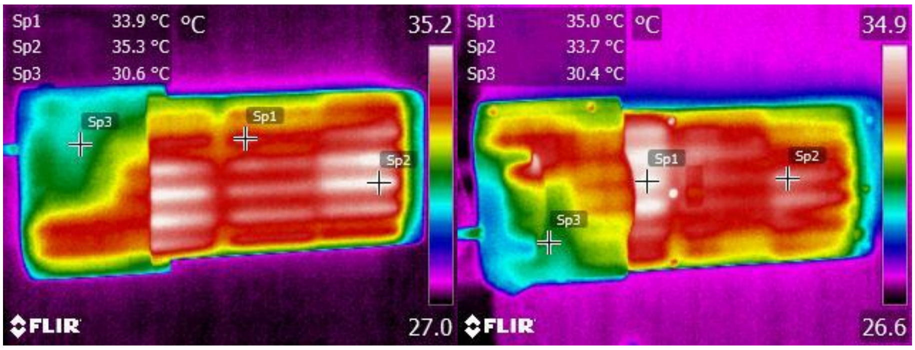

Figure 9. Battery pack thermal pattern in charging process
(left top view, right bottom)

When after 4 years the battery could not exceed more than 800 meters, we carried out an additional thermographic analysis and determined the existence of a hot spot. Fig. 10 shows a thermal hot spot on the cells that have stopped working. Hot spots represent the healthy cells that are in parallel with the defective cell and conduct a current of the serial circuit.

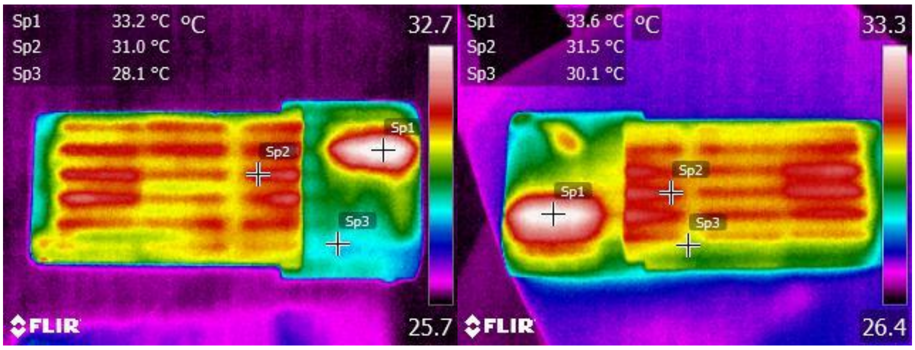

Figure 10. Battery pack thermal pattern at end of lifetime
(left top view, right bottom)

Taking average PEDELEC speed and radius of autonomy, it is possible to estimate the average engine power. The drop in capacity that is manifested through reduction of autonomy is shown in Table 2 as an estimate of the capacity of a battery pack and of a particular cell.

Table 2. Battery pack capacity estimation based on PEDELEC average speed and range

PEDELEC range (km)	Operating time (h)	Battery pack capacity (Ah)	Average power (W)	Cell capacity (mAh)	Percentage of initial battery capacity
40	1.75	9.00	185	2250	100
15	0.66	3.38	185	844	38
7	0.31	1.58	185	394	18

CONCLUSION

Batteries are the basic element of electro-mobility. With the launch of the Li-Ion battery on the market, the intense development of various forms of electric vehicles begins. For the needs of electric bicycles, PEDELEC especially, various battery packs are developed based on standard 18650 cells. In order to achieve the necessary voltage, the battery cells are put in series. Battery capacity increases by joining individual cells in parallel. The difference in characteristics and the need for voltage control, require BMS in each battery pack. BMS controls the voltage of an individual cell in the serial connection so that there is no overcharge and fire. Manufacturers declare battery life over the number of charging and discharging cycles. The number of the lifecycle for Li-Ion battery is 1000. Under realistic conditions of exploitation, battery life is 4 years. Based on two practical examples, the charging number is estimated to be from 120 to 200. Main cause of the deviation from the manufacturer's reference is the temperature regime of exploitation and charging. Temperatures that are during charging process higher form standard testing temperature, significantly short the battery life cycle. On analyzed batteries, we can see that the capacity drops by an average of 20 % per year and the end of battery use occur suddenly. Infrared thermography, as an NDT method, can help to detect the inhomogeneity of the thermal pattern which is a consequence of uneven aging of individual cells in the battery pack.

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MICROSTRUCTURAL DIFERENCES BETWEEN CONVENTIONAL AND SINTERED TOOL STEEL

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Abstract: Tools steels through the mankind history have played a crucial role in various production methods, either in cutting or deforming processes. All types of tool steels were produced on a classical manner by: casting, deforming, turning and/or milling, heat treating and finaly grinding. In past decades new shedule is appeared for production of tool steels, which is based on powder metallurgy and sintering.
Some alloying elements, which present in tool steels offer advantages in improving the tool characteristics such as vanadium or others, are very chemical active, it means that they easily react with oxygen, nitrogen or carbon, so that alloying of steel on classical manner shows a lot of limitations. If elements to be added into steel were produced by powder metallurgy methods, after that they are mixed, following by compacting and sintering, so many of those tools become more attractive for usage. The comparison of possibility for producing on such shedule by using a microsopic view is, however, reasonable method for better understanding why the new method posses an advantage over classical production methods. Here will be analysed steel samples obtained by conventional production methods and by powder metallurgy method, of course with the same nominal chemical composition of used samples.
Key words: tool steel, classical production methods, powder metallurgy&sintering, microstructure

INTRODUCTION

New production methods of high speed tool steels by using powder metallurgy (P/M) and sintering methods have shown some improved properties in comparison to conventional ingot metallurgy (I/M), but many aspects of such production&products still are not well known both to tool designers or tool consumers. Many of tool steel grades are renewed, approximately obout 60% of total steel number is changed just in last two decades. It is clear that many (dis)advatages of proposed shedule production require more detailed investigations/inforNew production methods by using powder metallurgy and sintering methods have shown some improved properties of such obtained high speed tool steels, but they still are not well known to many tool designers or tool consumers. Many of tool steel grades are renewed, approximately obout 60% of total steel number is changed just in last two decades. It is clear that many (dis)advatages require more detailed investigations or informations.
Conventional production of tool steels, including high speed steels, over decades (rather could be said during centuries) is provided on next shedule: melting, alloying, casting, forging/rolling, cutting by milling/turning, than heat treting and finely grinding. For tools with complex geometry this shedule commonly is favorable, but there are tool products for whom the P/M becomes more favorable. This statement is dedicated to the speccialy alloyed tool steel: addition of some reactive and alloying elements (such as vanadium, titanium, niobium, boron, etc.) posses such chemical and metallurgical properties that during melting/refining and alloying they easily made oxides, carbides, borides or nitrides. Those compounds after solidification of melted steel are distributed at grain borders, making a steel more brittle. Such problems could be markable avoided in P/M methods: powders of desired metals or nonmetals firstly are mixing, than pressing and undergo to sintering. In P/M production schedule making of brittle oxides, carbides, nitride, or borides could be avoided in a large scale. After 1960' many efforts have made in P/M producing.
Some of here mentioned facts pretty well may be registered by optical microscopy, that will be a goal in this paper. The microstructures presented here are not purely for academic discusion.

MATERIAL AND METHODS

Tool steels

No doubt that tools generally are highly loaded from all of other elements or components in entire mechanical engineering. This is a main reason that for long servicing, the tool must be carefully designed, used qualitative alloying elements and production method(s).
Tool steels are a pretty large group of steels. Almost of them must possess high hardness, good wear resistance, thermal stability, etc. [7,8]. According to their chemical composition they may have been (high) carbon or alloyed steels (usually with molibdenum, wolfram aand other high-temperature melted metals). A relatively novel group of tool steels are those made with addition of nonmetal powders, mainly those from a group of interstitial elements, as like boron, etc. Practically, tool steel are regarded as steels for making dies (either for cold or hot deformation) or cutting tools (most known from this group is high speed steel), etc.
Main shedule for producing different kinds of tool steels is *ingot metalurgy*, Fig. 1. Every production starts with melting (it includes also refining, alloying or degassing), after obtained as casted products they are shaped [5-11], by any of deformation processes (in hot or cold state).

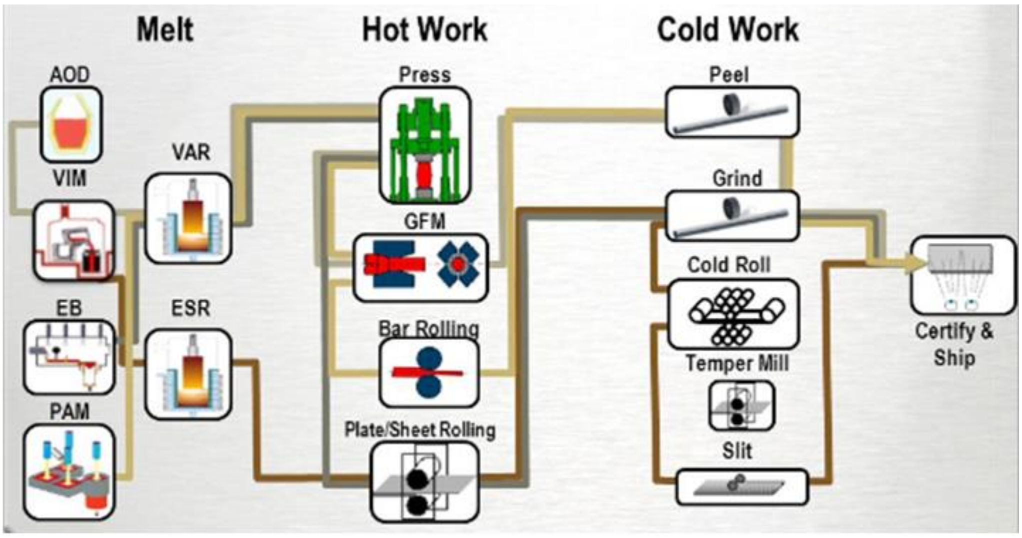
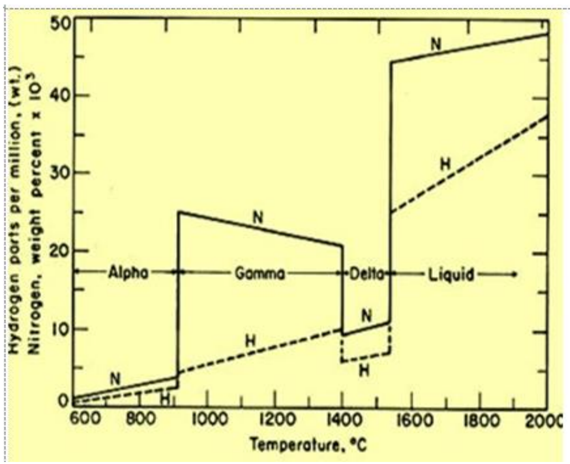


Figure 1. Typical shedule for producing different kinds of tool steels by ingot metalurgy

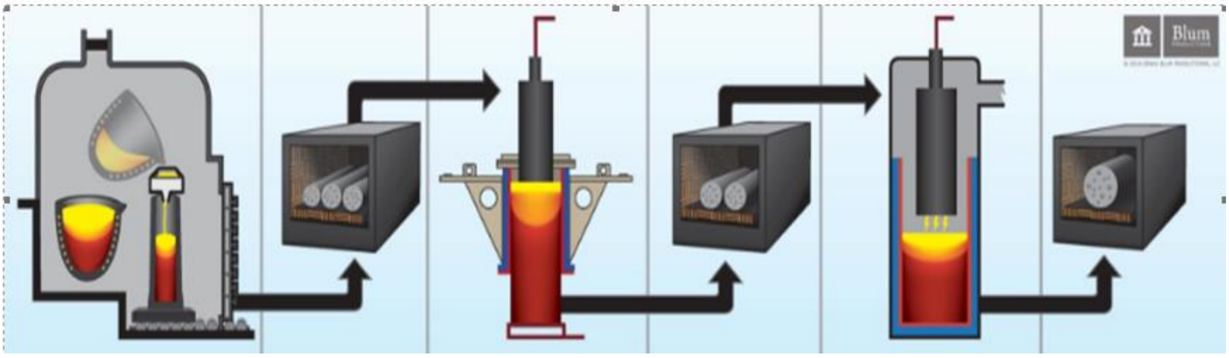
By this shedule are not shown intermediate heat treating annealing(s). During melting, the concentrations of gases are rapidly increased and stayed in solidified steel. One diagram which shows the nature of commonly gasses distributed in iron as a function of temperature is shown in Fig. 2a). During cooling of melted&alloyed steel many gasses will be liberated [2,3,11], Fig. 2b).



a) b)

Figure 2. Absorbtion of hydrogen and nitrogen in iron during heating a) and liberation of gasses during cooling of a small melting furnace b)

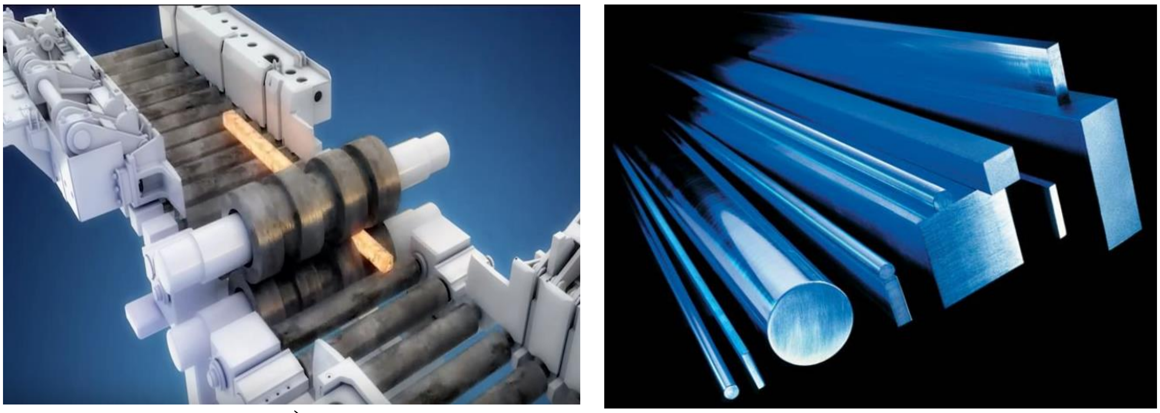
For quality tool steel this kind of treating was not enough, so the double or even triple remelted should be provided for obtaining an ingot, Fig. 3.



a) b) c)

Figure 3. Scheme for triple remelting of tool steel: a) vacuum induction melting (VIM), b) electroslag refining (ESR) and c) ESR in vacuum

After such treating is applyied, the amount of absorbed gases and non-metallic inclusion are dramatically decreased. It means that tool steels properties will be satisfactory improved. The next step in ingot metallurgy shedule is deforming, one kind is shown in Fig. 4a)



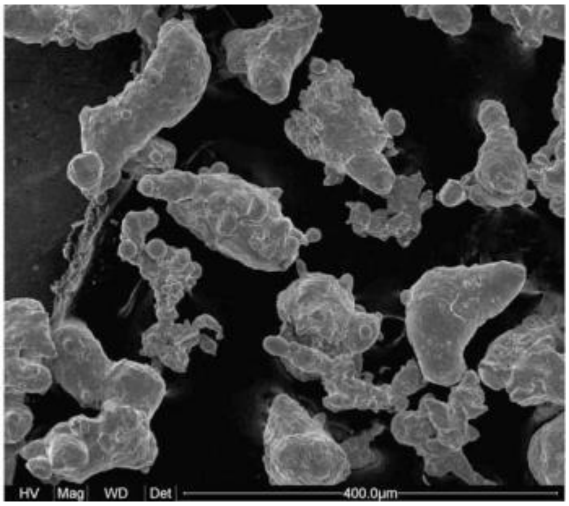
a) b)

Figure 4. Hot rolling of a bar from tool steel a) and principal shapes of I/M tool steel semiproducts b)

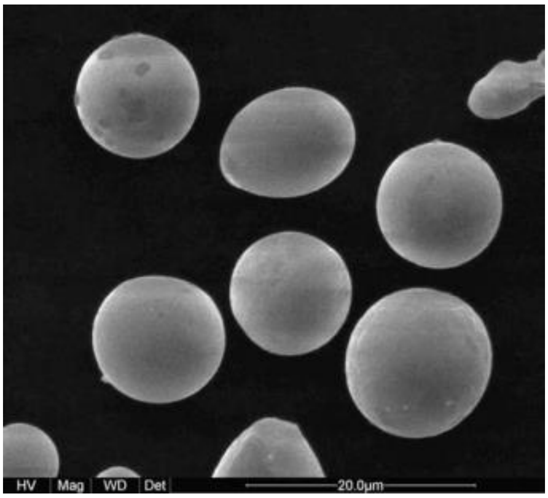
Assortiment of semifinal tool products usually is versatile, Fig. 4b).

Powder metallurgy and sintering methods

The shape of powder particles (grains), i.e. morphology of powder [2,5-7], may be different, Figure 5, depending to the production method. Irregular, dendrite like, particles are less desirable than spherical, neither from metals, carbides, nitrides, etc .



a)



b)

Figure 5. Two examples of typical powder grains: a) irregular and b) spherical; SEM images

Production and sintering of powder(s), either from metal or nonmetal, in its nature always is complex, Fig. 6, so this production is not profitable for cheep components.

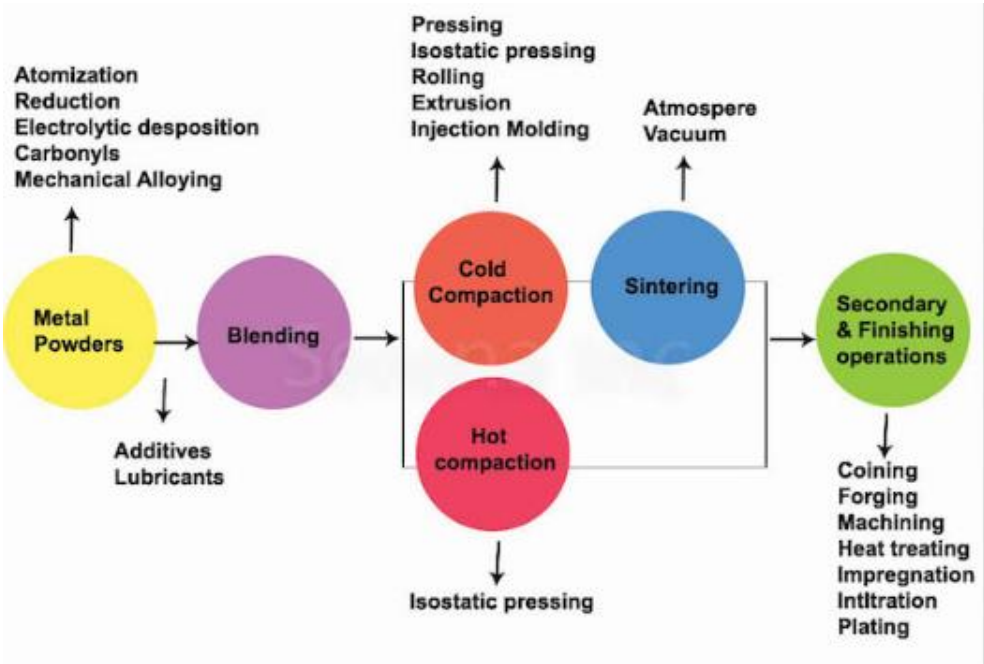


Figure 6. Technological shedule for production of P/M components

Of course that every step in this proces is important.

Pressing

Produced powders are mixing and next obvious operation is filling a die hole. For fullfilling a die hole, the shape of powder particles is of importance, and from that reason for tool making is better spherical than dendritic shape. After fullfilling a die hole is complited, next operation is pressing (compacting), and this operations consists from few steps, as shown in Fig. 7.

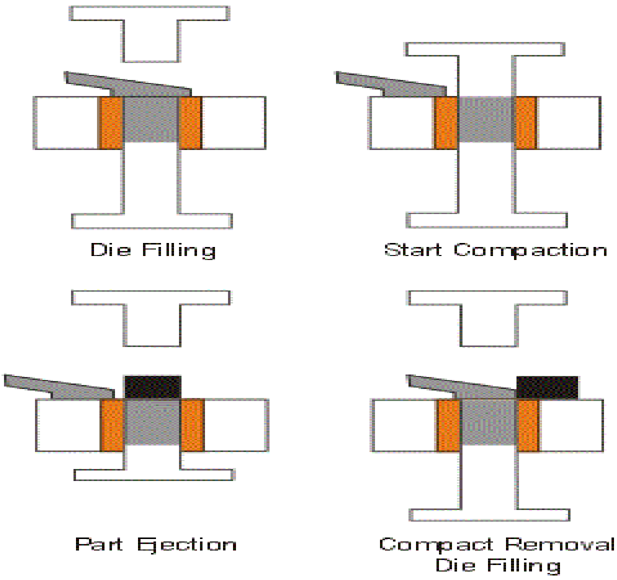
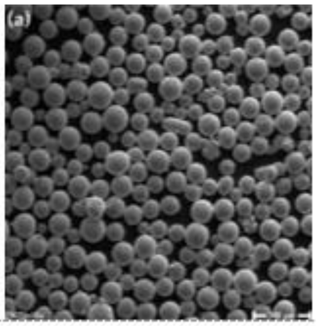


Figure 7. Principal steps in die filling and pressing for obtaining a compacted raw part

In passed period, even now, the pressing is provided at room temperature, so called *cold pressing*, by applying pressure usually in range 3-5t/cm^2. Pressing the components of simple geometry, as a polyhedral or similar form, is not a problem while for complex geometry becomes less feasible. Compacted components always posses quite small values of toughnes, strength („green strength“) or hardness, so after cold pressing those components obviously are going to sintering, when mentioned properties remarkably are increased.

Sintering

Sintering is a typical heat treating process in which the high working temperatures play an important role: at high temperatures the diffusion is emphasized [9-11] and powder particles became more dense. Macroscopic view of powder particles (≈5μm) before sintering is shown in Fig. 8a).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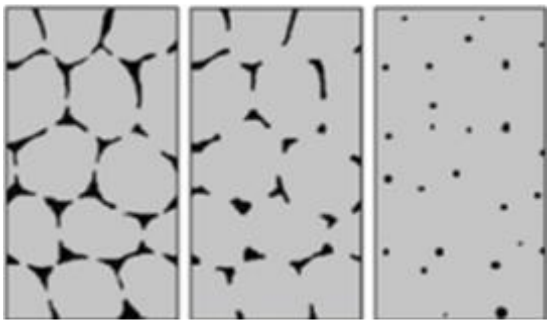

b)

Figure 8. Powder particles before pressing a), and tree stages of reduced porosity (black areas) b)

During sintering the particles are „joining“, either this process is providing in a solid state, when the porosity between them markably is decreased, as shown in tree stages in Fig. 8b). Pores are, generally, one of the greatest problem in obtaining a dense product by P/M methods.
As the sintering temperatures always are high, for steel in range 1100^{0}C – 1300 (1400)^{0}C, than present particles of (non)metals became more reactive, so they may oxidize. Oxides into such steels have the negative influence on joining particles during sintering process and later to the properties of such product [1-7]. It is clear that protective atmosphere should be applyied. The vacuum furnace is the best solution for avoiding an oxidizing atmosphere.
Furnaces used for sintering in their design may exist as chamber or continuous (commonly bell type), almost in protective atmosphere.

Hot isostatic pressing

It was shown that pressing at elevated temperature is more beneficial, because at the same time both pressing and sintering process are provided. This treatment is known as *Hot Isostatic Pressing - HIP*. For heating up of powders to be pressed and sintered, many methods were developed [12-17], but one of the advanced is by using a plasma, Fig. 9.

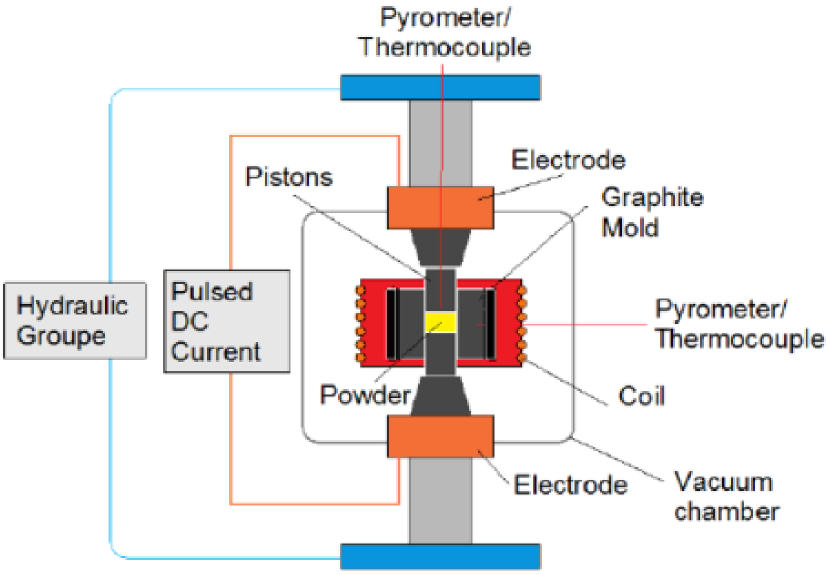


Figure 9. Principal scheme of hot isostatic presing and sintering in vaccum with pulsed plasma

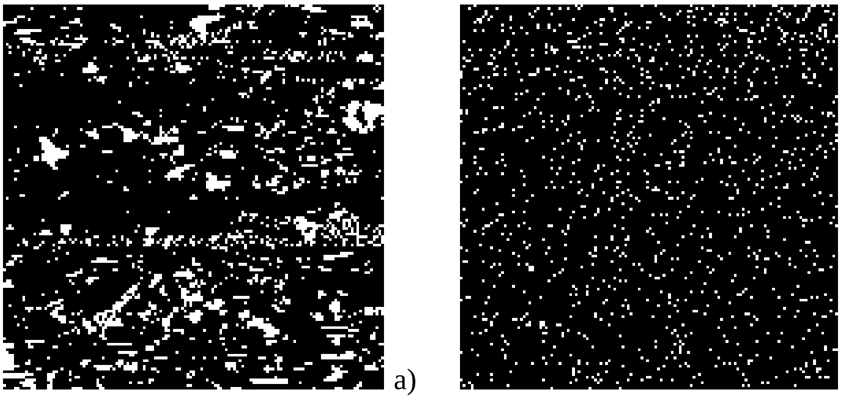
Graphite mold serves for ensuring the reducing atmosphere, in which is provided pressing and sintering, and for lowering the reactivity of some metals [12-15]. The pulsed DC current offers advatages than constant current suppplying for heating up of powder(s) to be sintered. It means that when pulsed DC current is used, than is a need for lower pressure during compacting in comparison to compacting at room temperature. Also, the amounts of pores are decreasing when pulsed current is used. All elements in such production are positioned in a vacuum chamber. The entire system still is expensive, so may be used only for precious components.

RESULTS AND DISCUSSION

There is no markable difference in hardness values between I/M and P/M products, for high speed steels those values commonly are in range 62-65HRC. Principal characteristics of as casted high speed steel is in great liquation (infomogeneos) and also in distribution of alloying elements and appropriate carbides [2,3,16]. By metal working processes, followed with heat treating (a kind of annealing), the degree of inhomogenity will be lowered, but not fully disappeared.

Microstructures of I/M and P/M tool steel

The most visible diference between I/M and P/M products could be seen just in their microstructures [7-10], one example is shown for one tool made of high speed steel, Fig. 10. Carbides, white phase at Fig. 10a), still are large (up to 50µm or more), although they are elongated and deformed in the direction of deformation. Carbide phase in sintered powder, Fig. 10b), is much smaller than carbides produced by conventional production methods.



a) b)

Figure 10. Microstructures of same high speed steel M3/2produced by: a) conventional melting and deforming and b) powder materials, x100

When mixing of powders is provided well, the obtained microstructure, Fig. 10b), is without large carbide phase. Higher sintering temperatures may have influence on appearing the large grains. The amount of carbides and their distribution, of course, markably influences on finished tool charasteristics, first of all on impact toughness, and however on tool servicing life.
P/M production methods are more expensive than conventional I/M methods, but available for special kinds of tool steels. Pores are still the large problem in P/M products.

CONLCUSIONS

Conventional methods (I/M) of tool steels production are pretty well developed, also their heat treatment. There are some tool steels in which the alloying by using a reactive elements, as like vanadium, niobium, etc, still represents the problem.
One usable solution is production the desired tool steel is in applying a powder metallurgy (P/M) methods: powders of diferent (reactive) metals with carbides or nitrides may be mixed, pressed and sintered, when conventional methods of steel melting are invalid. The microstructural monitoring, as a method in controling both I/M and P/M tool products, clearly has shown the differences in shape and kind of distributed phases, with special attention on carbides in high speed tool steel M3/2.

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Session 1.

Mechanical Engineering

A MODEL FOR MANUFACTURING OPTIMIZATION AND ACHIEVING HIGHER PRODUCTIVITY IN SMALL AND MEDIUM-SIZED ENTERPRISES

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Abstract: Manufacturing optimization is a crucial part of productivity increase. There is a large set of tools and techniques that can contribute to manufacturing optimization. Now, the small and medium-sized enterprises (SMEs) can be depicted as the cornerstone of economic stability and economic growth in developing countries and in developed countries as well. In this paper, manufacturing optimization for higher productivity in SMEs is addressed. The main idea was to thoroughly analyze literature in this domain and to develop a model for manufacturing optimization. After a literature analysis, this present paper presents a generic, theoretical manufacturing optimization model for achieving higher productivity. The model moderately contributes to the existing body of literature and it can be used for future research in this domain.
Key words: manufacturing optimization, SMEs, reengineering, lean manufacturing, TQM

INTRODUCTION

Small and medium sized enterprises (SMEs) are considered to be the backbone of economic growth [1]. Additionally, it was noted that SMEs can be observed as "incubators" of technological change, advancement and innovation [2]. The flexibility and positive social impact of SMEs has a tremendous value for every country and they provide employment opportunities and support for large scale manufacturing companies [3]. In a turbulent and dynamic business environment companies have to continuously improve in order to survive on the market and to establish a competitive market position [4]. Over time, manufacturing SMEs have to consider optimizing their manufacturing processes in order to reduce costs and increase productivity, thus increasing their competitive position on the market. Similarly to large scale manufacturing companies, SMEs also have to consider the level of sustainability of their manufacturing model. Sustainability can be achieved through thorough evaluation, and through optimization of various products, processes on various levels of the manufacturing model [5]. Manufacturing optimization can be conducted in various ways such as lean manufacturing [6], business process reengineering (BPR) [D38], total quality management (TQM) [7], six sigma [8] and other methods. Now, these methods further include various tools and techniques. The approach to manufacturing optimization depends on the type of product, number of employees, organizational structure and culture, and a large set of other business and performance metrics. Therefore, it is not practical to address manufacturing optimization for specific products. A more efficient way of manufacturing optimization is through generic approach that is applicable to a wide range of SMEs, and to develop intricate, and specific actions of optimization internally. This would include the identification of various processes, tasks, and other elements of the manufacturing system. Furthermore, when it comes to manufacturing optimization, there is a large body of literature that addresses a large number of case studies where manufacturing is optimized. For this paper, a few dozen literature sources are studied with the idea to provide a good basis for future research in this domain.

In this paper a theoretical model for manufacturing optimization in SMEs is developed. The main idea was to develop a generic model that could be customized for the needs of specific SMEs. The optimization methods such as business process reengineering, lean manufacturing, six sigma, total quality management, kaizen and other tools and techniques are analyzed. The paper has two main sections. The first section analyzes the mentioned optimization methods. The second section presents the proposed model for manufacturing optimization. Finally, conclusions are drawn and future research is discussed.

PROCESS OPTIMIZATIO METHODS

Business process reengineering

Business process reengineering (BPR) can be viewed as a radical and overall thorough change of various processes in the company and a drastic change of the workflow design with the goal to achieve higher business performance including reduced costs, increased productivity, higher quality, and better service [9]. The main critical success factors when it comes to business process reengineering are top management commitment and support, collaborative working environment, employee training, IT infrastructure, organizational culture, adequate financial and other resources, and a decrease in the bureaucratic structure [10]. If implemented correctly, BPR could dramatically enhance the business performance of SMEs [10]. Competitiveness of SMEs and other companies in general, refers to the ability to adequately manage resources, knowledge, competencies and adapting faster and more effectively to market changes compared to the competition. Thus the main triggers for conducting BPR are external pressure from competitors, managing change, acquisitions, and the overall need to reduce costs [11]. Why is BPR important for SMEs and manufacturing optimization? Is it not too radical and expensive? Well, this approach brings a lot of risk, thus it is important to address all the possibilities before engaging with BPR. It is inevitable that BPR and performance measurement affect manufacturing strategies [12]. It can be concluded that BPR should be conducted only when other methods can’t improve business performance. It is a complex method, thus it requires a lot of resources [13].

Lean manufacturing, six sigma and lean six sigma

In order for companies to remain competitive on dynamic markets, it is not enough to develop good products and services, but also they have to improve and enhance their manufacturing system [14]. SMEs are often challenged by the lack of necessary knowledge that would improve overall business performance. Now, lean manufacturing should be implemented in accordance with the need of these SMEs [6]. Lean manufacturing can be viewed as a set of tools, and principles, as a philosophy, an approach or a system where the main goal is to reduce waste and unnecessary work during the manufacturing process [15]. Lean manufacturing focuses on waste that includes: waste of unnecessary motion, transportation, processing, inventory, defects, and underutilized people. These have to be taken into consideration when lean manufacturing implementation is conducted [16]. Lean manufacturing has the potential to drive up value of products, thus ensuring continuous improvement of the company’s market position. Lean manufacturing is often depicted as a way of thinking that nourishes a culture that supports continuous improvements of various processes in the organization [17].

Six sigma is a structured method that integrates and uses statistical methods to dramatically decrease defect products or services from a customers’ point of view [18]. Six sigma has a quality goal of 3.4 defects per million opportunities/products (DPMO) [18]. Now, it was mentioned that SMEs operate under a lot of pressure that comes from financial and non-financial constraints [19]. Six sigma can’t be applied to SMEs in a way that large scale manufacturing companies apply it. Changes have to be made in order to successfully apply the six sigma method in SMEs. This is achieved through data driven decision making, optimum manufacturing parameter settings, employee training, advanced statistical tools, critical quality issue identification, competitive awareness and effective management [19]. It is interesting to note that six sigma has a more positive impact on performance in ISO certified companies [20]. A pre-existing quality management system is certainly a good basis for six sigma implementation.

Lean six sigma utilizes both lean manufacturing and six sigma. Through lean management waste is reduced, and six sigma reduces the number of defect products. This leads to dramatic cost reduction, higher productivity and overall improved business performance [21]. Some of the main critical success factors of lean six sigma in SMEs are employee training; management involvement, commitment and support; customer orientation and customer satisfaction; project prioritization; leadership; cultural change; understanding lean six sigma; process management; product design; employee satisfaction; employee reward; inventory control; and communication of information [22]. Next, the Kaizen approach will be discussed.

Kaizen

Kaizen (from two Japanese words "Kai" meaning change and "Zen" meaning good/improvement) can be defined as an approach towards continuous improvements in terms of productivity, costs and quality [23]. The changes that occur under Kaizen are not necessarily drastic, but rather incremental and continuous. Further, the Kaizen management approach includes principles and values, and techniques that fall under the Kaizen "umbrella". These principles and values are employee participation; focus on processes; maintenance and improvement; top management commitment; experimentation and observation skills; and discipline. The used techniques are total productive maintenance; total quality control; automation; Kanban; just-in-time; total flow management; zero defects; and quality control circle [24]. It is evident that Kaizen includes a large variety of techniques and tools. Thus using Kaizen in SMEs requires identifying the processes, procedures and skills of employees and take small steps towards improvement. Kaizen is also used as tool in the lean manufacturing approach.

Total quality management

Total quality management (TQM) can be viewed as a management practice that focuses on improving the quality of products and/or services. There are seven main categories of TQM practices. These are strategic planning; leadership; human resource management (HRM); customer focus; process management; information and analysis; and supplier management [25]. There is evidence of a strong, positive relationship between TQM practices and SME organizational performance. However, the positive effects of TQM practices on financial performance in SMEs is weak [26]. Furthermore, when it comes to TQM implementation, it is important to note that TQM practices can have a significant a negative effect on role stressors (when employees are uncertain about their tasks, responsibilities and duties in the company). Therefore, it is necessary to clearly define the tasks, processes, responsibilities, and duties of every employee during and after the TQM implementation process [27]. The objective of TQM is to manage processes that focus on effectiveness and business performance [28]. In this case business performance includes financial performance (market share, profitability, return of investments etc.) and operational performance (product quality, inventory performance, and customer satisfaction). For SMEs, TQM could be considered as a management tool that facilitates the improvement of organizational performance in a dynamic environment [29]. Certainly, it can be seen that TQM practices can bring improvement to SMEs.

Other tools and techniques of manufacturing process improvement

Some of the tools for manufacturing process optimization may include mind maps [30], Fishbone/Ishikawa diagram [31], DMAIC (define, measure, analyze, improve and control) [32][33], principle of 5S, PDCA (plan-do-check-act/adjust) [32][34], Pareto charts [35], value stream mapping, particle swarm optimization [D5], data mining driven manufacturing optimization [36], supply chain, employee scheduling, gantograms and other. Evidently, there is a wide variety of tools and techniques that can be used for manufacturing optimization. However, not every tool is adequate for every SME, and it is necessary to address specific characteristics of a specific SME in order to use the right tool and technique to optimize the manufacturing process. In the next section, a theoretical model for manufacturing optimization and improvement is presented.

A MODEL FOR MANUFACTURING OPTIMIZATION AND IMPROVEMENT

The theoretical model for manufacturing optimization is based on studies conducted in the domain of SME manufacturing, business process and manufacturing process improvement, and overall optimization of manufacturing systems. There are various models of manufacturing systems, therefore the presented model is generic in nature and it should be viewed as a framework that requires specific customization in order to be suitable for a specific manufacturing system. The model is depicted on Figure 1.

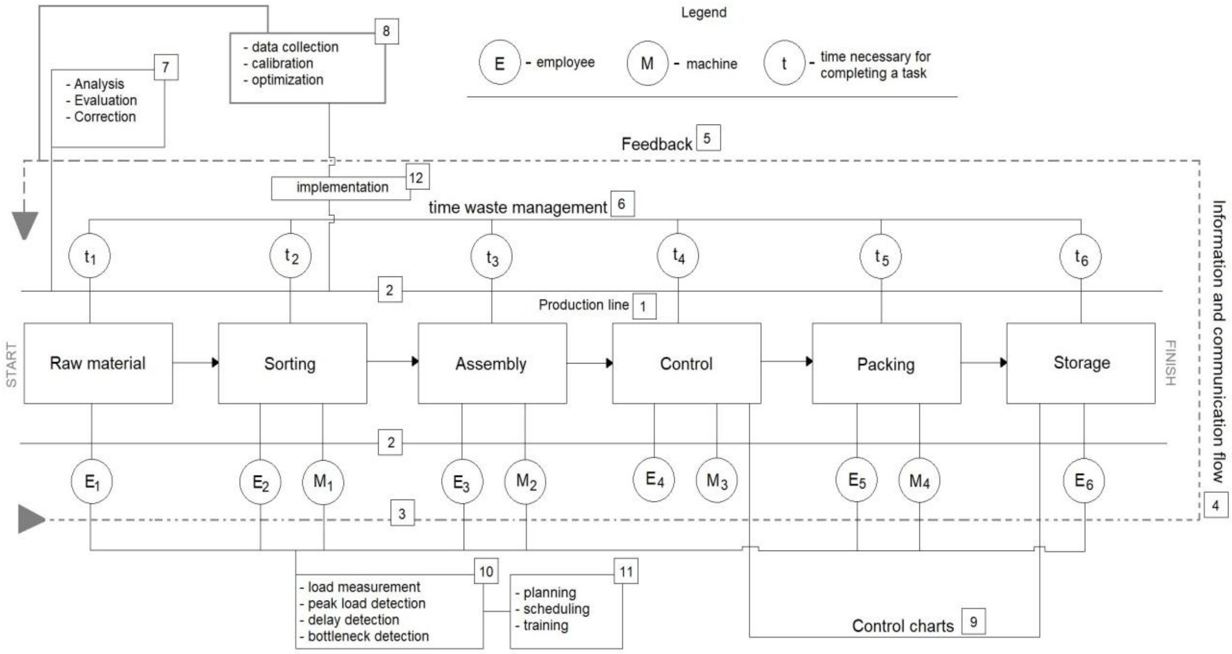

Figure 1. A theoretical model for manufacturing optimization and improvement

The model for manufacturing optimization and improvement is depicted through an example of a simple production line. Several procedures are labeled with numbers from 1 to 12. The detailed explanations for these labels are given in Table 1.

Table 1. Label description

#	Description	#	Description
1	Production line. In this case it represents a generic production line which from start to finish includes the following elements: - Raw material (materials that are necessary to create a product); - Sorting (sorting the raw material and preparing it for the assembly process); - Assembly (this can also include production of parts from raw materials that are part of the product. It is depicted as the core of the production line as this is where the products are created); - Control (at this point quality control is conducted); - Packing (the products are packed and prepared for storage); - Storage (when the products are stored, additional quality control is conducted).	**7**	Analysis, evaluation, and correction refer to the data from the feedback. That data is processed and analyzed thoroughly. The weak points of the production line are evaluated, and necessary corrections are conducted. Here, a fishbone (Ishikawa) diagram may be helpful. This step is similar to the feedback loop, thus it repeats itself in accordance with the objectives of the production/manufacturing line. Similar to the feedback, this element of the optimization process also plays a crucial role.

2	Production line border. Within this border the generic production/manufacturing process is conducted. Additionally, employees (E), machines (M) and time necessary to complete a task (t) are included.	**8**	Data collection, calibration, and optimization. Here, the data collection process involves the already analyzed data from the feedback and from the time management module. Calibration is used to clearly define some of the manufacturing elements before optimization. The main optimization process may include incremental improvements to certain employee movements, robotic arm movements, time delays between raw material insertion, storage speed and inventory organization, or it can involve drastic changes (BPR) to the whole manufacturing process. This is all based on the feedback data, and the optimization has to be in-sync with the main objectives of the business strategy.
3	The dashed line represents the flow of information and communication in the manufacturing process. This also includes feedback of information.	**9**	Control charts are a great tool to for quality control. However, there may be other tools that could be used such as histograms, scatter diagrams, flow charts, statistical sampling etc.
4	The information and communication flow includes data/information about: raw material type; raw material quantity; employee work load; machine workload; information about time, raw material and defect waste; control charts; packaging; storage/inventory; schedules; quota status; number of pre-packaging and post-packaging product defects.	**10**	Here, the load of employees and machines are measured, and that data is used to optimize future workload. Additionally, peak loads, delays and bottlenecks are also addressed. This way if there are issues in the production line, they can be fixed in an adequate manner.
5	Feedback is a crucial part of the optimization process. The feedback provides the necessary data through which the manufacturing process is optimized. As mentioned in the literature review, the optimization can be quality oriented (TQM, Six sigma, ISO 9000 etc.); continuous improvement oriented (Kaizen); minimum waste oriented (lean manufacturing) or oriented towards an increase in overall business performance.	**11**	Planning, scheduling and training activities in this case, are referred to employees. Planning and scheduling is an efficient way to address bottlenecks, and delay in the manufacturing system. Training activities can increase productivity, and reduce overall production costs.
6	Time waste management. The time necessary to complete certain task is addressed. Before the data collection, time has to be managed in clearly defined by steps. This means that there is overall time (t_o) for a production cycle that consists of time necessary to complete a specific action on the production line (raw material-t_1; sorting-t_2;… storage-t_6). Further, these can be sub defined. For example, assembly time is t_3, employee time to complete the assembly task is t_{3E}, machine time to complete assembly task is t_{3M}. Depending on the complexity of the optimization algorithm, the time for a certain task is defined accordingly. Therefore, time waste management keeps track of these times and includes them into the optimization algorithm.	**12**	The implementation process includes the execution of the defined changes to certain elements of the production line with a goal to achieve desired levels of productivity and workflow.

Furthermore, a simple algorithm that depicts a potential optimization process at the assembly module is developed. This algorithm is shown on Figure 2.

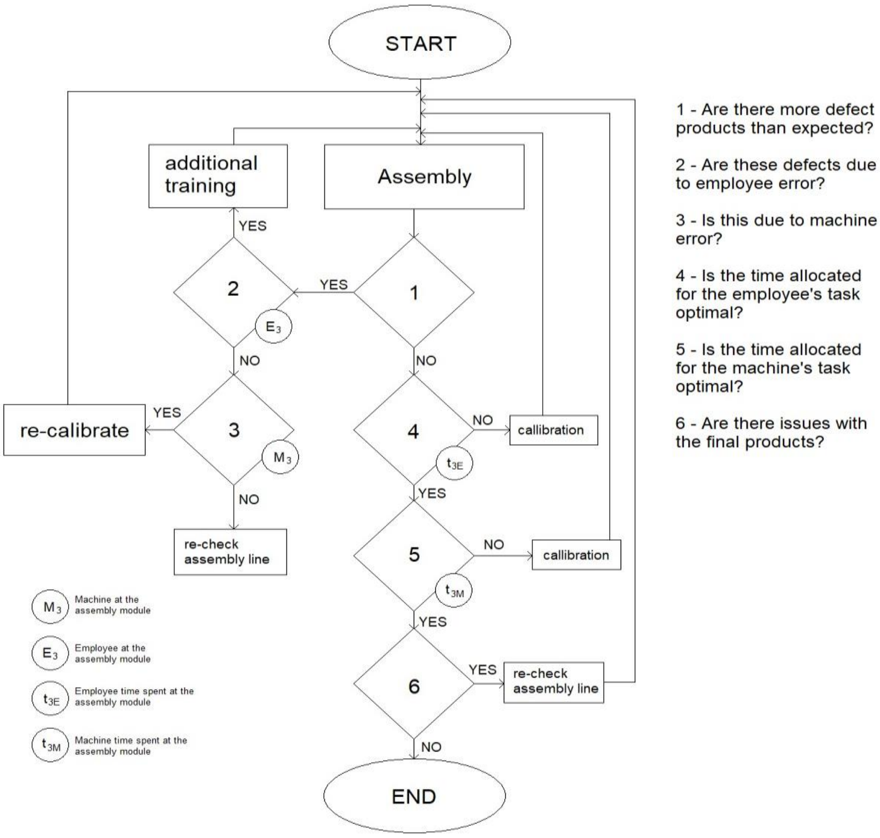

Figure 2. An optimization algorithm for the assembly module

The algorithm depicts the elements in the optimization process that include employees, machines, and the time allocated for specific tasks. For the model and algorithm development process, credible literature sources were used [37], [38]. The optimization algorithm, similarly to the optimization model, is generic in nature, and in practice these can be far more complex.

CONCLUSION

Based on the conducted research in the domain of manufacturing optimization, it can be concluded that there is a vast amount of methods, techniques and tools which can be used to optimize manufacturing systems. When it comes to SMEs, manufacturing optimization differs compared to large-scale manufacturing. Therefore, it is necessary to address all the factors that may affect productivity, costs, waste and other optimization parameters. In this paper a theoretical model for manufacturing optimization and improvement is shown. Additionally, an algorithm for optimization which is based on the model is depicted. The approach in this research is focused on pointing out the potential solutions when it comes to optimizing and improving the manufacturing process. In order to implement the proposed model it is necessary to specify the manufacturing parameters such as allocated manufacturing time for each process, number of employees, number of procedures, number of products manufactured, etc. The algorithm includes only the assembly module. This way the optimization approach can be more precisely depicted.
It can be noted that this paper has a moderate contribution to the existing body literature in the domain of manufacturing optimization in SMEs. The main limitation of this paper is the generic framework of the proposed models. For future research it is recommended to develop a more complex model that includes more modules in the production line, thus providing a wider range of possible practical applications. Additionally, existing optimization models should be addressed and analyzed thoroughly. This paper provides a good basis for this future research.

ACKNOWLEDGEMENT

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USING SCADA SYSTEM FOR PROCESS CONTROL IN WATER INDUSTRY

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Abstract: In this paper, we explained the concepts of industrial engineering, the ecological aspect of water treatment and the systems for wastewater purification. The goal of introducing the automation of the process of processing and purifying water is to make as many functions of the technical process as possible in an economically acceptable manner. SCADA is a system for measuring, monitoring and controlling industrial systems in different fields. This paper presents the SCADA application in the control of technological processes in water treatment. The advantages of using the described SCADA application represented in this paper showed increasing the safety of employees, the accuracy of the water treatment process within the given parameters and the economy of the automated industrial water process.
KeyWords: industrial engineering, water treatment process, SCADA, ecology.

INTRODUCTION

The rapid increase in human activities and the industrial revolution have led to an increase in energy production and consumption of natural resources [13], [16]. At the same time, the increase in production levels and increased energy consumption significantly disturbs the ecological factor and the natural balance [1], [2]. Consumption of large quantities of natural resources creates enormous amounts of waste and pollution. New technologies often result in greater consumption of natural resources [2]. Industrial engineering explores the principles of design, organization and management of production processes and systems [13]. Industrial engineering finds a way to conduct analysis and to improve the segments of production activities or the production system as a whole, especially from the aspect of technical efficiency [16]. Industrial engineering finds application of modern methods and approaches for the purpose of planning and optimizing the process already at the stage of designing production systems [13], [16].
Environmental technology envirotech or greentech or cleantech is the application of environmental science and green chemistry to preserve the natural environment and resources [8], [14], [15], [16]. Sustainable engineering is a process of using energy and resources at a rate that does not endanger the natural environment [16]. Water is a necessary raw material in industrial production, energy, food industry, utility needs and all other production processes. The most demand for cleanliness of water is set by the food industry as well as utility systems for supplying citizens with drinking water [8], [16]. All of the raw water treatment processes are of great importance, solid suspended, organic and inorganic chemical components, bacteria and chemicals that give a bad taste and smell [8], [11], [14], [15]. Due to high raw water treatment costs, suitable technologies must be combined in the best way to strike a balance between price and water quality obtained.
SCADA (Supervisory Control And Data Acquisition) applications in industrial systems is the highest quality, but a costly solution. SCADA systems have wide application in the management and monitoring of the operation of industrial plants and equipment in telecommunications, energy, wastwater systems and other fields [3], [4]. SCADA represents a system for monitoring, monitoring, archiving and control of industrial systems with parameter display, with the availability and reliability of such a system at a high level [6], [7]. These systems include a wide range of equipment, subsystems and technical solutions that enable the collection and processing of process data, and responding in an adequate optimal way. Process management can be automated or initiated by the operator. In the field

of treatment, water can be used from simple monitoring of flow, pressure, residuals, to complex monitoring and control of technological processes of water disinfection [1], [2], [3].

MATERIAL AND METHODS

The paper presents an example of the application of the SCADA system used in water supply systems [3], [4], [6], [7]. For this purpose, the Wonderware InTouch software package can be used [18]. The most common relay system is built up through two SCADA configurations [10], [12]. The first application is introduced by PLCs (Programmable Logic Controllers), with a proposed TCP/IP (Transmission Control Protocol/Internet Protocol) protocol based communication connection [5], [9], [17]. This application uses a simple signaling and alarm system and simplifies process management through increased functionality and productivity. On this application it is necessary to perform a clear signalization of the condition of the equipment as well as an alarm signal indicating when the process does not meet the nominal working conditions.The three components of the SCADA system are: multiple remote terminal units PLC master station and HMI (Human-Machine Interface) computer and communications infrastructure. Master station refers to servers, to software for communicating with equipment, and to HMI software running on one or more computers in the control room. In smaller SCADA systems, the main station can be only one PC, while in larger SCADA systems, the main station can consist of multiple servers and distributed software applications. Depending on the chosen configuration, the communication infrastructure is selected. This involves the choice of signal levels for transmitting data from the encoder to PLCs as well as linking the PLCs to the computer on which the SCADA is installed [9]. The signal communication link is based on the TCP/IP protocol [5], [17]. The application of SCADA system offers a number of advantages: the existing installed equipment can be used to expand the production capacity, the realized relay management scheme is retained, the security is increased because the centralization is reduced (one computer runs the entire process, and in the event of a failure it stops completely all parts of the process) there is a group of users of the system trained to work with the Wonderware InTouch software package for SCADA system [6], [10], [12], [18].

The simplest configuration of the SCADA system is reduced to a system that consists of one-way switches, encoders, relays, etc. on the other hand, a PC that receives data through its acquisition card, processes them, forms information about the controlled process, and determines management actions. Simple structures include the configuration that is formed from one PLCs and PC with SCADA system. With this SCADA system configuration, the introduction of a PLCs means the ability to monitor / manage one other process from one computer. PLC device is placed in the control room, in order to provide optimum operating conditions and receive information on the pressure, level and position of the valve on the input module. It is also possible to use PLCs with digital input and output module. InTouch is a software package that creates applications for SCADA systems. For the purposes of this work, version 10.0 was used. Wonderware InTouch allows two trends to display the values of the defined variables: real-time and history data [10].

SCADA system in plumbing systems

In cases where the water treatment plant is separated from the control center, it is possible that all signals related to the basic process parameters will be brought from the automation to the master PLCs with the touch screen operator panel and the control system connection. In this way, the user is enabled to inspect the status of water treatment and chlorination systems and there is the possibility of changing certain process parameters.

The remote touch screen panel are particularly practical in geographically diluted water systems is shown in Fig. 1. The touch screen control panel is located on the front and has a sound indication of touch. Over a dozen screen displays provide an optimal view of all the information necessary for quality monitoring of the water treatment process, as well as a detailed system management procedure.

Figure 1. Remote control panel for process automation

The control touch screen panels can be installed in the front door of the control electrical cabinets are shown in Fig.2. The characteristics of the touch screen panels are: remote control of all process parameters, remote control of the process of chlorination from the control room, data storage in the cloud or other way of storing and storing process parameters (flow, residual, valve position, amount of chlorine to be dosed, etc.), adjusting system parameters for process automation.

Figure 2. PLC with electrical cabinet

Figure 3. Electrical cabinet with touch screen panels

The Fig. 4. shows the workflow automatically monitored to control the operation of the filter fields. The flow meter signal reaches the PLCs at the command of the PLCs and the pump pumps and opens the electromagnetic valve. The picture shows whether the pump is working, whether the valve is open and how open is it, the flow rate on the flowmeter, the valve opening on the drain.

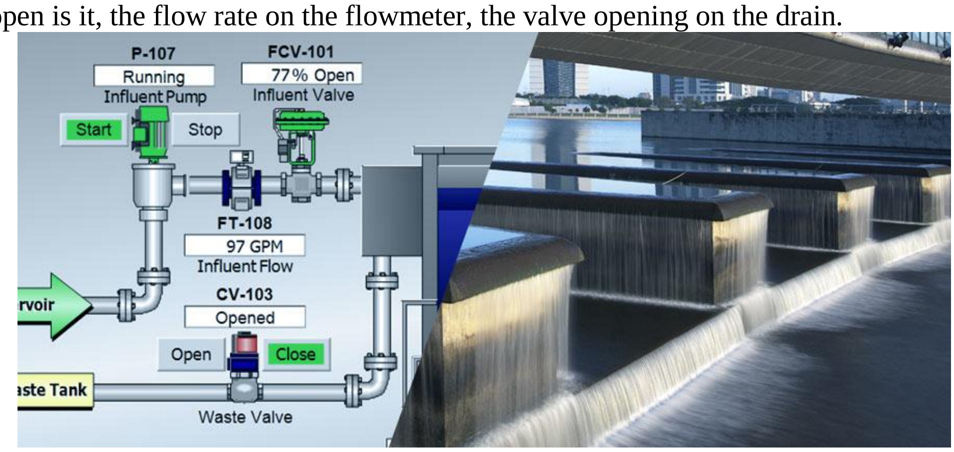

Figure 4. Monitoring the operation of the filter fields via the SCADA

The SCADA system involves a higher degree of automation of industrial processes used to collect data from sensors and instruments located at remote stations, to transmit and display data at a central station for the purpose of controlling or managing the process. The collected data is viewed on one or more SCADA computers in the central control station. Analog signals that the SCADA system monitors are levels, temperatures, pressures, flux or gas flows and engine speeds. Digital signals controlled by the SCADA system are level switches, pressure switches, generator status, contact relay status, etc. Data collection begins at PLCs level and includes reading of values and status of controlled parameters. Data that is stored and monitored can be stored in the history to show trends. The SCADA system implements a distributed database, called the tag database. Tag represents one input or output value that is monitored or controlled by the system. HMI is a device that processes process data to an operator and through which the operator controls the process. The graphical interface of the operator is a set of graphic displays that represent the representation of the equipment being watched. The Fig. 5. shows the technological process of the primary, secondary and tertiary water treatment system with the equipment that the operator sees at the touch screens panel.

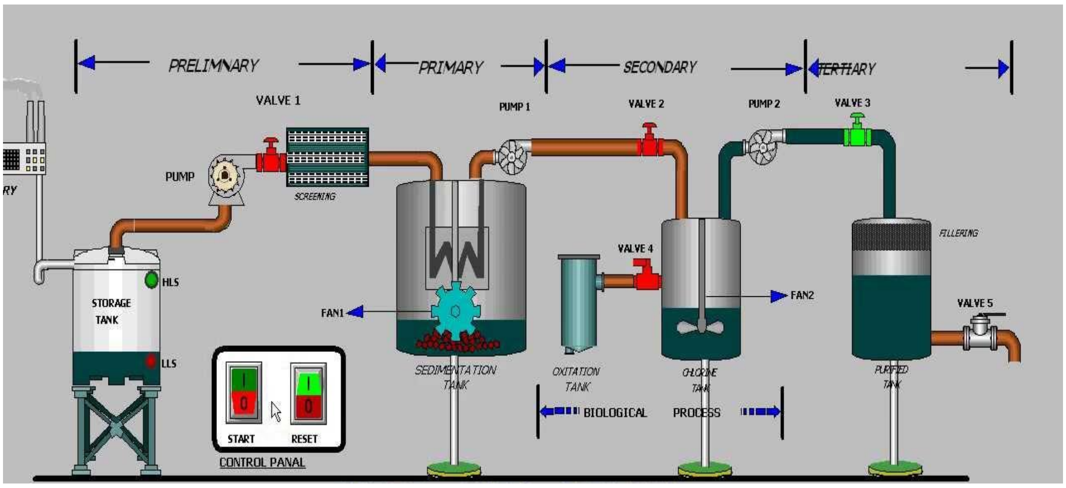

Figure 5. Water processing technology using SCADA

Bottles with chlorine and dosing device must be placed in a separate room (chlorine station) with forced ventilation, shower and drainage with sewage connection. On the outside of the chlorine station there is a cabinet and a switch to turn on the fan. In the room, a free chlorine indicator is connected to the alarm device (chlorine detector), which activates the neutralization system in the event of a chlorine expiration. The floor in the chlorine station must be carried out with the fall towards the drainage in the drain. As sensors for signaling the leakage of gas chlorine from the bottle, special electrochemical probes that react to elevated chlorine concentration in the air are used, and the electronic device includes a chlorine neutralization plant from the air. Chlorine neutralization is done in two degrees. For smaller quantities of detected chlorine in the air, a chlorine bleeding fan is started. The second phase involves the initial firing of the chlorine neutralization device from the air. The ejector within the device compulsorily inserts contaminated air through a filler that discharges with the neutralization fluid that is driven by the recirculation pump. In this forced circulation of polluted air and neutralizing fluid, the neutralization of chlorine from the air is carried out. This process lasts until the concentration of chlorine in the air drops below the given level. All activities record the PLCs device and send it to the database server and auto-record. The PLCs enables data downloading and data storage in addition to data transfer. Water entering the city water supply network should be chlorinated continuously, in order to prevent secondary infections. The adjusted concentration is independent of the amount of water flow, because the system automatically maintains a constant concentration of active chlorine. Raw water is collected in wells. Well pumps water into the precipitator. In the precipitator, physical impurities are deposited and aeration is performed. Water meters are installed in the precipitator. Measurement level meters are level ultrasonic or float system. When water is precipitated and reaches a certain level of water, the water is transferred to the filtration. From the filter fields, water is pumped into the reservoirs via filter pumps. Disinfection of water is carried out in the reservoirs and sent via the water supply system to consumers. Operation of well and filter pumps, water level measurement and automatic process control is performed by the PLCs controller. Everything is controlled and monitored by the operator in the control room of the water supply system. Special attention is paid if the parameters that deviate from the given parameters, then the system reports an error and sends the alarm signals. In the plant and control room, signal lights and sirens have come down. All employees who have the authorization to monitor and control the value of SMS messages on mobile devices. A part of the automatic system for controlling water parameters is a PLCs device with a touch screen where the parameters of operation are monitored. The most important parameters whose measurement is monitored in the on-line mode are: chlorine in water, humidity, temperature, pH value, flow, chlorine in the air, pump operation and chlorine neutralization system as shown in the Fig.6.

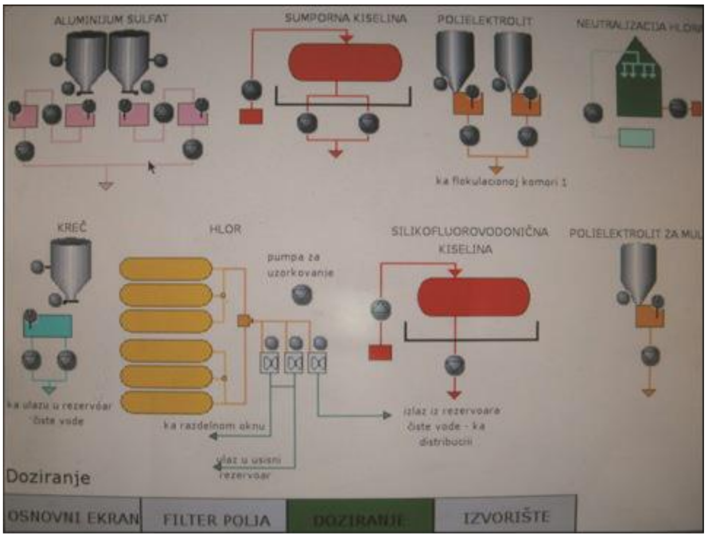

Figure 6. Technological process of water treatment using SCADA

Chlorine is dosed with a vacuum system in the reservoir [8]. In the reservoir, after dosing and disinfection of the chlorine volume measurement probe in the residual value, it sends the signal to a 4-20mA PLCs controller that opens /closes the electromotor valve on the chlorine bottles. The dosing is done by the flow of water by programming the chlorine dosing to the PLCs by the openness of the electromotor valve. According to the standards it is desirable for water to go to consumers with a concentration of chlorine in the residual 0,5 g / m3. Without the pump, the system could not function. Two pumps are always installed. One working and one spare. One of the screens of the PLC device provides information about their work. Which pump works, the number of hours of operation, the number of turns.

In the context of increasing efficiency and safety, a chlorine-producing device is produced and it is brought into the water network, by the process of chlorine production by electrolysis of salt. The device consists of several components (electrode materials, relays, programmable logic controllers, power supplies, sensor elements, converters, cooling systems, heat exchangers, dosing devices, etc.). The production process is conditioned by the electrolysis of the saline solution as shown in Fig. 7. The resulting sodium hypochlorite is subsequently dosed into the water network by the dosing system of the pump.

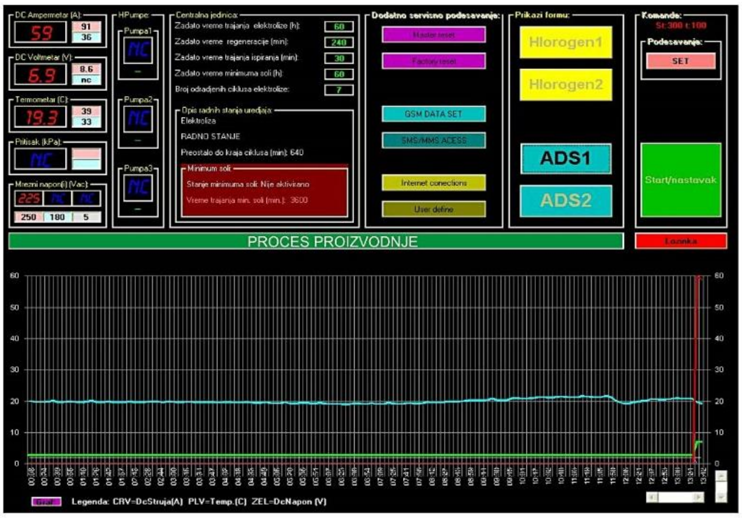

Figure 7. Process of chlorine production by electrolysis of salt

The advantages of using devices for obtaining active chlorine are: safe work for people and environment during production, reduced production costs, easy maintenance, improvement of water quality, reduced quantities of side products during disinfection, operation of the device does not depend on the purchase of special chemicals, the cheapest disinfectant.

The communication system provides the transmission of information between remote stations and the dispatch center [5]. Distant stations are independent microprocessor devices that provide communication between measuring equipment, executive organs and central station. Measurement equipment data is transmitted to the central station and from the central station the control commands are transferred to the executive bodies. The remote station monitors the status of the process equipment and signals the appropriate alarms. Remote stations are programmable logic controllers that have application software, microprocessor and components to control the activation of a PLC device. PLCs are specialized computers whose operating system allows simple and real-time processing of a large number of data and send the obtained results to executives. Under a remote water supply facility, a well, a tank, a shaft, a water-tower are understood.

Wireless data transfer from peripheral stations to a central unit can be done using a radio, wi-fi or GPRS (General Packet Radio Service) connection [5]. For high-speed transmission, radio and wi-fi connections require special conditions, primarily optical visibility. The new way of connecting is realized today by GPRS connections that do not need to invest in infrastructure, because they use existing communications, and data transfer using GPRS is fast, secure and accurate. The GPRS service does not charge for the duration of the connection, but the amount of downloaded data. The Fig. 8. shows the display of an electrical cabinet with a GPRS modem.

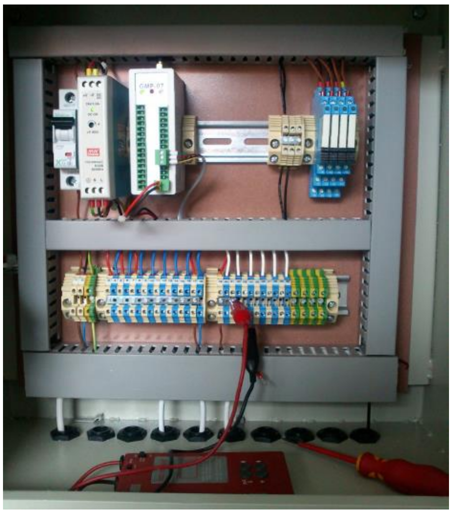

Figure 8. Electrical cabinet with a GPRS modem

RESULTS AND DISCUSSION

Remote monitoring and management systems are widely used in all industries. It is necessary that a communication link between the PLCs and one or more PCs is realized using a TCP /IP protocol and thus provides the possibility of remote monitoring and management from anywhere in the world. You need to know the IP address assigned to the controller and set up the communication server correctly.
Directions for further development of the application of SCADA systems in water supply systems are the creation of a unique dissemination center from which data on the status of all processes in the water supply will be available [6], [10], [12]. Contemporary data processing involves real-time data collection and storage, and information on each control process parameter can be obtained at any time from any location on the cloud storage. SCADA associated with automated processes enables the graphical display of data on the screen, along with numerical values, in a format suitable for the operator [6]. In addition to the graphical representation of the application's user interface, SCADA system also allows display of certain alarms if some of the parameters go outside of the specified range.

CONCLUSIONS

Benefits of automation through SCADA applications are: price-return of invested funds in the short term, significantly lower maintenance costs, smaller interventions and costs in revitalizing or reconstructing equipment and installations in water supply systems, simple expansion and replacement of system elements, higher safety because workers withdraw from potentially dangerous working conditions, rapid integration into existing parts of the system: databases and monitoring of resources and monitoring the activities of system users and operators. Application of SCADA application with GPRS data transfer is easier today because the coverage of the territory with the mobile network provides a centralized communication system [17]. Communication cost is minimal because only the amount of data transferred is charged. Communication is done only in groups that have secured access to data. The SCADA system that is installed can be expanded. Each location within the system must have a built-in GPRS modem, card and PC configuration. Each subsequent object to which the existing system is expanded should have its own modem and card, without new purchases on the side of the control computer. From all it can be concluded that the SCADA system can be upgraded and upgraded and there are no restrictions in the software model, but it is important to meet all hardware infrastructure conditions.

ACKNOWLEDGMENTS

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ANALYSIS OF PUMP SHAFT BEHAVIOUR BY THE APPLICATION OF CATIA SOFTWARE PACKAGE

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Abstract: This paper presents a part of research results related to the behaviour of centrifugal pump shaft assembly. The paper contains the research results of the main shaft assembly behaviour, whereby, due to the limited space, the indicated results are only those which relate to the effect of the shaft static behaviour of the considered structural solutions.
The analysis of the static behaviour is presented on the example of radial force effect to the pump shaft. Database building for the pump shaft by applying a Catia software package will allow for the creation of a model on which the various loads and constraints will be given, thus enabling the shortening of processing time and the model analysis time.
Key words: modelling, assembly, graphical environment, surface modelling.

INTRODUCTION

Mechanical analysis as an integral segment of engineering analysis comprises the programme procedures which allow the user, within the automatic mode, to perform the mechanical (static, kinematic and dynamic) analysis of the observed models under the conditions which correspond to the conditions of exploitaton. |In practice accepted programme systems for engineering analysis are based on the finite elements method [1]. In CATIA programme package, finite elements method is applied in *Advanced Meshing Tools and Generative Structural Analysis*. *Advanced Meshing Tools* application selects and adjusts the finite elements mesh network to the required model. So you can choose between the rectangular and trianglular elements which can be linear and parabolic. CATIA programme package, besides the control of mesh quality has the special module for computing finite elements deformation energy. Based on the obtained values of deformation energy we can determine on which model point we can expect the highest deviations from the real amount of deformation i.e. the strain within the observed structure. This evaluation is expressed in the form of a "map of computational errors" which represent the scalar field of deformation energy error. Namely, here is computed the reliability on the basis of which it is possible to give the evaluation of the global reliability of the obtained solution. In the procedure of adaptive meshing or automatic mesh refining of finite elements it is possible to evaluate the mesh validity on the basis of deformation energy computation [1, 2].
To be sure that the strains obtained by the finite elements method are close to the real strains , two analyses of the finite elements method will be performed. The first analysis is performed without specifying the desired flows. As CATIA programme package has the possibility of specifying the desired flows, in the second analysis we specify that the results obtained from CATIA deviates at the most 6% from the results we could obtain by analytical method, what is actually mesh refinement (adaptive analysis). The error of 6% is considered the sufficiently good result [2, 3].

MATERIAL AND METHOD OF OPERATION

Based on the analysis of CATIA programme package possibilities for a specific case it has been concluded that the easiest way to perfom the modelling is by 360^0 rotation of the upper half profile of axial section around the axis. In comparison with the actual shape of the shaft, the shaft modelling was made in such a way that the chamfered edges, grooves, radius, cones, etc. were omitted, Fig.1. However, in the later stage of finite elements mesh generation, some contours were grouped due to the problems in computation, what would represent the finite simplification model, Fig.2. Based on it, the simplified profile in Fig.3 was obtained showing the coordinating points of given contour. In addition to the defined contour points of shaft semi-section in coordinate system X and Y in Fig.3, the points defining the shaft model are also defined [2, 3, 4, 5].

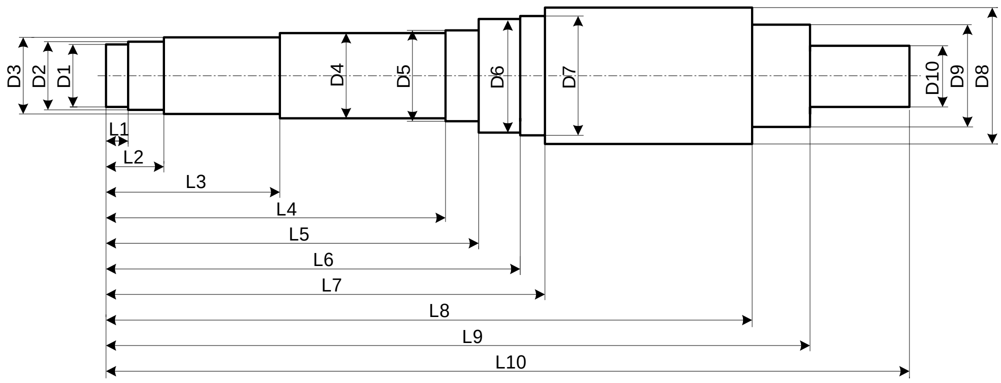

Figure 1. The first simplified shaft view,with indicated values

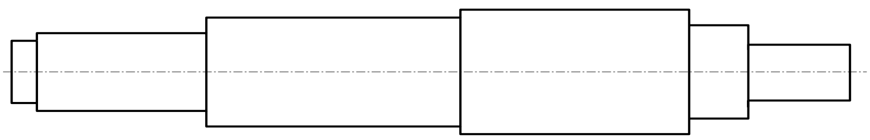

Figure 2. Final simplified view of pump shaft

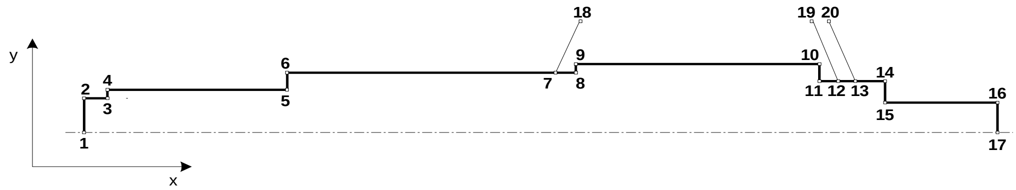

Figure 3. Characteristic points of profile upper half of shaft axial section

In order to implement the static analysis portal it is firstly necessary to make a model in environment *Part Design* inside CATIA programme, where we created the described surface rotating by 360^0, whereat the same will be divided into 16 equal parts. To define macro command next to the name it is compulsory to add the extension which, after macro start-up, is not to be entered. Geometric modelling is made by this command connection. For macro start-up it was necessary to mark ad-hoc point on any work surface and after that to delete it. In Fig. 4 and 5, it is shown on CAD plotter of shaft in 3 D model [2,3,4,5].

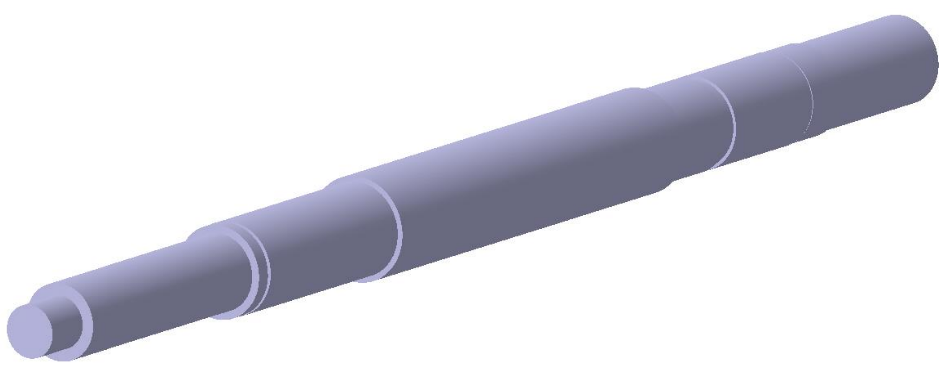

Figure 4. Volume model generated by semi-profile rotation around the axis of symmetry by 360^0 (simplification model without radius and grooves)

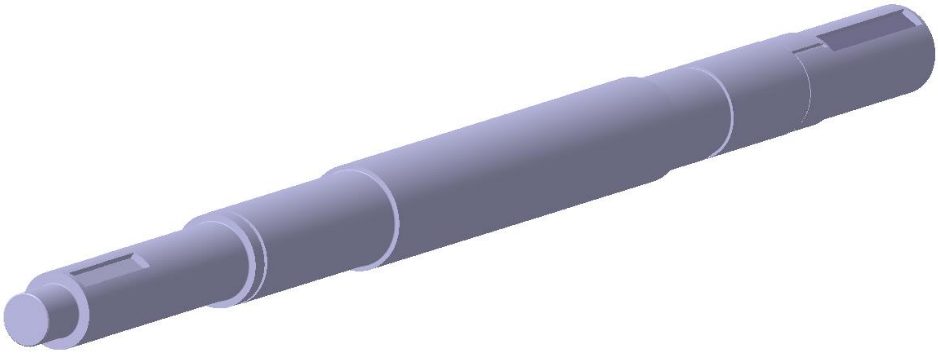

Figure 5. Shaft model in 3D – shown on CAD plotter

The model should have been simplified to facilitate the computer to compute the static analysis within the shortest possible time. Static analysis portal is implemented in *Generative Structural Analysis* environment enabling us to generate the mesh, to apply loads and constraints as well as to perform static analysis by means of finite elements method. When entering *Generative Structural Analysis* environment it is necessary to indicate the type and the value of mesh elements for the expressed model, therewith the mesh refinement at the points where the highest strains are expected.

RESULTS AND RESEARCH

The results of the pump shaft behaviour analysis for all three load variants are shown in Fig. 6, 7, 8, 9 and 10, 11, whereat the highest displacement of characteristic nodes and the highest characteristic strains in characteristic sections are shown. Graphical part of outlet results presentation is the illustration of equivalent strains distribution in elements of discretized model, then in the displacement of nodes towards Y-axis, as well as deformation of discretized model elements.
The numerical values are given alongside with graphical display of strains and nodes displacement in the shaft cross-section. The various ranges of strains and displaced nodes are indicated with various colours. Blue colour for strains indicates the minimum values of equivalent strains, while the red colour indicates the maximum values for given cases of load. For the displacement of nodes, the blue colour indicates the maximum and the red colour the minimum values of nodes displacement [2, 3, 4, 5, 6, 7, 8].

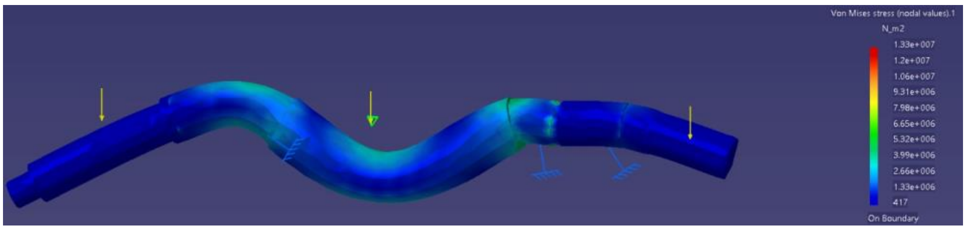

Figure 6. Strain distribution

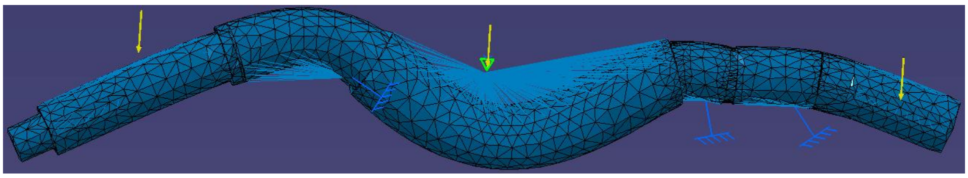

Figure 7. Deformation

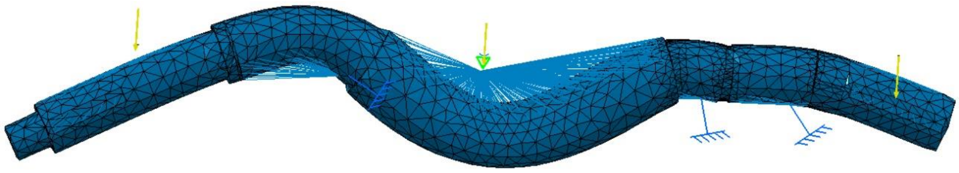

Figure 8. Mesh refinement at critical points

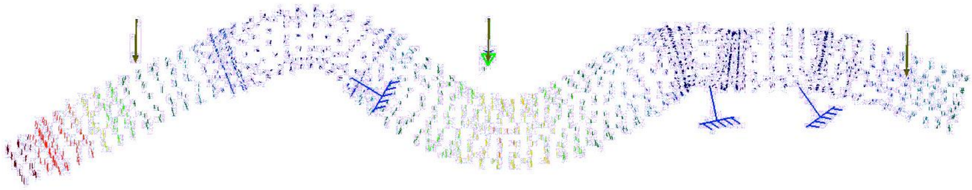

Figure 9. Deflection

Due to the shaft load effect, the reaction forces occur on the supports and cause unequal strain distribution. The shaft load causes the reaction on the support D_1 and strain increase at the support point, as well as maximum increase of strain close to the support. Parameters and by this method test results are shown below.

Components	Applied load	Reaction	Remainder	Relative error value
Fx (N)	0.0000e+000	5.3619e-008	5.3619e-008	4.1818e-012
Fy (N)	0.0000e+000	-1.9151e-007	-1.9151e-007	1.4936e-011
Fz (N)	-1.3823e+004	1.3823e+004	-2.2459e-007	1.7516e-011
Mx (Nm)	0.0000e+000	-1.0818e-008	-1.0818e-008	1.2113e-012
My (Nm)	-3.7333e+002	3.7333e+002	3.1009e-008	3.4723e-012
Mz (Nm)	0.0000e+000	-5.8020e-008	-5.8020e-008	6.4968e-012

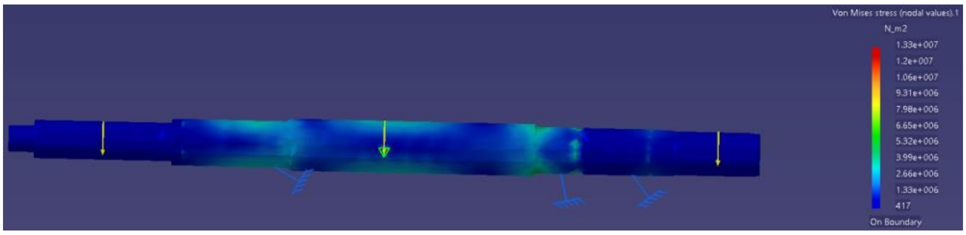

Figure 10. Strain distribution

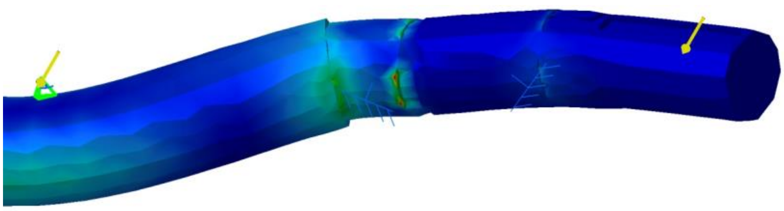

Figure 11. Maximum strains at some points

Equivalent strains on the shaft exposed to the effect of twisting moment; view of the coupling position and view of double-row bearing position

Research conducted in this paper gave the replies to some important questions related to this specific problem.

ANALYSIS OF RESEARCH RESULTS

From the stand point of equivalent strains in the first case of shaft load, maximum strain occurs in the node 525 on the shaft surface of Ø85 mm and amounts to σ_{ekv}=13,29 MPa. The strains of lower intensity are recorded on both sides, at shaft change-over from Ø95 to Ø85 in the node 6836 the recorded strain is σ_{ekv}=7,91 MPa. On the shaft surface Ø70 at the point of turbine vanes the maximum strain is recorded in the node 1220 and amounts to σ_{ekv}=0,24 MPa. The strains in the position of annular single-row ball bearing range from σ_{ekv}=3,44-1,27 MPa, and the same ultimate strains occur in nodes 926 resp. 1446.
The node 1009 was displaced to the greatest extent under the effect of impeller for the value of -0,0134 mm.

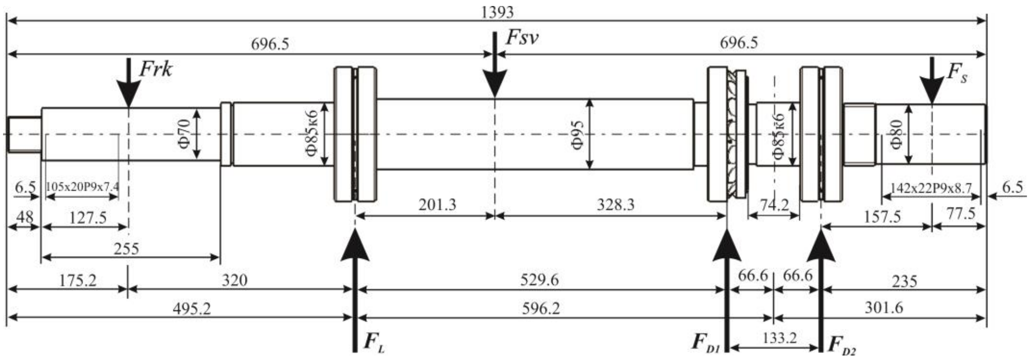

Figure 12. Shaft load layout

Under the effect of radial force on the shaft surface of Ø95 mm between two bearings the greatest equivalent strain of σ_{ekv}=3,91 MPa was recorded in the node 978.
The displacement of nodes in case of twisting moment effect to the shaft at the position of coupling was not recorded.
In case of load, the maximum strain amounted to 13,29 MPa. On the basis of the obtained results it can be concluded that no unpermissible load conditions occurred in any of the characteristic sections of the observed shaft or in any case of load, since the obtained equivalent strains in the most critical sections are far less than the limit of flow which for the observed material amounts to 335 MPa.
Based on the research results of the shaft static behaviour and strain in various cross-sections by the application of CATIA V5 programme it can be concluded that the work and simulation load values of the analyzed shaft will not affect the deteriotation of condition and reduction in service life both for the bearings and the shaft.

CONCLUSION

The basic objective of the shaft static behaviour testing by the application of *Generative Structural Analysis* (Catia) programme system was to determine the shaft static stiffness, since this is the value which directly affects the complete pump operation.
By analyzing the research results, it was concluded that the largest displacement of nodes under the effect of radial force amounted to σ_{ekv}=3,91 MPa and was recorded on the node 978 and as such could not affect the shaft deformation. Maximum strain was 13,29 Mpa on the basis of which can be concluded that according to expectations no occurrence of unpermissible strain conditions was recorded in any of the characteristic sections of the observed shaft, since the obtained equivalent strains even in the most critical sections are far less than the permissible strains which for the observed shaft material amount to ≈600 Mpa.

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APPLICATION OF FEA SIMULATION IN PRESSURE VESSEL DESIGN WITH RESULT ANALYSIS

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Abstract: Modern engineering and construction in mechanical engineering, civil engineering, architecture, traffic and electrical engineering is a complex task, which is today, in vast amount, supported by computer oriented technology methods. The calculation of dimensions of components is completed using existing formulas according to air pressure and material characteristics. Stress simulation is performed in SolidWorks program on 3D model, which is previously created in the same program. After that, the Factor of safety for pressure vessel assembly is simulated and calculated, with analysis of simulation results.
Key words: compressed air tank engineering, CAD, FEA, simulation

INTRODUCTION

Design process begins with an idea to create a new product, and most of the time it finishes with a prototype testing. A modern constructor aim is to create a virtual, computer supported prototype which can be analyzed. [1]
Experiments, mathematic modeling and simulations are the most powerful engineering tools today. [2]
Finite element analysis - FEA could be applied in very complex mechanical and architecture shapes.
The basic idea of FEA is splitting the continuous mass of 2D or 3D model to discrete (finite) elements. [3,4,5].
SolidWorks simulation is able to convert a 3D component into triangle or tetrahedron or trihedron elements of the mesh (fig 1.)
This study will show calculation of pressure vessel, creating a 3D model of it, and FEA analysis in SolidWorks.

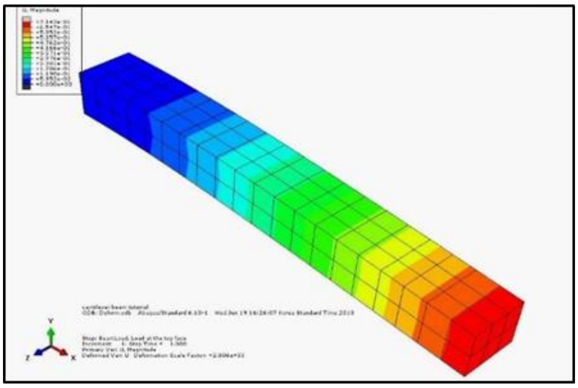

Figure 1. 3D mesh

MATERIAL AND METHODS

Pressure Vessel design

Stable pressure vessels are the ones which do not change the place from filling to disposing, under conditions:

$p \geq 1$ [bar]

$p \cdot V \geq 0.3$ [bar $\cdot$ m^3] [6,7]

Stable pressure vessels are mostly made in cylindrical or spherical shape. In this case, a horizontal, spherical shape with is analyzed. A drawing of pressure vessel assembly with parts and dimensions is shown on figure 2. [8, 10]

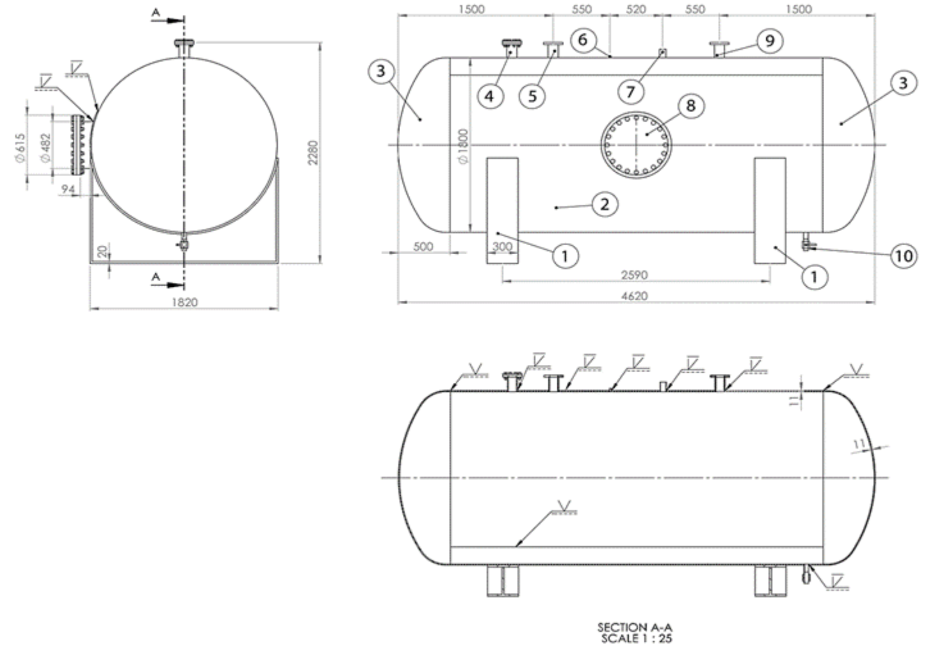

Figure. 2. Assembly drawing [9]

Using „Product / PhotoView“ tool, it is possible to add materials, lighting and shadows on the existing model, and finally get a photorealistic model of air pressure vessel (fig. 3).

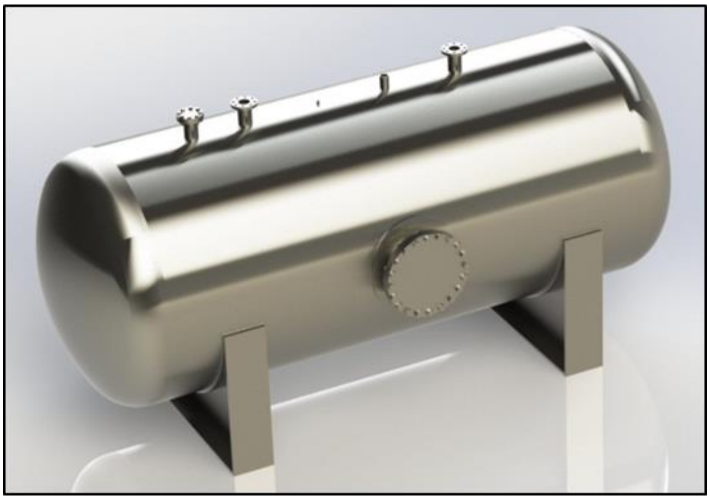

Figure 3. Rendering of air pressure vessel [9]

FEA simulation

In this case, the result depends on many parameters: Thickness of components, total vessel weight, air pressure inside the vessel, weldings etc. Using FEA on each of those parts in assembly it is possible to define the pressure and strain and deforming points.
The aim of this simulation is a reliable product, and FEA is efficient to shorten a way from thinking to the final product.
Materials for the simulation are applied from the drop-down list, where construction steel (S235 JR G2) is chosen (fig. 4). Welds are defined using option „Edge weld“ between two faces and defining weld characteristics. (fig. 5).

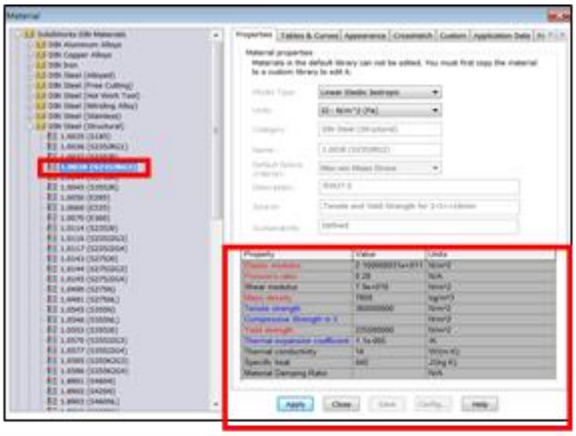

Figure 4. Material list

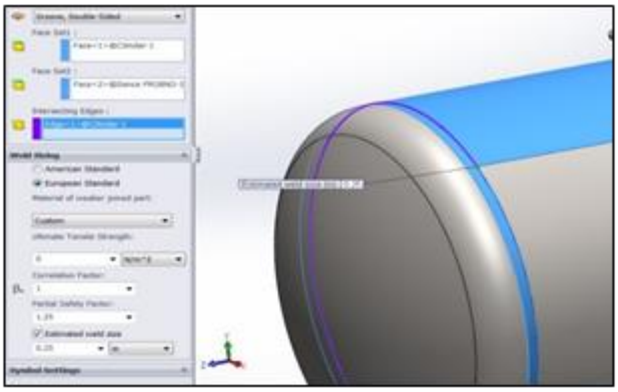

Figure 5. Edge weld

The next task is to define fixed geometry and surfaces on which the air pressure is applied. It can be selected in section view. After that external loads are applied (Pressure), in this case, the maximum working pressure of the vessel: 10 [bar], or 1 [MPa]. There is also a gravity force to be applied on the model, which is also important.
Creating mesh is the next step. Size of the mesh can be adjusted, and it depends on parts size and complexity (fig. 6.).

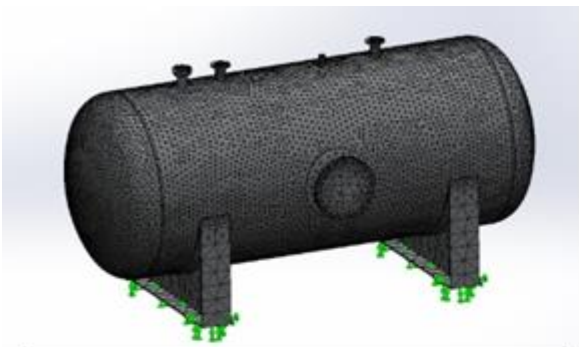

Figure 6. Mesh on air pressure vessel model [9]

After the simulation is finished according to given parameters, a loaded model appears on the screen. Colors are showing the level of stress, where the blue is the lowest, and red color is the highest stress (fig. 7).

For the steel used in this simulation, yield strength is 235 [N/mm^2], and it is rounded on the fig.7. It is visible that all components are below yellow color, which means that the assembly can resist pressure and other applied forces.

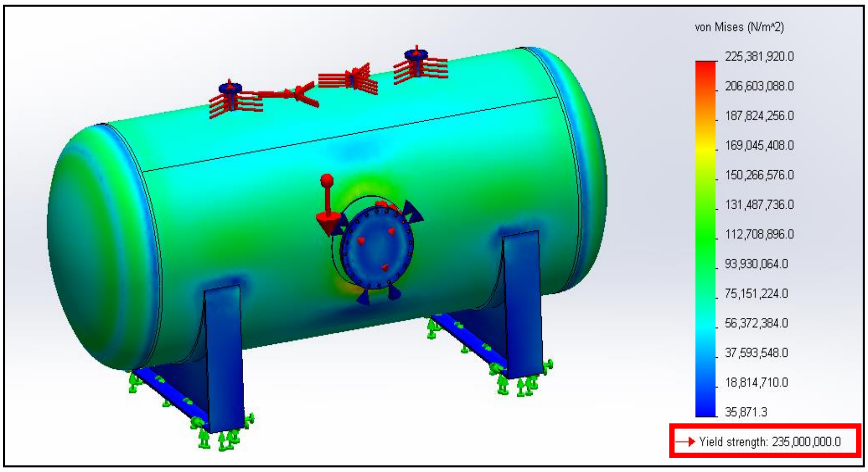

Figure 7. Model after the simulation [9]

Factor of safety

Factor of Safety (FOS) for the given forces is calculated as the next step. All segments of the assembly that are safe are light blue, while the non-safe segments are red. In this case, model is completely blue which means that it is completely safe (fig. 8).

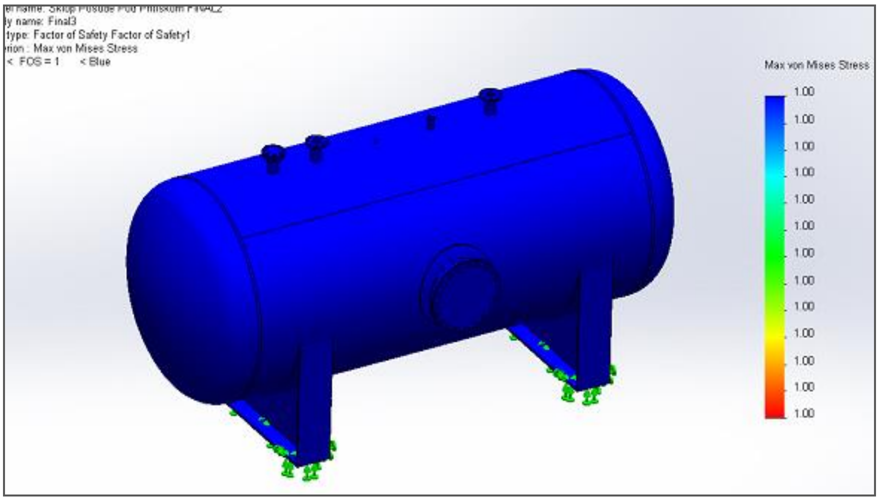

Figure 8. Factor of safety [9]

In the next table are presented forces and model displacement, as a result of applied forces.

Table 1. Results

Name	**Type**	**Min**	**Max**
Stress1	VON: von Mises Stress	249.579 N/m^2 Node: 66508	2.23248e+008 N/m^2 Node:56041
Name	**Type**	**Min**	**Max**
Displacement	URES: Resultant Displacement	0 mm Node: 46858	2.17545 mm Node: 626

CONCLUSION

With computer-powered simulation it is possible to get relevant data for complex shapes of mechanical parts and assemblies much quicker then with the other methods. All results are presented visually, on the 3D model itself, with colors, so user can monitor placement of stress as well as displacement surfaces.
Using FEA can also eliminate need for physical prototype, and therefore, be much quicker and cheaper way to develop a product. That is why this method is very popular in the industry today.

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APPLICATION OF MFF METHOD IN CONCEPTUAL DESIGN

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Abstract: This work presents use of MFF (Matrix of function and functionality) method in conceptual design stage. Compared to the morphological matrix, MFF is structured as multidimensional matrix, which according to mathematical model presented in this work, generates a functional structure as multilayer functional structure. MFF collects and binds data from the requirement list and transform them into functional requirements. This matrix transforms functions and functionalities as sets from the functional domain and design elements domain. MFF model is searching cross-sections (submatrices) of function and functionality sets. Also is presented application of MFF model in generation of product conceptual variants.
Key words: Conceptual design, Function, Functionality, MFF (Matrix of function and functionality)

INTRODUCTION

Conceptual design phase is initial stage of product design and product development process [1, 2]. Design process in this phase, is usually specified by complexity [3], unpredictability and creativity [4], which mainly rests on an individual’s intuition that is hard to repeat in creating new product concepts. During conceptual design there are no geometric dimensions [2], exactly defined product shape, tolerances and design structure. Initial data are stored in the form of customer requirements, which need to be transformed into data acceptable to the further design process. These data are not unambiguous and exact as is the case for data in phase of detailed design. This is the problem of abstraction in conceptual design, because the input data in this stage are unarranged, complex and for design process unacceptable.
The problem of transformation customer requirements into functional requirements and mapping of customer, functional, physical and process domain involves axiomatic design [5-7]. Since the conceptual design phase connects the customer requirements and the stage of detailed design, it`s aim is to transform the information and data obtained from the market, into a form that is acceptable for designers for further guiding of the design process. According to the theory of technical systems [8], each product represents the use of a function and therefore, it reflects solving initial functional requirements [9].
In conceptual design, also is important transmission of knowledge, because it is definitely the missing shackle [10], and it is extremely important to show the models in a practical implementation (e.g. computer programming environment in stage of conceptual design.
In the conceptual design stage are developed different matrix models, one of them is morphological box [11]. Matrix is using the intuitive classification of data without a special mathematical model or solving rules for connection between functional domain (functions) and design elements domain (technical systems). It is not possible to connect simultaneously customer, functional, physical and design elements domain. Also is not possible to arrange functions in functional structure. There is no fundamental principles for a selection the best solutions and design forms.
As a contribution to solving above mentioned problems, a MFF method was developed. This matrix method transforms customer requirements into the functional requirements. The process of transformation is mapping of customer domain into the functional domain. With four function categories, technical systems are described as the part of design elements domain. These technical systems we cold functionalities. Thus, the connection between functional and design elements domain is achieved. It is also possible to generate conceptual variants and their functional description in matrix form.

MATHEMATICAL DESCRIPTION OF MFF

In the mathematical model of MFF (Fig. 1) functional requirements $F_i; i = 1,..., n$ are marked with corresponding marks and the following applies:

$$F_1, F_2, F_3,..., F_n; \forall n \in \mathrm{N} \tag{1}$$

Functionalities $TS_j; j = 1,..., m$ are marked with corresponding marks and the following applies:

$$TS_1, TS_2, TS_3,..., TS_m; \forall m \in \mathrm{N} \tag{2}$$

Individual cross-sections $F_i \cap TS_j$ or $TS_j \cap F_i$ (solutions, i.e. submatrices) are defined as (Fig. 2) and the following applies:

$$\begin{aligned} & F_i \cap TS_j = TS_j \cap F_i \\ & F_i \cap TS_j = \left\{ \mathbf{X}_{F_i,TS_j} \middle| \mathbf{X}_{F_i,TS_j} \in F_i \wedge \mathbf{X}_{F_i,TS_j} \in TS_j \right\} \\ & i = 1,..., n; j = 1,..., m \end{aligned} \tag{3}$$

All cross-sections represent solutions or submatrices. They are one functional requirement. So it is possible to write:

$$\mathbf{R}_{F_i} = \left\{ \mathbf{X}_{F_i,TS_1}, \mathbf{X}_{F_i,TS_2}, \mathbf{X}_{F_i,TS_3},..., \mathbf{X}_{F_i,TS_m} \right\}, \tag{4}$$

where $i = 1,..., n$.

All cross-sections represent solutions or submatrices. They are one functionality. It is possible to write:

$$\mathbf{R}_{TS_j} = \left\{ \mathbf{X}_{F_1,TS_j}, \mathbf{X}_{F_2,TS_j}, \mathbf{X}_{F_3,TS_j},..., \mathbf{X}_{F_n,TS_j} \right\}, \tag{5}$$

where $j = 1,..., m$.

The whole matrix of cross-section (solutions, submatrices) is written:

$$\mathbf{R} = \begin{bmatrix} \mathbf{X}_{F_1,TS_1} & \mathbf{X}_{F_1,TS_2} & \cdots & \mathbf{X}_{F_1,TS_m} \\ \mathbf{X}_{F_2,TS_1} & \mathbf{X}_{F_2,TS_2} & \cdots & \mathbf{X}_{F_2,TS_m} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{X}_{F_n,TS_1} & \mathbf{X}_{F_n,TS_2} & \cdots & \mathbf{X}_{F_n,TS_m} \end{bmatrix} \tag{6}$$

In *m* dimensional vector space, rank r of $m \times n$ dimensional matrix $\mathbf{R}$ is less than or equal to number m or n:

$$rank(\mathbf{R}) = r \leq \min\{m, n\} \tag{7}$$

A $n \times 1$ matrix can be transformed in the column vector:

$$\mathbf{M}_{TS_j} = \begin{bmatrix} \mathbf{X}_{F_1,TS_j} \\ \mathbf{X}_{F_2,TS_j} \\ \vdots \\ \mathbf{X}_{F_n,TS_j} \end{bmatrix}; j = 1,\ldots,m \tag{8}$$

A $1 \times m$ matrix can be transformed in the row vector:

$$\mathbf{M}_{F_i} = \begin{bmatrix} \mathbf{X}_{F_i,TS_1} \\ \mathbf{X}_{F_i,TS_2} \\ \vdots \\ \mathbf{X}_{F_i,TS_m} \end{bmatrix}; i = 1,\ldots,n \tag{9}$$

The transpose form is:

$$\mathbf{M}_{F_i}^T = \left[\mathbf{X}_{F_i,TS_1}, \mathbf{X}_{F_i,TS_2}, \cdots, \mathbf{X}_{F_i,TS_m}\right] \tag{10}$$

F	**TS**			
	TS_1	**TS_2**	**···**	**TS_m**
F_1 [R_{F_1}]	X_{F_1,TS_1}	X_{F_1,TS_2}	···	X_{F_1,TS_m}
F_2 [R_{F_2}]	X_{F_2,TS_1}	X_{F_2,TS_2}	···	X_{F_2,TS_m}
F_3 [R_{F_3}]	X_{F_3,TS_1}	···	···	X_{F_3,TS_m}
⋮	⋮	···	⋱	⋮
F_n [R_{F_n}]	X_{F_n,TS_1}	X_{F_n,TS_2}	···	X_{F_n,TS_m}

Figure 1. Mathematical representation of MFF

The set of all possible solutions of MFF is written:

$$\mathbf{R}_{MFF} = \begin{Bmatrix} \mathbf{X}_{F_1,TS_1}, \mathbf{X}_{F_1,TS_2}, \mathbf{X}_{F_1,TS_3}, \cdots, \mathbf{X}_{F_1,TS_m} \\ \vdots \quad \vdots \quad \vdots \quad ,\cdots, \quad \vdots \\ \mathbf{X}_{F_n,TS_1}, \mathbf{X}_{F_n,TS_2}, \mathbf{X}_{F_n,TS_3}, \cdots, \mathbf{X}_{F_n,TS_m} \end{Bmatrix} \tag{11}$$

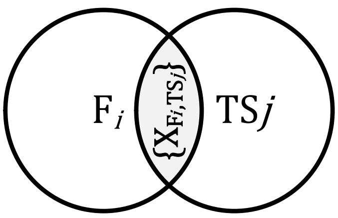

Figure 2. Cross-section (solution, submatrix) $F_i \cap TS_j = \mathbf{X}_{F_i,TS_j}$

The sum of all possible solutions of MFF is:

$$\mathbf{R}_{\sum MFF} = \sum_{i=1}^{n}\sum_{j=1}^{m}\mathbf{X}_{F_iTS_j} \tag{12}$$

COMPUTER APPLICATION OF MFF

Figure 3 presents a flow diagram of the MFF application. It is evident that there are two ways of work with the application. One way is filling the knowledge base, and the other is to use the knowledge base to create new product concepts. When using the application it is possible simultaneously to use both modes.

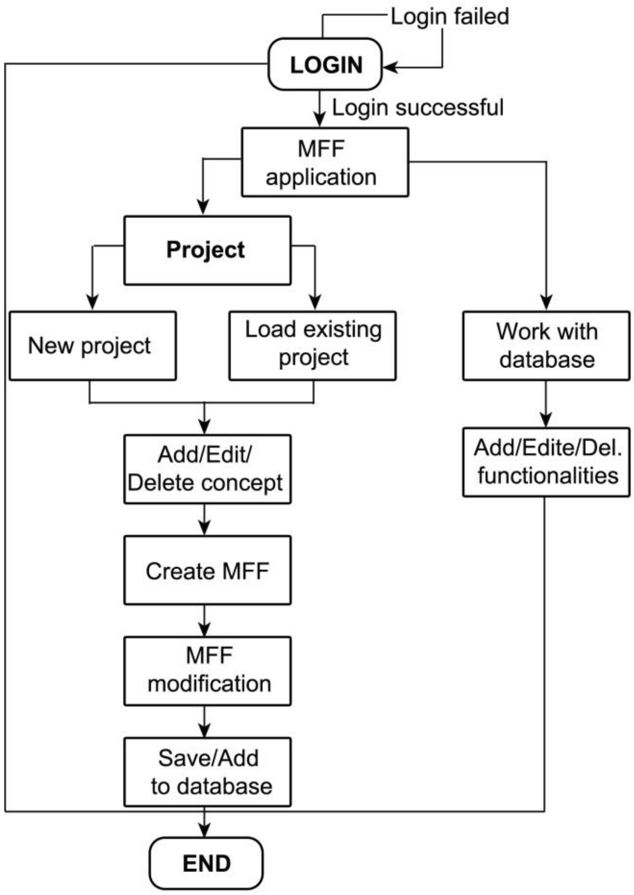

Figure 3. MFF application flow chart

According to the mathematical model, a computer application has been developed (Fig. 4). Application is divided in six sections. The most important from this standpoint are *database* and *product structure* sections. Inside of this sections we generate a new concepts described with functions and physical sizes.

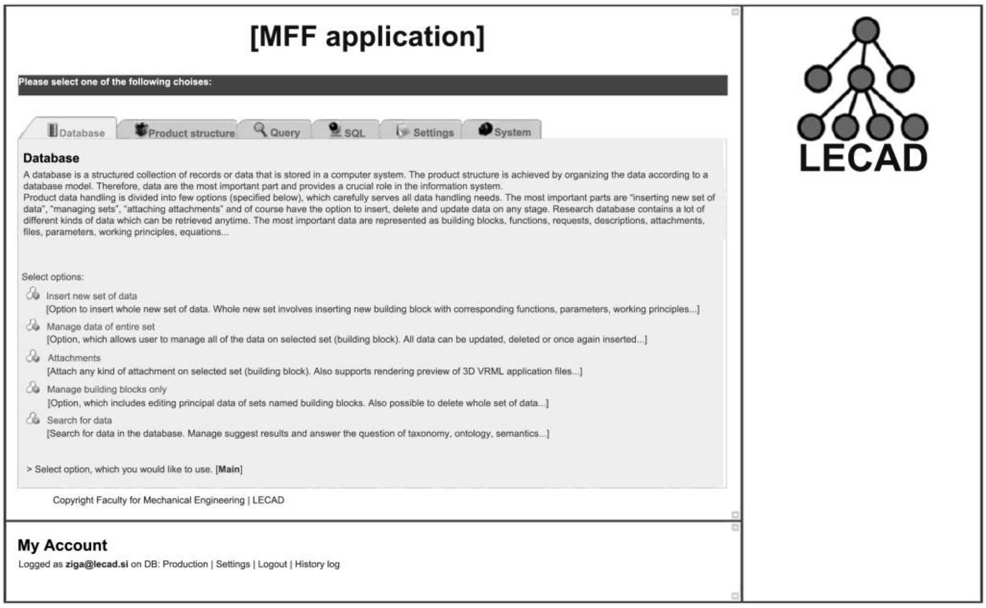

Figure 4. MFF application

Process of conceptual design starts with transformation of customer requirements into the functional requirements through the input list of functions (Fig. 5). Also functionalities stored in application database, is possible to prepare and edit through the input list of functionalities (Fig. 5).When functions and functionalities are prepared for conceptual design, through the lists, we put them in MFF and begin generation of conceptual variants.

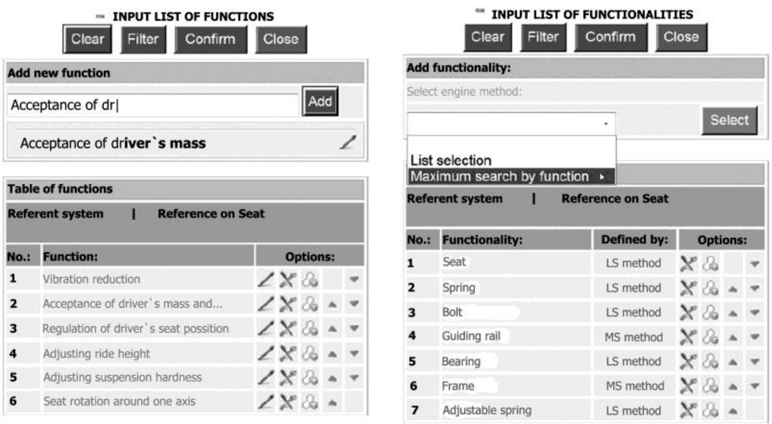

Figure 5. Input list of functions and input list of functionalities

FUNCTIONAL AND MATRIX STRUCTURE

Matrix structure is composed of the MFF matrices (Fig. 6). The matrices are organized by levels and interconnected by binding links for linking towards matrices at the same level and towards matrices at other levels. For matrix structure generation it is necessary to establish rough functional structure. This is input in MFF. On the basement of rough functional structure and by means of MFF, designers search solutions and determine exactly certain functionalities. Rough functional structure, on this way, is completed and stored as detail functional structure.

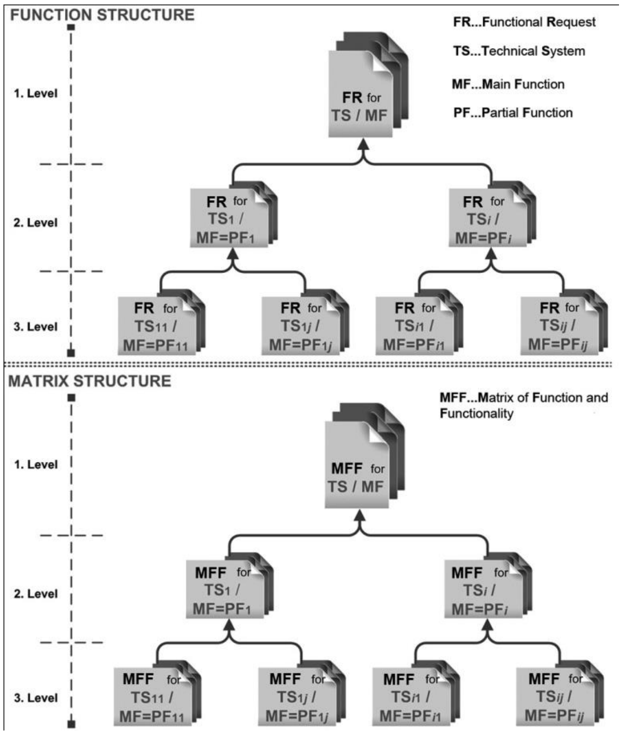

Figure 6. Functional and matrix structure of product

Matrix structure for a listed product is generated from the product detailed functional structure. The total number of matrix structure levels corresponds by analogy to the total number of levels of the product’s detailed functional structure. In matrix and functional structure is stored design knowledge for a listed product.

CONCEPT GENERATION BY MFF METHOD

In this chapter is described procedure of generation conceptual variant of assembly *Turbo-blower*. This assembly is part of product at a higher hierarchical level-*Suction unit*. Therefore, *Turbo-blower* is a subassembly in Suction unit product shape structure. Concept is determined by function "*Negative pressure generation and fluid flow calming*" (Fig. 7). The function is on the second level of the functional structure of Suction unit. This function is necessary to solve with six partial functions, which were generated by transformation of selected customer requirements (Fig. 7). Using the input list of functions, functions are implemented in the matrix.

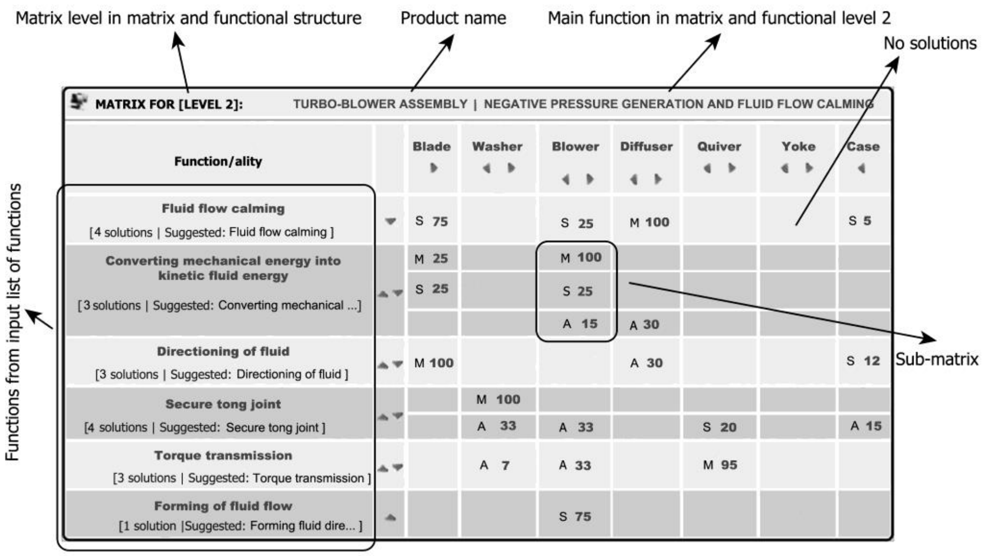

Figure 7. No arranged MFF of conceptual variant

Depending on the number of functions, arranging process of matrix starts and can be very long, because involves functional modelling procedure.
In Table 1 are presented functions from input list and accepted functionalities whose functions in submatrices are solving them. It`s possible to see category of function in submatrix and percentage value of solution.

Table 1. MFF solution of functions from input list

Function from input list	Functionality	Function category	Solution percentage value
Fluid flow calming	Diffuser	Main function (M)	100
Converting mechanical energy into kinetic fluid energy	Blower	Main function (M)	100
Directioning of fluid	Blade	Main function (M)	100
Secure tong joint	Washer	Main function (M)	100
Torque transmission	Quiver	Main function (M)	95
Forming of fluid flow	Blower	Supplementary function (S)	75

When concept *Turbo-blower* is arranged in MFF (Fig. 8) this matrix will be implemented in general matrix and functional structure of Suction unit (Fig. 9). After the detail design of this concept, according to MFF (Fig. 8), final shape and assembly of Suction unit is presented on Fig. 10.

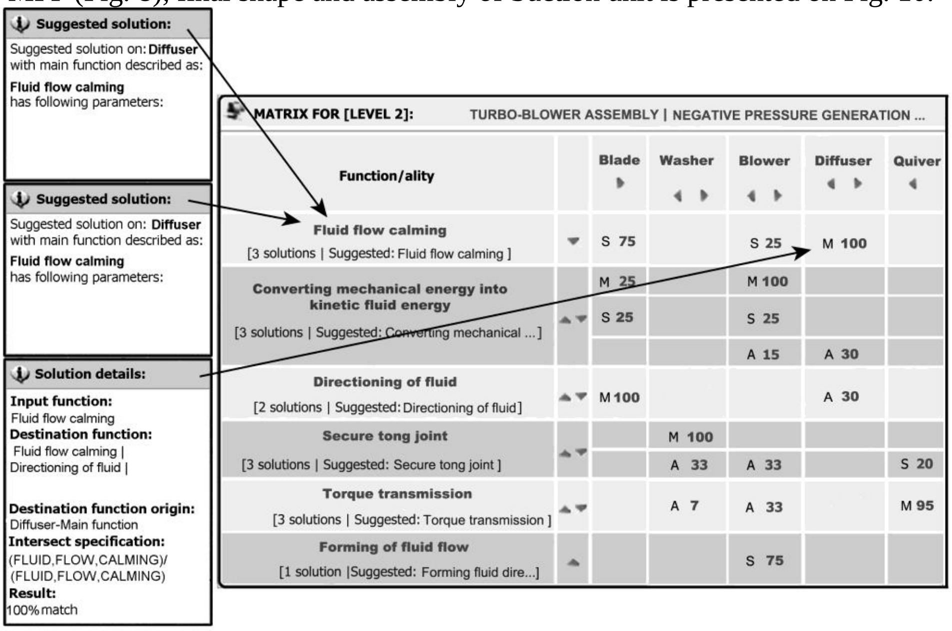

Figure 8. Arranged MFF of conceptual variant

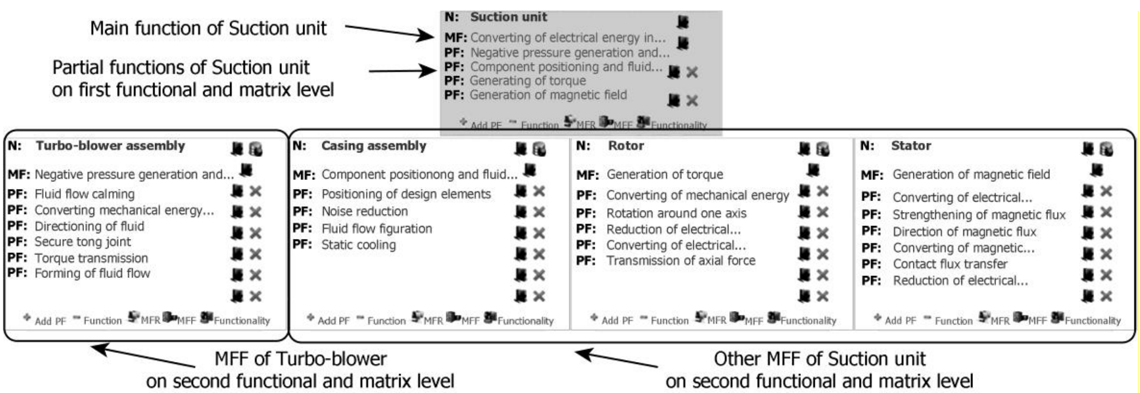

Figure 9. General Suction unit functional structure generated through the MFF

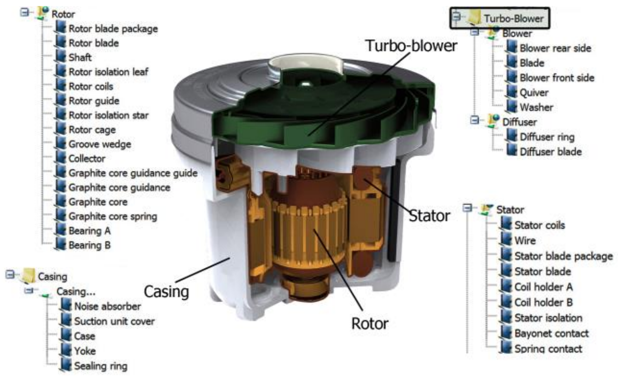

Figure 10. Detailed design of Suction unit

CONCLUSION

By analysing matrix methods (especially morphological box) used at the conceptual design stage, the problem of associating, displaying and transforming of customer requirements into acceptable data for further guidance of design process was noticed. In order to contribute to the solution of this problem, a MFF method was developed. Using this model, according to the theory of technical systems and axiomatic design, binding between customer, functional, physical and design elements domain was achieved. The mathematical description of the model as well as the developed computer application are presented in this work.

The beginning of the design process requires a new set of customer requirements. Through the set of rules, the process of mapping customer requirements into the set of functions represents a transformation a customer domain into the functional domain. Solutions of a new set of functions are obtained through the MFF by linking with the functions who describe functionalities. These functions are divided into the four categories (main, supplementary, auxiliary and binding function). On this way functionalities are solutions of new set of functions. Every new set of functions represent a new conceptual variant of new future product.

Also is presented generation of multilayer matrix structure. Inside of this structure is stored a product functional structure. Possibility of generation functional structure, stored in matrix structure, enable fully review of data to designer. This data describe product and present design knowledge stored in MFF.

For further research, it is necessary to develop model who can create weight factors and map them to evaluation criteria. According to this, it is necessary to upgrade present computer application. On this way, with this models and this application it will be possible to simulate a creation of new conceptual variants and also will be possible to simulate a decision making process in conceptual design stage.

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CFD STUDY OF A HORIZONTAL AXIS WIND TURBINE: VALIDATION AND PARAMETRIC ANALYSIS USING VARIOUS SWEPT BLADE DESIGNS

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Abstract: Wind turbines are one of the most efficient renewable energy generators that are operated all over the world. Aerodynamically, blades are crucial in terms of conversion of wind energy to useful energy. Computational Fluid Dynamics (CFD) is a good way to simulate the flow around wind turbine blades. In this study, NREL Phase II wind turbine is used as a baseline and the CFD method is validated against the experimental results of the original wind turbine using various turbulence models. In addition, different swept blade designs have been tested and mechanical power outputs and thrust forces are calculated and compared with the original wind turbine. According the results, k-ε Realizable model was the most successful turbulence model showing close results compared to the experimental data. In addition, the study with swept blades showed that it is possible to obtain some increase in power output using swept blades, however, this also causes an increase in thrust force.
Key words: Wind turbine, HAWT, blade, validation, swept, CFD.

INTRODUCTION

Wind energy is being used as one of the leading renewable energy sources all over the world [1-4] Blades are crucial components of wind turbines because of having the role of converting the wind energy to mechanical energy. Previously, it was difficult to design and test new blades since it was very expensive to make experimental tests. Now, Computational Fluid Dynamics (CFD) is being used to design and test various blades designs {. When the decision is made to use CFD to test or design a new blade, validation of the CFD model is very important. Advanced turbulence models help to obtain relatively good results that are close to experimental test results. Many studies are available in the literature about validating the CFD model to test the wind turbines with various blade designs. Swept blades are one of the different blade designs. Khalafallah et al. (2015) validated their CFD model and investigated sweep direction and sweep begin section affecting the performance of a HAWT with swept blades and concluded that some performance increase can be achieved using swept blades [5]. Kaya et al (2018) tested various swept blades and obtained a significant increase in power coefficient using a specific forward swept blade [6]. Verelst and Larsen (2010) and Hansen (2011) have used 5 MW NREL wind turbine as a baseline and investigated the performance of swept blades and the findings of both studies were that backward swept blades present slightly lower power outputs in general [7-8]. On the hand, many studies can be found in the literature about investigation the aerodynamic performance of HAWTs using CFD. Wang and Zhan (2013) investigated the performance of a micro-wind turbine using CFD and concluded that the performance of the wind rotor with semi-circular blades is comparable to that of the semi-cylindrical wind rotor, and is slightly lower than that of the helically twisted wind rotor [9]. Bai et al. (2013) designed a 10 kW horizontal axis wind turbine blade and performed aerodynamic investigation using numerical simulation of it. It has been reported that CFD is a good method compared to the improved BEM theory method on the aerodynamic investigation of HAWT blades [10].
In this study, a Horizontal Axis Wind Turbine (HAWT), NREL Phase II, is simulated using various turbulence models and results are compared with experimental data. In addition, various swept blades that have different sweep begin section (r_{ss}/R) and tip displacements (d/R) are tested using the validated CFD model in terms of power production.

MATERIAL AND METHODS

In this study, NREL Phase II wind turbine was used as the baseline rotor. It was developed by the National Renewable Energy Laboratory (NREL) of US and it has a 3 bladed rotor with 10 m diameter. Information about the wind turbine can be found in Table [11-13].

Table 1. Information about NREL Phase II wind turbine

Number of blades	3
Rotor diameter (m)	10.06 m
Cone angle	3 degrees
Rotation speed (rpm)	71.6
Pitch angle	12 degrees (down)
Airfoil	S809
Chord length (m)	0.4572 (fixed)
Twist angle	0 degrees (fixed)

The flow around the wind turbine was simulated using ANSYS Fluent 17.2 software in a moving reference frame. The computational domain was created from a circle that has 3R radius. The upstream and downstream boundaries of the computational domain were 3R and 10R, respectively. Only one third of the rotor issued in the CFD simulations with rotational periodic conditions applied. The 3-D drawings of the NREL Phase II rotor can be found in Figure 1.

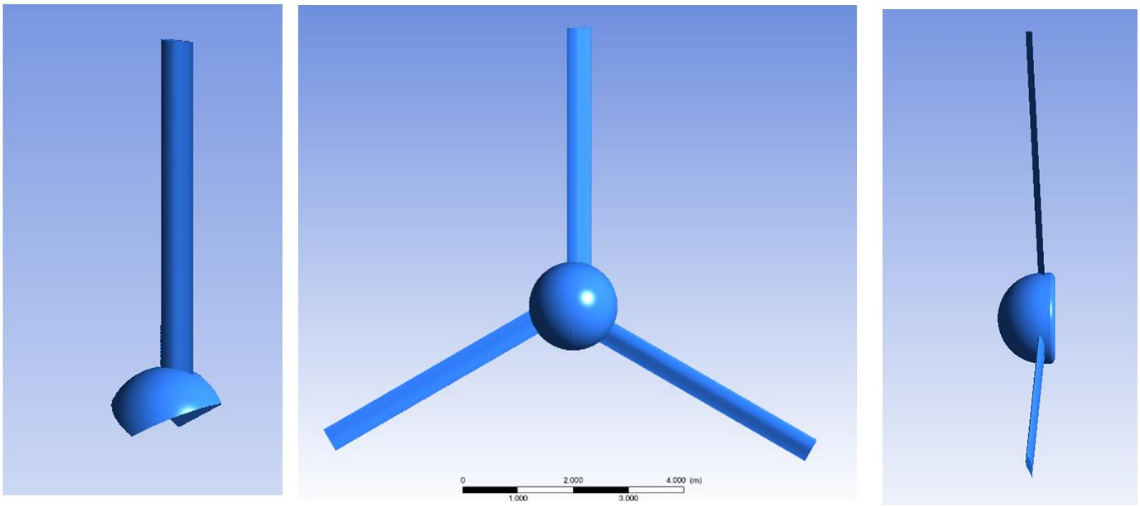

Figure 1. 3-D drawings of the NREL Phase II rotor

ANSYS Meshing was used in order to create the mesh. The mesh used in this study consist of nearly 6 million elements. First layer height was selected as $2x10^{-5}$ m to ensure the y+ value is less than three. This value is suitable for all the used turbulence models (El Farra, 2011). Applied boundary conditions are velocity inlet at the inlet, pressure outlet at the outlet and non-slip wall on the blade. The boundary conditions together with the computational domain was given in Fig. 2.

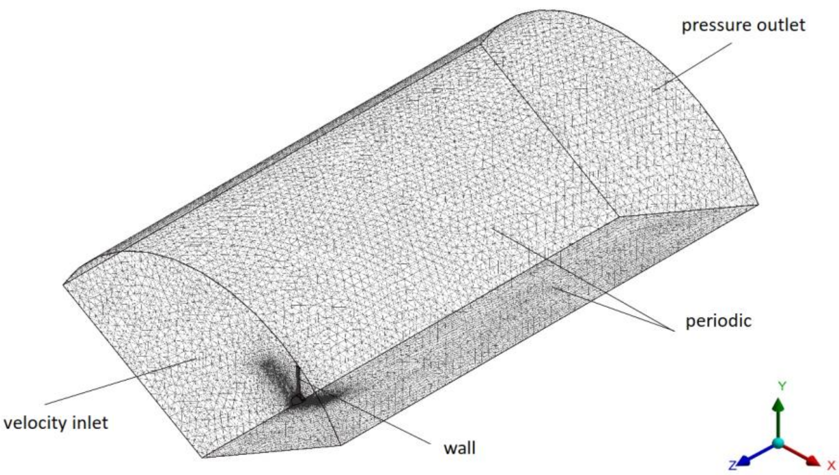

Figure 2. Computational domain and boundary conditions

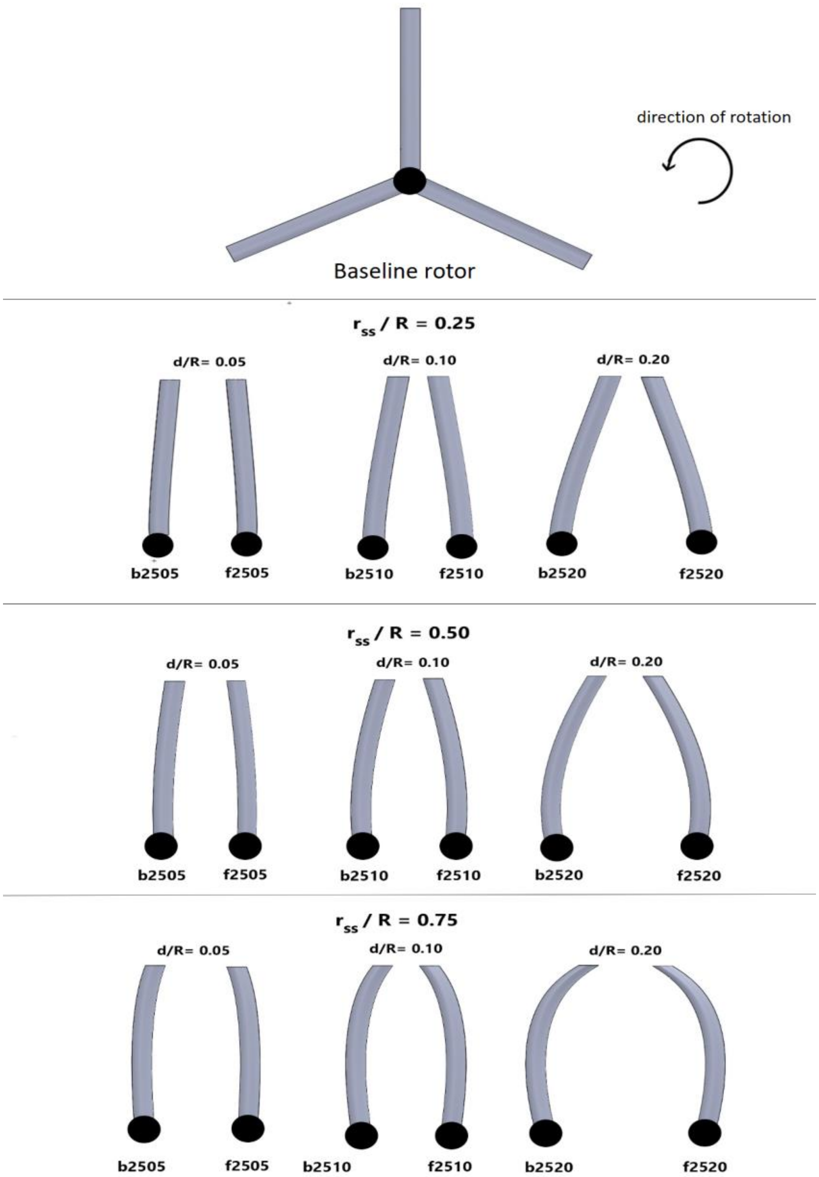

Figure 3. Newly designed swept blades.

Newly designed swept blades

Using the NREL Phase II blade as the baseline, swept blades in two rotor plane directions, forward and backward, three sweep begin sections (r_{ss}/R), 0.25, 0.50 and 0.75, and three tip displacements (d/R), 0.05, 0.10 and 0.20, were designed. The drawing of the newly designed swept blades were given in Fig. 3. In Fig. 3, d/R shows the ratio of the tip displacement (d) to the blade radius (R), r_{ss}/R shows the ratio of the sweep begin section (r_{ss}) to the blade radius. In order to name each blade, a method was developed where “f” is used for forward swept blades, “b” is used for backward swept blades. Following to numbers are used to indicate the sweep begin section and the last two digits are used to indicate tip displacement. For instance b2505 is the name of the backward swept blade that has sweep begin at 25% of the blade radius, and tip displacement that is 5% of the blade radius.

RESULTS AND DISCUSSION

The validation results for four turbulence models were given in Table 2. The simulation results were compared with experiment results for two wind speeds, 7.2 and 10.56 [11-13]. As it can be seen k-ε Realizable model has showed best performance among all turbulence models.

Table 2. Comparison of experimental and HAD produced mechanical power outputs

Wind speed	Turbulence Model	HAD Torque	Experimental Torque	Error (%)
7.2	k- ω SST	247	286	13.6
	k-ε Realizable	282		-1.4
	Spallart-Allmaras	250		12.5
	transition SST	291		1.7
10.56	k- ω SST	1073	1207	-11.1
	k-ε Realizable	1215		0.6
	Spallart-Allmaras	1068		-11.5
	transition SST	1085		-10.1

Pressure distribution results of k-ε Realizable turbulence model was used since it showed the best results. In Fig. 4 and 5 pressure contours on the pressure side (PS) and suction side (SS) of the blade were given for 7.2 and 10.56 m/s, respectively. The pressure difference is obvious between PS and SS for both wind speeds. In Fig. 6 and 7, pressure distributions on various blade sections were presented at same wind speeds and compared with the experimental data [11-14]. As it can be seen, simulation results are in a good agreement with experimental results.

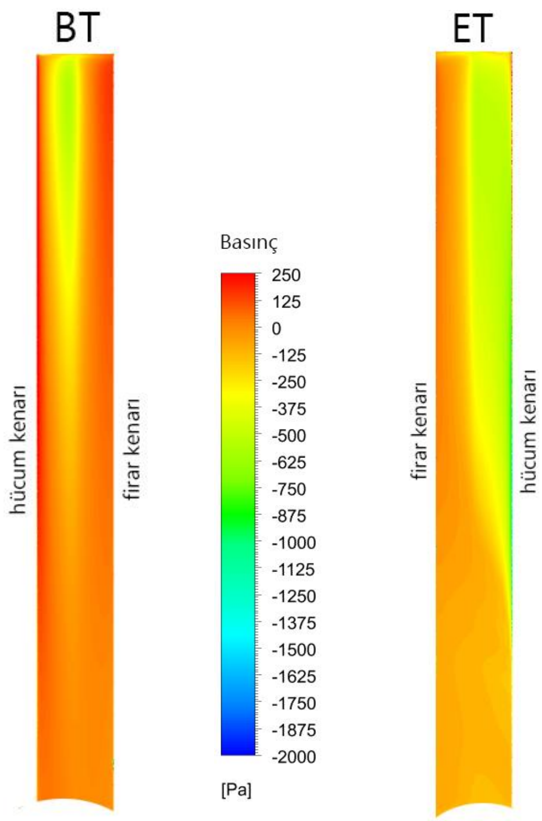

Figure 4. Pressure contours on the blade at 7.2 m/s wind speed

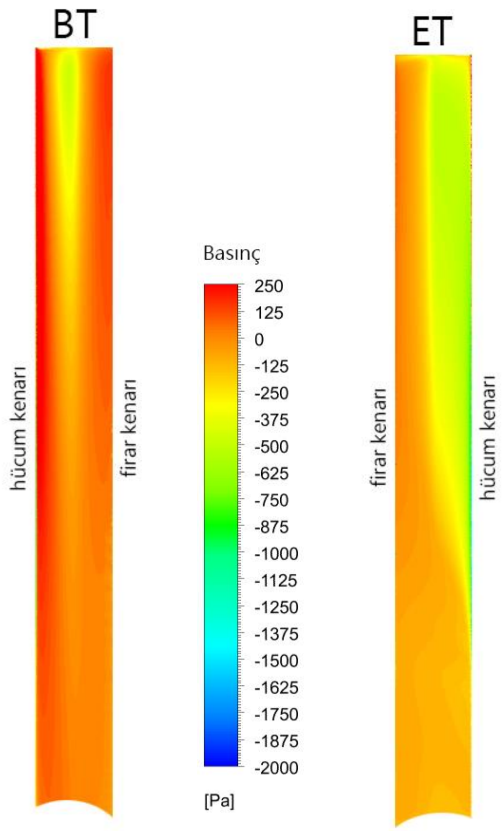

Figure 5. Pressure contours on the blade at 10.56 m/s wind speed

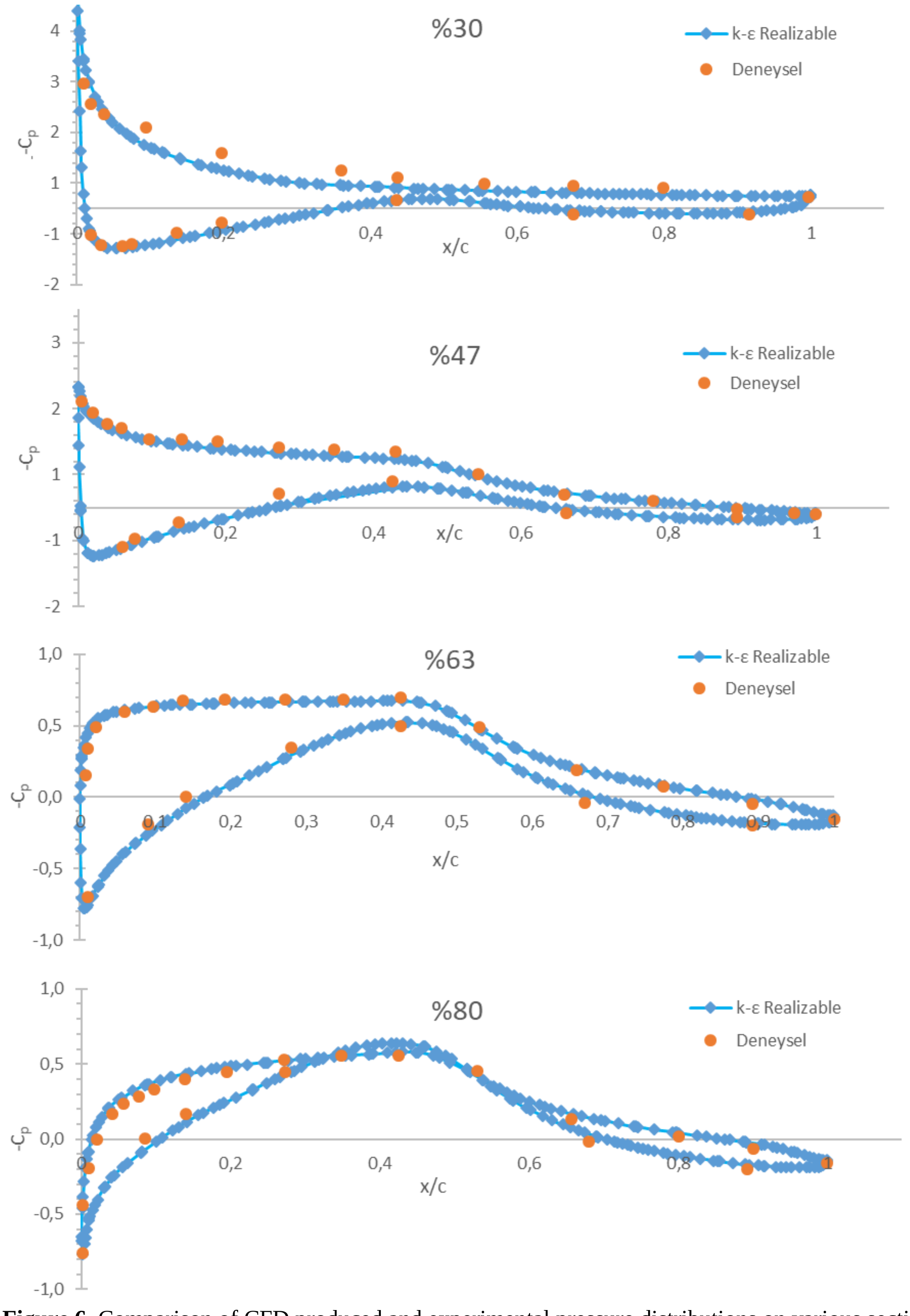

Figure 6. Comparison of CFD produced and experimental pressure distributions on various sections at 7.2 m/s wind speed

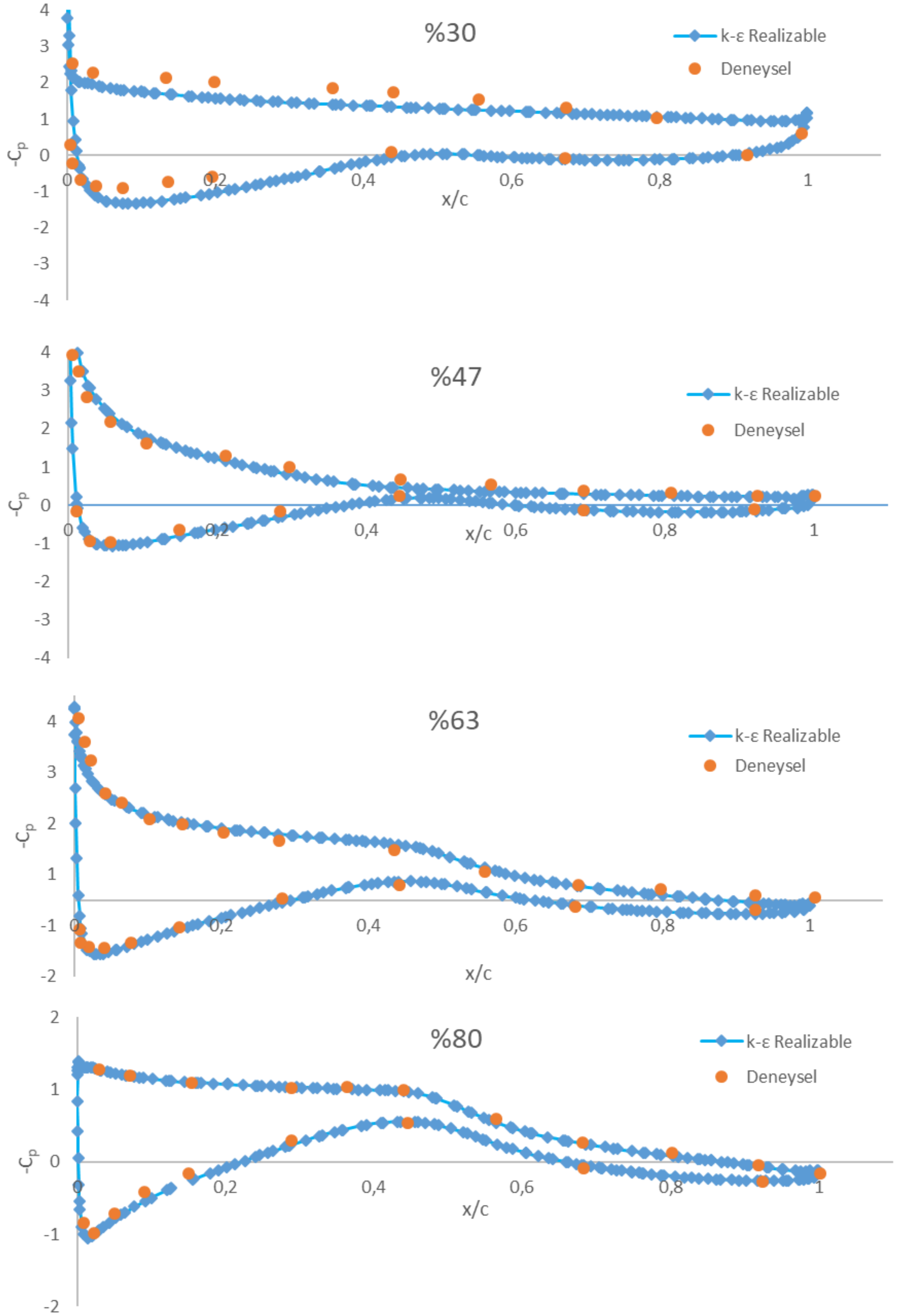

Figure 7. Comparison of CFD produced and experimental pressure distributions on various sections at 10.56 m/s wind speed

Lastly, change in mechanical power outputs using swept blades were tested for 7.2 and 10.56 m/s wind speeds and given in Table 3. As it can be seen from the Table 3, some forward swept blades had positive effect on the power production while backward blades caused to a reduction in power production. In terms of thrust force, backward swept blades had positive effect while forward swept blades caused to an increase.

Table 3. Changes in mechanical power and thrust force with swept blades compared to baseline design

Blades	7.2 m/s		10.56 m/s	
	Change in torque (%)	Change in thrust (%)	Change in torque (%)	Change in thrust (%)
f2505	-1.8	-1.2	**0.2**	-5.5
f2510	**2.0**	3.1	**0.4**	-5.6
f2520	**1.9**	3	-0.3	-4.8
f5005	**2.1**	1.3	**1.4**	0.4
f5010	**0.5**	0.1	-1.9	-0.8
f5020	-5.1	-2.9	-2.8	-1.31
f7505	-3.7	-3.2	-4.2	-8.2
f7510	-9.9	-5.5	-8.9	-11.3
f7520	-21.3	-9.1	-12.4	-13.4
b2505	-5.2	-2.5	**0.7**	-5.0
b2510	-5.2	-2.8	-0.6	-5.7
b2520	-3.8	-8.4	-9.7	-9.4
b5005	-19.3	-4.3	-10.2	-10.1
b5010	-11.2	-1.0	-13.7	-7.5
b5020	-4.0	-4.6	-1.3	-6.0
b7505	-12.1	-1.7	-8.4	-8.7
b7510	-1.4	-4.1	-12.3	-10.3
b7520	-9.6	-3.2	-3.8	-7.7

CONCLUSION

In this work, CFD method was validated using various turbulence models and NREL Phase II rotor as a baseline. The k-ε Realizable model has showed the best performance among all turbulence models and it was used to compare the pressure distributions on the blade with experimental data. Also the pressure distributions were found to be in a good agreement with experimental data. As for the swept blades, generally, forward swept blades have showed an increase in power production whereas backward swept blades reduced the power output. The advantage of the using backward swept blades was found to be having some reduction in thrust force.

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FABRICATION OF AN AUTHENTIC PART USING MATERIAL EXTRUSION TECHNOLOGY

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Abstract: This paper presents the process of rapid production of an authentic part using additive manufacturing, i.e. using technology of material extrusion. Polylactic Acid - PLA polymer was used as the material for making the part. The basic parameters set on the 3D printer are listed, as well as the parameters obtained which have shown the economic justification of fabrication of the part using material extrusion technology.
Keywords: Additive Manufacturing, FDM, PLA Polymer, 3D Printer**.**

INTRODUCTION

Modern design, development of new products and the development of prototypes and functional parts involves the application of technologies that are based on the principles of rapid fabrication. This approach allows us to obtain a physical model, which is identical to the virtual model, by joining the material layer by layer without the use of conventional tools and accessories. This concept of fabrication is known as additive manufacturing (AM) in the scientific-professional public. Its basic advantage over the traditional method of production is reflected in the faster achievement of aims that require access to the modern market. This primarily implies a significant shortening of the time until the product release and reduction in production costs. In some cases, additive manufacturing technologies represent the only possibility of obtaining geometrically complex components. Though being relatively briefly applied, Rapid Prototyping - RP and Rapid Tooling - RT technologies have become irreplaceable in terms of Rapid Manufacturing - RM components from different materials and a wide range of uses. In the time of general globalization, the use of the advantages offered by the additive manufacturing of prototypes, models and tools allows the realization of optimal and rational production which is superior to conventional technologies (Figure 1).

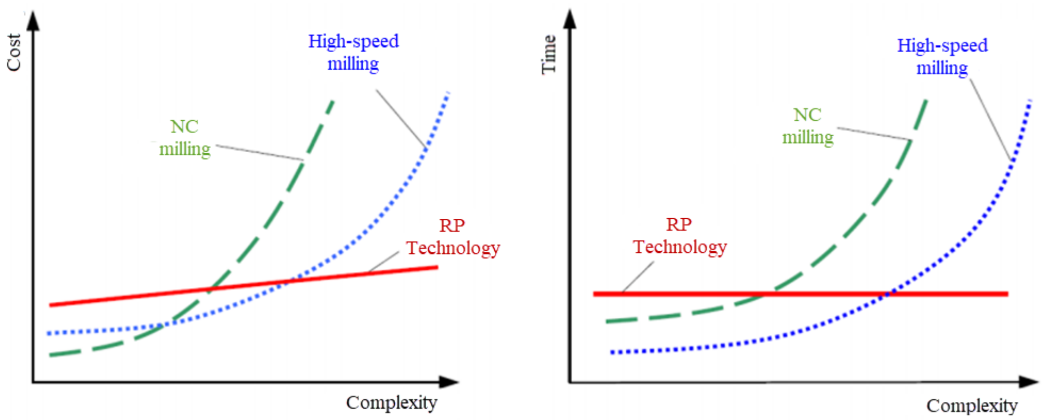

Figure 1. Comparison of conventional and RP technologies [1]

Fused Deposition Modeling - FDM is an additive process for the fabrication of prototypes and final parts. This procedure was presented in the paper and was used to obtain an authentic part. The complete procedure was analyzed, from the modeling of the part, through the conversion of the 3D model into the Standard Tessellation Language - STL file, which represents the standard for each process of AM [2], to the production itself or 3D printing. The paper presents a part of the research that was performed as an experimental part of the master thesis [3].

MATERIAL EXTRUSION TECHNOLOGY

FDM consists of 3 steps: preprocessing, production and postprocessing [4]. In this process, the plastic or wax material is extruded through a nozzle that follows the geometric layer of the section of the cross-section. FDM uses two materials: material for model making and support material. The nozzles contain resistant heaters that hold the plastic at a temperature above the melting point so that it easily flows through the nozzle and forms a layer (Figure 2). The plastic immediately hardens after it exits the nozzle and attaches to the layer below. When the layer is applied, the platform is descended to match the thickness of the layer, and the extractor nozzle deposits another layer. The thickness of the layer and the vertical dimensional accuracy are determined by the diameter of the extruder mass, ranging from 0.013 to 0.005 inches. At x-y level, the resolution is up to 0.001 inches [5].

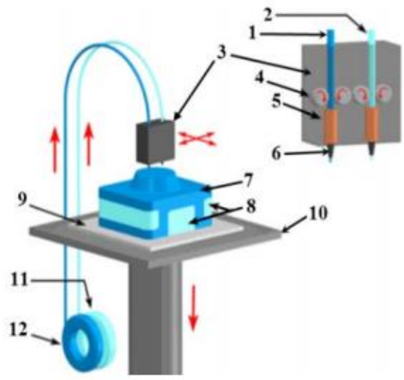

Figure 2. Schematic representation of the FDM process: 1-Build material filament, 2-Support material filament, 3-Extrusion head, 4-Drive wheels, 5-Liquifiers, 6-Extrusion nozzles, 7-Part, 8-Part supports, 9-Foam base, 10-Build platform,11-Support material spool, 12-Build material spool [6]

EXPERIMENTAL RESEARCH

Experimental research was realized with the aim to explain in detail the principles and methodologies of rapid prototyping by extrusion material technology, whereby the optimal and recommended parameters for the manufacturing are given. The design of the coat of arms of the Faculty of Mechanical Engineering in East Sarajevo was used for the production of the authentic part. The material used was polylactic acid - PLA polymer. Although this polymer is not used frequently in the FDM process, it has been used to print the coat of arms due to the availability of the material as well as the price itself. PLA is biodegradable under certain conditions. It has a low melting temperature (between 160 ℃ to 220 ℃) and a higher friction factor. The disadvantage is that it easily absorbs moisture from the environment, therefore it is necessary to pay attention to the storage of this material. All types have a biodegradability certificate EN12342 [7].
Experimental research was carried out at the Laboratory for Plasticity and Processing Systems at the Faculty of Mechanical Engineering in Banja Luka. The LeapFrog Creatr XL 3D printer (Figure 3) was used, and in Table 1 provides its basic parameters.

Table 1. Basic parameters of the 3D printer [6]

3D printer	**Creatr XL (LeapFrog)**
Type of extruder	Double extruder
Volume	230x270x600 mm
Material	ABS, PLA, PVA, Nylon
Layer thickness	0,2 mm
Infill percentage	100 %
Process temperature	60 °C (heated plate)
Price	≈5 000 $

Figure 3. LeapFrog Creatr XL 3D printer

The technology of material extrusion, i.e. the FDM technique, as well as any other rapid prototyping technologies, starts with a 3D model in the CAD program. The 3D model of the authentic part is created in the SolidWorks software package (Figure 4).

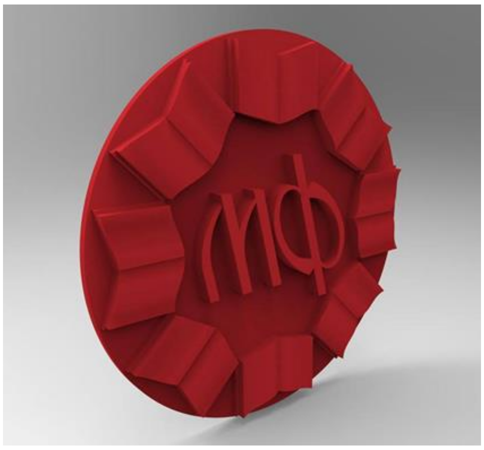

Figure 4. 3D model of coat of arms in SolidWorks software package

The 3D model was then exported to the LeapFrog Creatr XL 3D printer, i.e. its Simplify 3D software, where the processing of the CAD model and preparation for 3D printing was done (Figure 5). The Simplify 3D program defines the process parameters, generates layers and supports. First, the position of the model in the x-y level was determined, then the orientation of the model. In regards with the orientation, it is very important to have large surfaces on a horizontal plane, as this increases stability and reduces the consumption of the material for supporting structure. In doing so, it should be taken into account to avoid contact between the details of the model and supporting structure so as not to damage the model when releasing it from the supporting structure material. The optimal position and orientation of the model are shown in Figure 5.

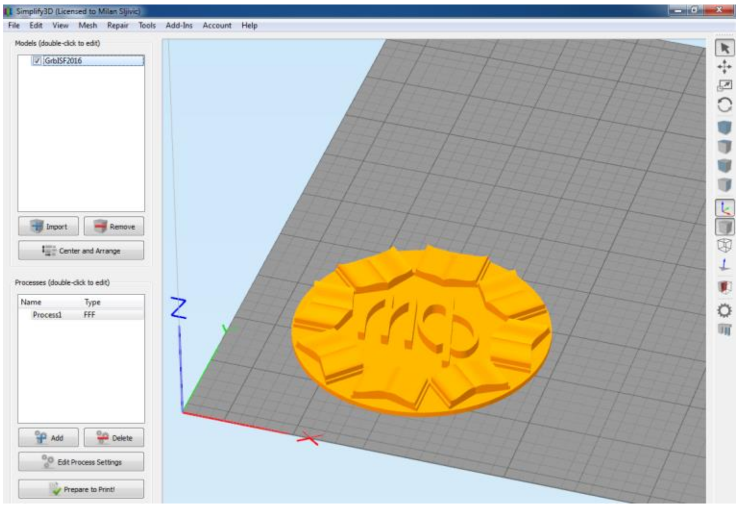

Figure 5. The 3D model of the coat of arms in the Simplify 3D program

Figure 6 shows the setting of the print parameters in the Simplify3D program.

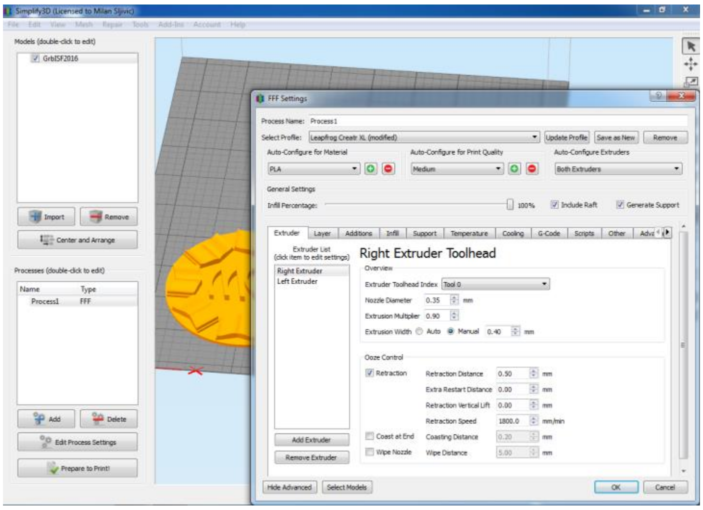

Figure 6. Setting up the operating parameters in the Simplify3D program

The 3D printing parameters that are set in the Simplify 3D program are:

- Platform temperature: 70 °C

The adjustment interval ranges from room temperature to 90 ° C, but based on the recommendations of the material manufacturer and on the basis of our own experiences and previous experimental research, the temperature of 70 ° C was selected.

- Temperature of the operating (right) nozzle: 250 ° C

The printer has two nozzles used for 3D printing. Right (working) nozzle is used to apply the basic material, or to print the part, in this case the coat of arms. The recommendation of the material manufacturer is that the temperature should be in the interval of 190 - 230 ° C. However, also based on previous research, a higher temperature was chosen due to the printing process itself, i.e. because of the easier flow of material through the nozzle and better bonding of the material with the platform base.

Since the similar studies have been carried out earlier in paper [8], these parameters have been corrected in order to obtain a better quality of the final part.

- The temperature of the second (left) nozzle for support material

The left nozzle on the printer is used for the extrusion of the supporting material. However, to print the coat of arms, the supporting material was applied using right (working) nozzle because the geometric configuration of the part there was no need for the use of the left nozzle. In case there was a need for its use, the temperature would have been 190 ° C. The fabrication time of the authentic part depends on the thickness of individual layers during the extrusion and the flow of material through the nozzle. When using PLA material, the recommended values have been selected, as follows:

- Layer thickness: 0.2 mm
- Material speed: 0.42 cm3/min
- Material speed in the first layer

  Due to the possibility of better adhesion of the first layer to the base, the material speed is 50% lower than the speed in the formation of other layers. The thickness of the first layer is 10% lower than the thickness of the other layers and the reason is also better adhesion for the base.
- Model infill percentage: 100%

Since the model of the coat of arms is rather small, the interior of the model is completely filled. However, if parts of larger dimensions are printed, a smaller model infill can be selected. In this way, material savings are achieved with the mandatory fulfillment of the requested requirements.

- Support material infill percentage: 30%
- Type of printed base: Raft

It is used as an additional print base that is printed larger than the basic model. In the particular case, the offset is 2 mm, or the print base is 2 mm larger than the coat of arm. The aim is to have larger surface area in contact with the ground in order to ensure greater stability of the model. The print base is mechanically removed after the model has been printed.

- Protective cover: Ooze shield

A shell around the model is printed, in order to provide a slower cooling of the material, and therefore a better adhesion of the layers. The shell corresponds to the thickness of one layer.
Figure 7 shows the coat of arms model in the STL format ready for printing.

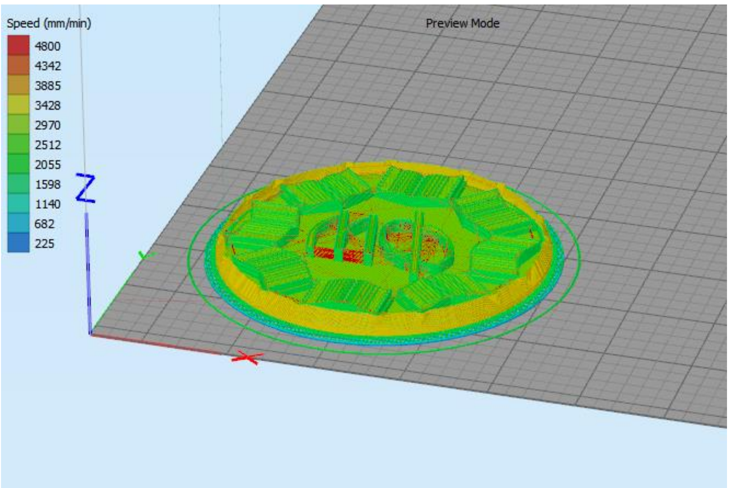

Figure 7. The model of the coat of arms in the STL format

RESULTS AND DISCUSSION

To design the part, it was necessary to go through a series of steps. First, it was necessary to model the coat of arms, with its surfaces specially designed with effects in the form of small chamfer and radius. Then the model was transformed into the basic format for 3D printing, i.e. in the STL format. In this way, the model view with mesh was obtained, which was adjusted so that the printed part had a satisfactory or desired surface quality. One of the most important steps in 3D printing was the processing of the machine, i.e. adjusting the basic process parameters, such as layer thickness, material flow, defining support, model and support fulfillment and so on. The next phase was the fabrication of a coat of arms, i.e. its printing. The last phase of the material extrusion technology was postprocessing, that is, removing the support from the coat of arms and its final processing. In the final processing of individual surfaces, that were deliberately left untreated, in order to have as little details as possible on the part, which could be used later for making tools using vacuum casting technology. As a result of the FDM procedure, the coat of arms is shown in Figure 8.

Figure 8. The coat of arms obtained by 3D printing

Also, when implementing the FDM procedure, the economic parameters of the part fabrication were analyzed. Since the printing time was 2h and 12min, a relatively short period for such processes, and due to the small amount of consumed material as a result of the volume of the product, it can be concluded that there is economic justification for making prototypes of the authentic product by the FDM procedure. In that case, it is also important to point out the fact that the price of the material consumed is very low and its value is approximately 2.5 BAM.

CONCLUSION

Lately, more attention has been paid to the development of products and methods of their easier production in order to get a faster market position and to achieve competitiveness. Because it is not possible to achieve the said aims by conventional procedures, an alternative is required in additive production, which implies rapid development of the product. The advantages of additive production are also reflected in the construction of parts of a complex geometric shape, as well as the ability to inspect all phases of development, production and functional characteristics of the product.

This paper presents the FDM process, showing the complete procedure, from the modeling of the part, through the conversion of the 3D model into a STL file that represents the standard for each process of additive manufacturing, up to the production itself, i.e. 3D printing. Experimental research was carried out in order to explain the principles and the methodology of rapid prototyping in detail on a practical example of complex geometry (the design of the coat of arms of the Faculty of Mechanical Engineering, East Sarajevo) using material extrusion technology where improved parameters were used, compared to the recommended ones, which were obtained as a result of the previous research.

The obtained part was later used as a master model for vacuum casting mold, using vacuum casting technology, in order to integrate two technologies, which is not shown in this paper.

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INFLUENCE OF FUNCTIONAL ADDITIVES ON STRUCTURE AND MORPHOLOGY OF $Ti_{0.8}Sn_{0.2}O_2$ BASED VARISTOR CERAMICS

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Abstract: This paper briefly describes the influence of adding the small amounts of functional additives on structure and morphology of titanium-tin-oxide (TTO) based ceramics intended for the use as varistor (variable resistor) in the electrical systems for protection against the voltage surge. These ceramic materials were synthesized by the solid-state method. Evolution of the obtained ceramics microstructures with the change of the doping elements composition and number were studied by scanning electron and electron dispersive spectroscopy, while Raman analysis confirmed the formation of nanocrystalline ceramic materials with $Ti_{0.8}Sn_{0.2}O_2$ solid-solution matrix. Room temperature current-voltage characteristic of niobium and zinc doped titanium-tin-oxide (TTO:NZ) ceramics, in direct current mode, has been also determined. The varistor-type behavior with sufficient low breakdown voltage and an acceptable high nonlinear coefficient was observed.
Key words: oxide ceramics, semiconductors, solid-state processing, varistor

INTRODUCTION

The $(Sn_xTi_{1-x})O_2$ solid-solution based polycrystalline ceramics are an extremely promising type of material for the application in electrical systems as a protection from the high voltage (as variable resistors, i.e. varistors) [1-5]. Their advantages compared to the others is the presence of TiO_2 in the majority, which somewhat solves the problem of SnO_2 poor densification and contributes to its high sinterability. This is very important for the functionality of this type of ceramics for varistor applications. The small additions of Nb_2O_5 or/and ZnO to the $(Sn_xTi_{1-x})O_2$ lattice should improve the densification even more by the substitution of matrix cations with dopant cations (Nb^{5+} and Zn^{2+}), and creation of oxygen vacancies which are the key defects responsible for the densification processes and electron mobility enhancement in the bulk grains [4, 5]. Formation of the defects also leads to the desired increase of resistivity in the grain boundaries [5]. Namely, the varistor materials are featured by a specific microstructure consisted of the conductive grains (matrix oxide) which are surrounded by the resistive grain-boundary regions (Fig. 1a). The material with this type of microstructure shows the nonlinear current-voltage characteristic (Fig. 1b). The varistor materials, which are also known as voltage-dependent resistors (VDR), are used in parallel with an electrical circuit that needs to be protected from the voltage surge (Fig. 1a).

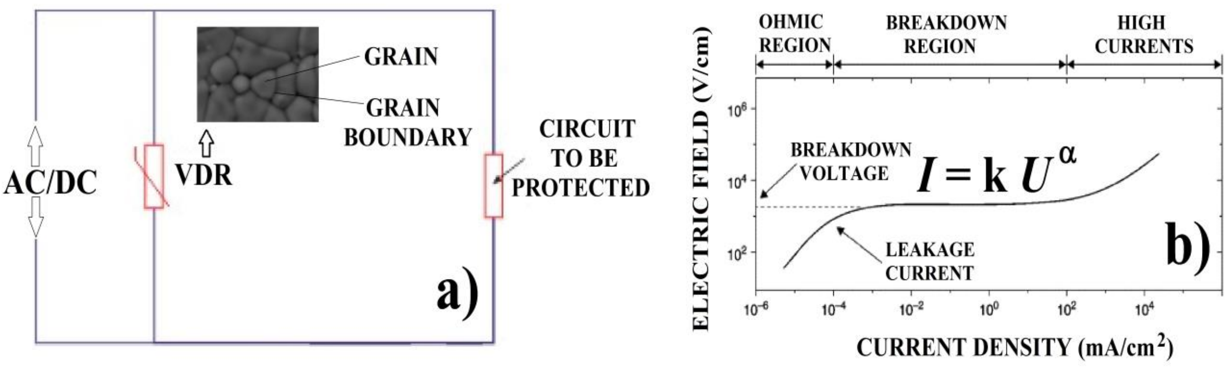

Figure 1. Schematic representation of a) VDR microstructure and its application in an electrical circuit that needs to be protected from the voltage surge, and b) VDRs current-voltage characteristic

In this paper, we summarized the findings of a new solid-state processing procedure for obtaining the titanium-tin-oxide based ceramics with $Ti_{0.8}Sn_{0.2}O_2$ matrix, and its microstructural evolution with doping. The results of the current density-electric field (*J-E*) behavior study in these ceramic materials are also reported.

MATERIAL AND METHODS

Titanium-tin-oxide ceramic samples were prepared by a traditional solid-state method starting from the commercial powders of rutile SnO_2 (Sigma-Aldrich; ~325 mesh powder; purity 99.9% trace metals basis) and anatase TiO_2 (Sigma-Aldrich; purity 99.7% trace metals basis). The 1 mol% of Nb_2O_5 (Alfa Aesar; purity 99.9% metal basis) and 1 mol% of ZnO (Aldrich; purity 99.999% trace metal basis) were the sources of the dopant ions. The stoichiometrical amount of the starting precursors were mixed to achieve $Ti_{0.8}Sn_{0.2}O_2$ composition, milled with zirconia media (Retsch GmbH PM100) in ethanol for 6h, and then calcinated at 800 °C for 2h with a heating rate of 10 °C/min in an alumina crucible. The treated powder mixtures were then uniaxially pressed in 10 mm pallets under 500 MPa and sintered at 1280 °C for 2h. The $Ti_{0.8}Sn_{0.2}O_2$ matrix, Nb-doped $Ti_{0.8}Sn_{0.2}O_2$, and (Nb,Zn)-doped $Ti_{0.8}Sn_{0.2}O_2$ ceramic samples obtained were marked as TTO, TTO:N and TTO:NZ, respectively. The scanning electron microscope, SEM (JEOL JSM-6460LV) equipped with an energy-dispersive spectrometer (EDS) was used to investigate the morphology, microstructure and elemental concentration of the obtained ceramic samples. The Raman spectra were measured using the Centice MMS Raman spectrometer equipped with a CCD detector. A diode laser operating at 785 nm (1.58 eV) with the power of 70 mW was used as the excitation source, and all measurements were carried out at room temperature. For electrical measurements, the opposite surfaces of the sintered pellet were coated with silver paste to ensure good ohmic contacts. At room temperature, the current density-electric field characteristic of TTO:NZ in direct current mode was determined by using a Source Meter Keithley 2410.

RESULTS AND DISCUSSION

The X-ray diffraction (XRD) analysis, shown in detail elsewhere [4,5], confirmed the formation of the tetragonal titanium-tin-oxide (ICSD#01-070-4404) solid-solution phase, $Ti_{0.8}Sn_{0.2}O_2$ in all three ceramic samples. Peaks of no other phases were noticed. The XRD profile analysis [4,5] also confirmed the TTO, TTO:N and TTO:NZ ceramic samples nano-crystallinity. The crystallite size and lattice microstrain values were lower for the TTO:NZ compared to the matrix (TTO) and Nb-doped TTO (TTO:N) samples [4,5]. Comparable SEM micrographs for TTO, TTO:N, and TTO:NZ ceramic samples, are shown in Fig. 2, while the example of their EDS spectrum is shown in Fig. 3.

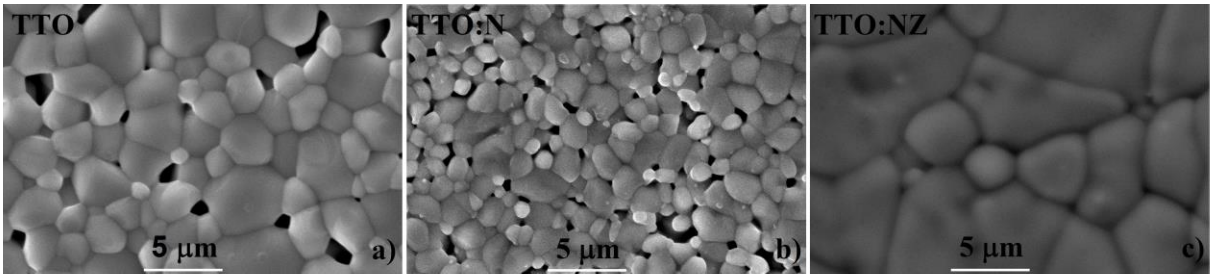

Figure 2. The SEM images of a) TTO, b) TTO:N, and c) TTO:NZ ceramic samples taken with the same magnification

The microstructure of TTO:NZ (Fig. 2c) is highly dense compared to TTO and TTO:N, and is characterized by the irregularly shaped and much wider in range grain sizes (from 1.43 μm to 6.21 μm, and even 15.2 μm) [5], which is certainly the consequence of a positive synergic two dopant effect in TTO:NZ. The TTO and TTO:N ceramic samples (Fig. 2a,b) show a microstructure with more pronounced closed porosity. Table 1 confirms the incorporation of dopants into the matrix lattice in

TTO:NZ and shows the weight percentage of the elements present (obtained from the EDS measurements, Fig. 3). Similar data were shown for TTO:N and TTO:NZ, previously elsewhere [4,5].

Table 1. EDS elemental composition (weight %) for TTO:NZ ceramic sample

Composition	O	Ti	Sn	Nb	Zn
$Ti_{0.8}Sn_{0.2}O_2$: Nb^{5+},Zn^{2+}	30.63	35.97	30.04	2.49	0.87

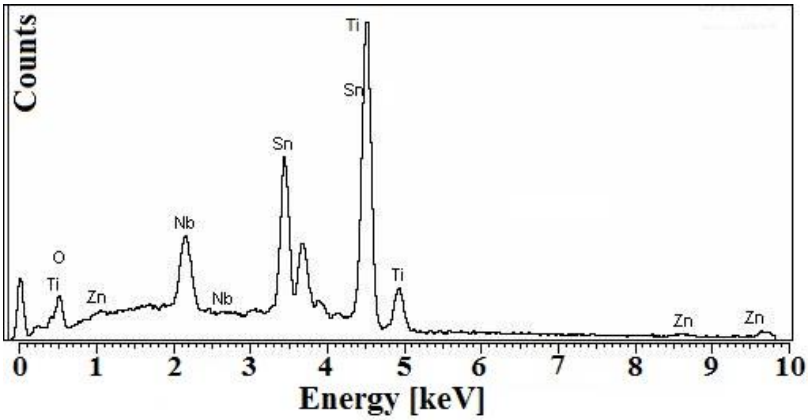

Figure 3. The example of the EDS spectrum for TTO:NZ ceramic sample

Figure 4 shows the example of the Raman spectrum.

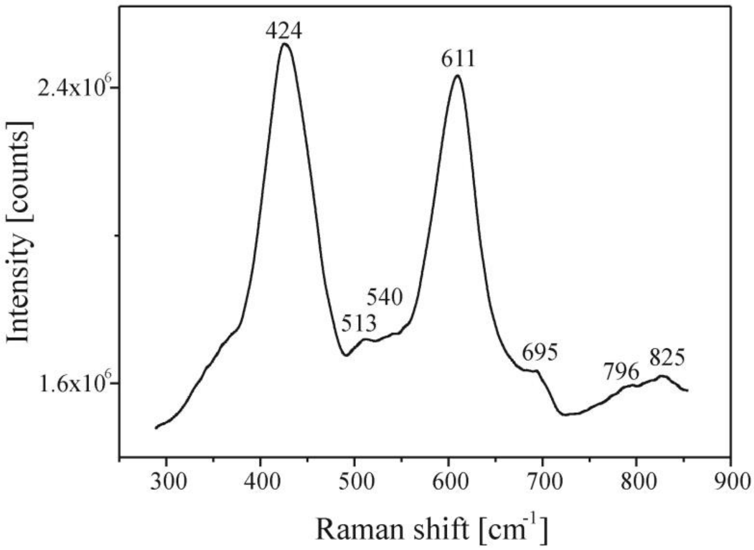

Figure 4. The Raman spectrum of TTO matrix ceramic sample

The Raman peaks positions (frequencies) were determined by the peak fitting procedure and marked in Fig. 4 for TTO matrix sample. The shape of the spectrum is almost the same as for the TTO:NZ (shown in [5]), and characterized by the two most intense peaks at 424 and 611 cm^{-1}. Compared to the double cation doped TTO:NZ Raman spectrum shown in ref. [5], the most intense 424 cm^{-1} peak in the Raman spectrum of TTO assign to E_g mode vibration of the $Ti_{0.8}Sn_{0.2}O_2$ rutile-type matrix, is blue-shifted. Blue-shifted is also the leakage Raman peak at 513 cm^{-1}, 540 cm^{-1}, and 695 cm^{-1} as well, which presumably originate from the second-order Raman scatterings [5]. Raman supports the XRD analysis [4,5] in the conclusion that all of the obtained ceramic samples crystallize in the tetragonal titanium-tin-oxide (TTO) solid-solution structure. The red-shift of 424 cm^{-1} peak, and the appearance of the new peaks in TTO:NZ is a result of a grain size increase [4,5] seen in Fig. 2, as well as the formation of much-wanted structural defects such as oxygen vacancies when both functional additives (Nb and Zn) are introduced into the TTO lattice.

In order to investigate the varistor effect, determining the current-voltage characteristic is of particular importance. The current density-electric field (*J-E*) characteristic of TTO:NZ obtained in direct current mode is given in Fig. 5. The electric field and current density were obtained from $E = V/d$ and $J = I/a$ [5], respectively, where V and I represent the measured voltage and current, respectively. The parameter d represents the sample thickness (0.215 cm), and A is the area of the electrode deposited on the surface of the sample (0.657 cm^2). Generally, the varistor phenomenon is characterized by the breakdown voltage and the nonlinearity coefficient. According to the obtained experimental results, the value of nonlinear coefficient α has been estimated to be about 6.5 by using the equation $\alpha = \log(J_2/J_1)/\log(E_2/E_1)$ [5]. This relatively high value of α defines the rate of change from the high resistive to low resistive state.

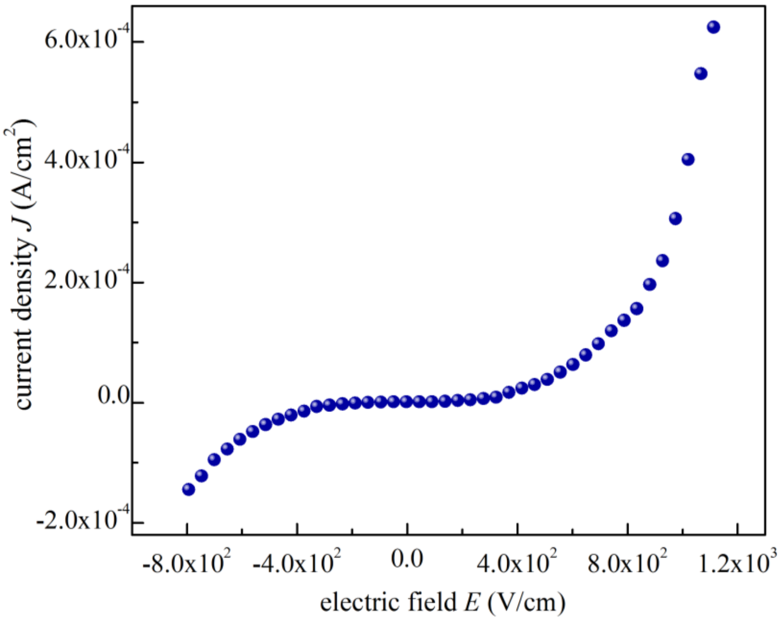

Figure 5. Current density-electric field characteristic of TTO:NZ varistor at room temperature.

CONCLUSION

This work shows the result of microstructural evolution investigation for $Ti_{0.8}Sn_{0.2}O_2$ solid-solution ceramics with the addition of dopant ions. The highly dense microstructure was obtained only after the synergic effect of two dopant cations (Nb^{5+} and Zn^{2+}). It was established that small amounts of functional additives have a positive influence on TTO ceramics densification through the formation of oxygen vacancies that most definitely ensure the electron mobility in the $Ti_{0.8}Sn_{0.2}O_2$ matrix grains as well. All these overall reflects in a positive manner on the obtained material (TTO:NZ) varistor properties [5]. Namely, TTO:NZ has the breakdown voltages lower than 130 V and high nonlinear coefficients, approximately 6.5, which makes this ceramic material promising candidate for fabrication of the low-voltage varistors.

ACKNOWLEDGMENT

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EVALUATION OF OPEN HOLE TENSILE QUALIFICATIONS OF HNT-EPOXY/BASALT FIBER NANOCOMPOSITE MATERIALS

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Abstract: One of the most effective ways to improve the mechanical properties of composite materials is matrix improvement. The mechanical properties of composite materials and their structural uses increased with the modification of nanoparticles. This work aimed to enhance experimentally tensile strength of halloysite nanotube (HNT) modified epoxy and epoxy/basalt fiber nanocomposites . Therefore, 1, 2 , 3 wt% of HNT particles filled into the epoxy matrix and 2 wt% HNT , better effective than the others, was used impregnate basalt fiber. The drawn up basalt fiber nanocomposite were conducted to tensile and open hole tensile test. As a result of all experiments, the addition of HNT exhibited higher tensile performance compared to neat epoxy composite. It also changed the mode of the fracture surface in the OHT test.
Key words: open hole tensile, halloysite, basalt, nanocomposite

INTRODUCTION

Basalt fiber reinforced composite have been commonly used in many areas, including automobile, aircraft, ship, marine, civil construction, electro-technical application and other industries areas due to their good properties such as thermal properties, high chemical resistance and high mechanical resistance. In fiber-reinforced composite materials, epoxy is generally used as a matrix because of its superior polymeric properties. The weakest point of fiber reinforced polymer matrix composite materials is known to have low interlaminar shear strength. For this reason, the researchers are concentrated their study on the polymer matrix. Many attempts have been realized to improve the mechanical properties of epoxies by modifying epoxy resins with additives micro and nano fillers. It has been found that inorganic additives such as silica, alumina glass particles can improve the properties of epoxy [1-5]. In recent years, the rapid development of nanotechnology has led to the modification of epoxy resins with nanoparticles and the emergence of nanocomposite materials [6, 7]. Hussain et al. have attempted to increase the properties of epoxy resins with montmorillonite particles but they did not achieve significant improvement [8]. In recent studies, nano silica particles have changed the mechanical properties of the epoxy matrix visibly at ambient temperature, in cryogenic conditions and at elevated temperatures [9-13]. In another study, Eskizeybek et al. are increased the impact strength and mechanical properties of epoxy resin by using nano $CaCO_3$ [14]. In a study conducted by Kaybal et al., nano Al_2O_3 is improved both the mechanical properties and the impact strength of the epoxy resin [15].
Recently, Halloysite Nanotube (HNT) have been studied as a new type of additive for epoxy resin [6, 16, 17]. In the study conducted by Liu et al. with Halloysite Nanotube particles, it was stated that the thermal expansion coefficient and strength modulus of nano composite material increased [16].
The presence of holes in the assembly of composite materials is required. These holes directly affect the strength of the composite material. Studies on the stress behavior of these materials with circular holes are of interest. The effect of geometric and material parameters on the strength and damage mechanisms of composite materials has been demonstrated by different studies [18, 19]. In the studies, fiber damages and matrix damages are defined as a damage mechanism [20]. In the specimens, fiber damages are formed perpendicular to the hole boundaries, while matrix damages generally are occurred tangent to the hole and parallel to the direction of the fiber [18].
This work focus on open hole tension (OHT) strength of basalt fiber reinforced epoxy nanocomposite. Firstly, the epoxy matrix was modified from 1 to 3 wt % with HNT particles. Fiber reinforced nanocomposite material is produced in the best effective ratio (2 wt %) with optimum strength values.

Secondly, the open hole tensile strength values of the basalt fiber nanocomposite material were discussed and compared with the neat epoxy composite material.

MATERIAL AND METHODS

Production of HNT-Epoxy Nanocomposites

Epoxy and hardener, which have code of L160 and H160 respectively, purchased from Dost Kimya Company and the HNT particles are supplied from Eczacibasi Company for fabrication of HNT-Epoxy nanocomposite. A certain amount of epoxy and HNT particles are mixed in the mechanical mixer for up to 15 minutes for the powder to wet. Then, the mixture of HNT-Epoxy is mixed with ultrasonic stirrer for 1 hour at 15 minute intervals. After the last process, the curing agent is added into the HNT-Epoxy mixture and mixed with the mechanical mixer. The mixture of HNT-Epoxy/agent is poured into steel molds. The steel mold is kept at 80 °C for 2 hours and the production of HNT-Epoxy nanocomposite materials is completed. It can be seen fabrication of nanocomposite in Figure 1.

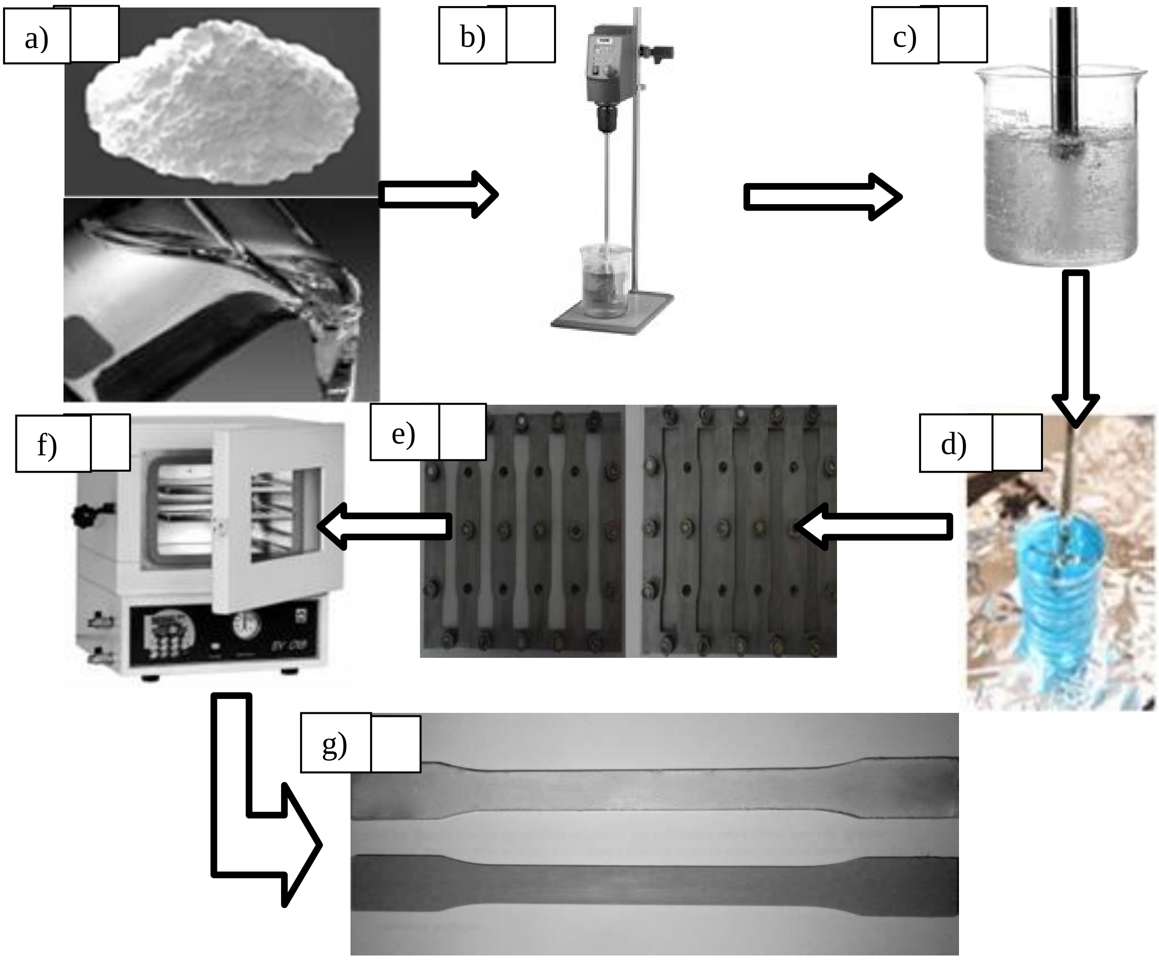


Figure 1. Fabrication of HNT-Epoxy Nanocomposites a) HNT particles and Epoxy b) Mechanical mixer c) Ultrasonic stirrer d) Mixing of HNT-Epoxy with Hardener e) Steel mold f) Furnace for curing g) Specimens

Production of HNT-Epoxy/Basalt Fiber Nanocomposites

Plain weave basalt fiber fabric with 300 g/m2 areal density was purchased from Spinteks Company. The Vacuum Assisted Resin Infusion Method (VARIM) was used to production of HNT-Epoxy/Basalt fiber nanocomposites laminate consisting of ten plies of basalt fabrics. The epoxy matrix of the basalt fiber reinforced composite was made according to the above process at 2% by weight HNT. Also, neat epoxy specimens were fabricated following the same procedure. Images from the production process are given in Figure 2.

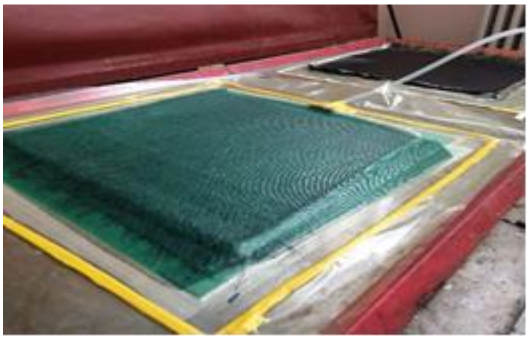


Figure 2. Fabrication of HNT-Epoxy/Basalt Fiber Nanocomposites a) Vacuum process b) Basalt fiber nanocomposite

Test Procedure

Tensile and Open Hole Tensile (OHT) test were carried out using Instron 8801 testing machine at environmental temperature. The tensile properties of HNT-Epoxy and HNT-Epoxy/Basalt Fiber nanocomposites were investigated in accordance with ASTM D 4762 – 11a and D3039 standards, respectively. On the other hand, D5766 / D5766M standard was used for OHT strength. Tensile tests were performed with 2 mm/min tensile speed. Also, HNT-Epoxy/Basalt fiber nanocomposite specimens were drilled 6 mm diameter for the OHT test.

RESULTS AND DISCUSSION

Tensile Properties of Nanocomposites

Typical stress-extension curves of HNT modified epoxy are given in Fig. 3. As seen in this figure, the addition of HNT particles increases the tensile strength of epoxy resin and the tensile strength attains its maximum at 2 wt% HNT content as 81,9 MPa with 30% increase compared to 0 wt% HNT-epoxy composite. Also, the tensile strain at fracture increase with the increase in HNT content due to the physical and chemical interactions between HNT nanoparticles and epoxy. In addition, Table 1 summarizes the effect of HNT nanoparticles on the tensile properties of the composites.

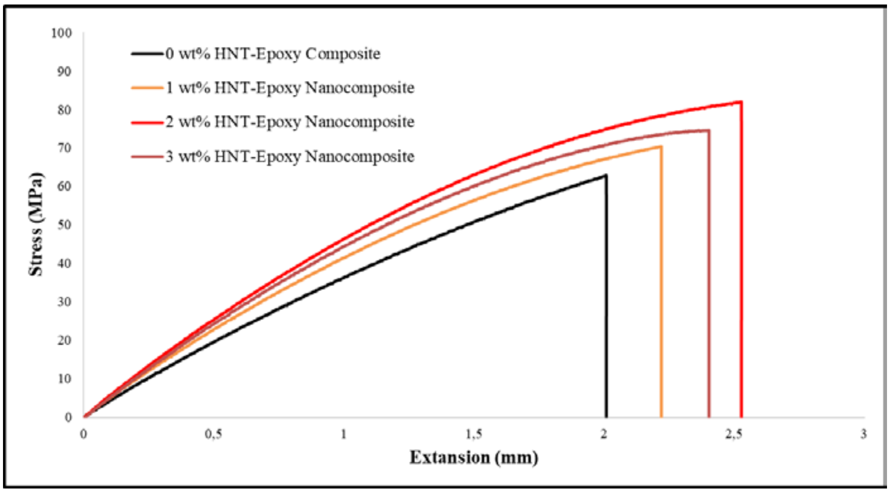


Figure 3. The tensile stress-extension curves of epoxy nanocomposites

Table 1. The tensile test result of epoxy nanocomposites

Materials	*Stress (MPa)*	*Extension (mm)*
0 wt% HNT-Epoxy Composite	62,8 MPa	2,01 mm
2 wt% HNT-Epoxy Nanocomposite	81,95 MPa	2,52 mm

Stress-extension curves for basalt fiber reinforced HNT-epoxy are shown in Fig. 4. While the tendency is similar for that of the tensile strength epoxy nanocomposites, the addition of HNT within epoxy/basalt fiber composites results in an increase in the tensile properties. The drastic increase in tensile strength of 2 wt% HNT-Epoxy/Bazalt Fiber nanocomposite is found as 22 % compared to neat epoxy composite. In addition, Table 2 summarizes the effect of 2 wt% HNT nanoparticles on the tensile properties of the composites.

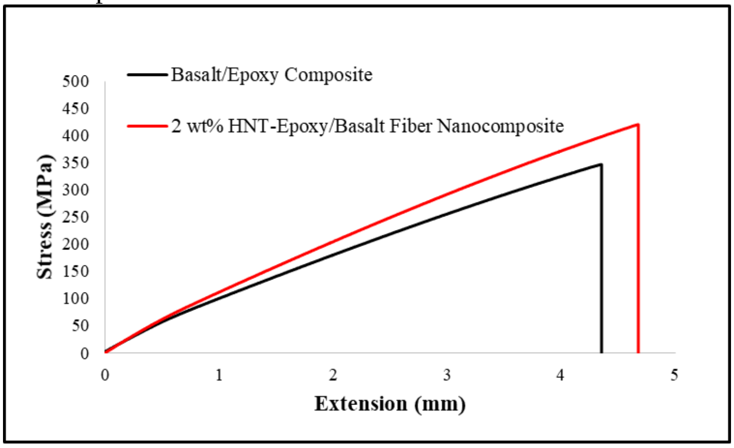


Figure 4. The tensile stress-extension curves of epoxy/basalt fiber nanocomposites

Table 2. The tensile test result of epoxy/basalt fiber nanocomposites

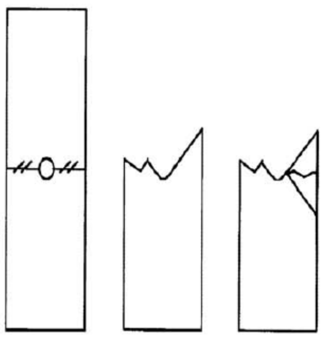
Materials	*Stress (MPa)*	*Extension (mm)*
0 wt% HNT-Epoxy/Basalt Fiber Composite	346,91 MPa	4,35 mm
2 wt% HNT-Epoxy/Basalt Fiber Nanocomposite	420,41 MPa	4,68 mm

Open Hole Tensile Test

Open Hole Tensile (OHT) test is similar to previous tensile test moreover a hole of 6 mm diameter is drilled at the center of the specimen. The results of OHT test can be utilized for structural design allowable, material specifications, research and development [21]. To describe the failure mode, the three character codes are used. The character codes are given in Fig. 5a. The acceptable failure test codes for this test method are restricted LGM (Fig.5b), AGM (Fig.5c) and MGM (Fig.5d).

First Character		Second Character		Third Character	
Failure Type	Code	Failure Area	Code	Failure Location	Code
Angled	A	Inside grip/tab	I	Bottom	B
edge Delamination	D	At grip/tab	A	Top	T
Grip/tab	G	<1W from grip/tab	W	Left	L
Lateral	L	Gage	G	Right	R
Multi-mode	M(xyz)	Multiple areas	M	Middle	M
long. Splitting	S	Various	V	Various	V
eXplosive	X	Unknown	U	Unknown	U
Other	O				

a



b c d

Figure 5. Failure modes for open hole tensile strength accordance to ASTM D 5766/ 5766M
a) Failure mode code b) LGM c) AGM d) MGM

The stress-extension of open hole tensile (OHT) strength for HNT-epoxy/basalt fiber nanocomposite and neat epoxy/basalt fiver composite are given in Fig. 6. The result reveal that inclusion of HNT nanoparticles in epoxy composite have least influence on OHT strength. Furthermore, it seen that the nanocomposite material gas a higher strength modulus and extension compared to neat composite. The maximum OHT stress values of HNT-Epoxy/Basalt nanocomposite material is 342 MPa. Neat Epoxy/Basalt composite illustrates that the maximum OHT strength value as 234 MPa according to Table 3.

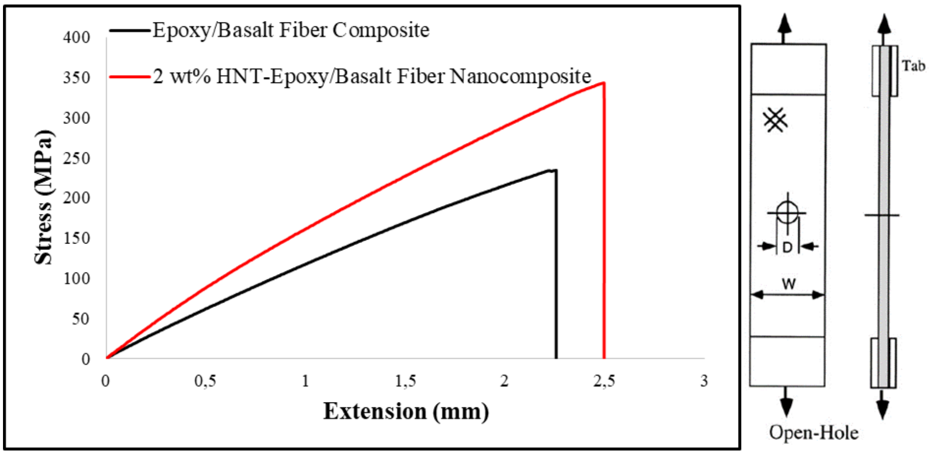


Figure 6. The tensile stress-extension curves of OHT for epoxy/basalt fiber nanocomposites

Table 3. Results of OHT test

Materials	*Stress (MPa)*	*Extension (mm)*
0 wt% HNT-Epoxy/Basalt Fiber Composite	234,5 MPa	2,25 mm
2 wt% HNT-Epoxy/Basalt Fiber Nanocomposite	342,9 MPa	2,49 mm

The Fig. 7. demonstrates the image of the laminates nanocomposite specimens after the OHT test. It seen that the breaking surface of composite materials are damaged in appropriate failure mode. Furthermore, it is clear that the HNT particles additive in epoxy resin has changed the failure mode of the nanocomposite from LGM to AGM.

Neat Epoxy/Basalt Fiber Composite	***2 wt% HNT-Epoxy/Basalt Fiber Nanocomposite***

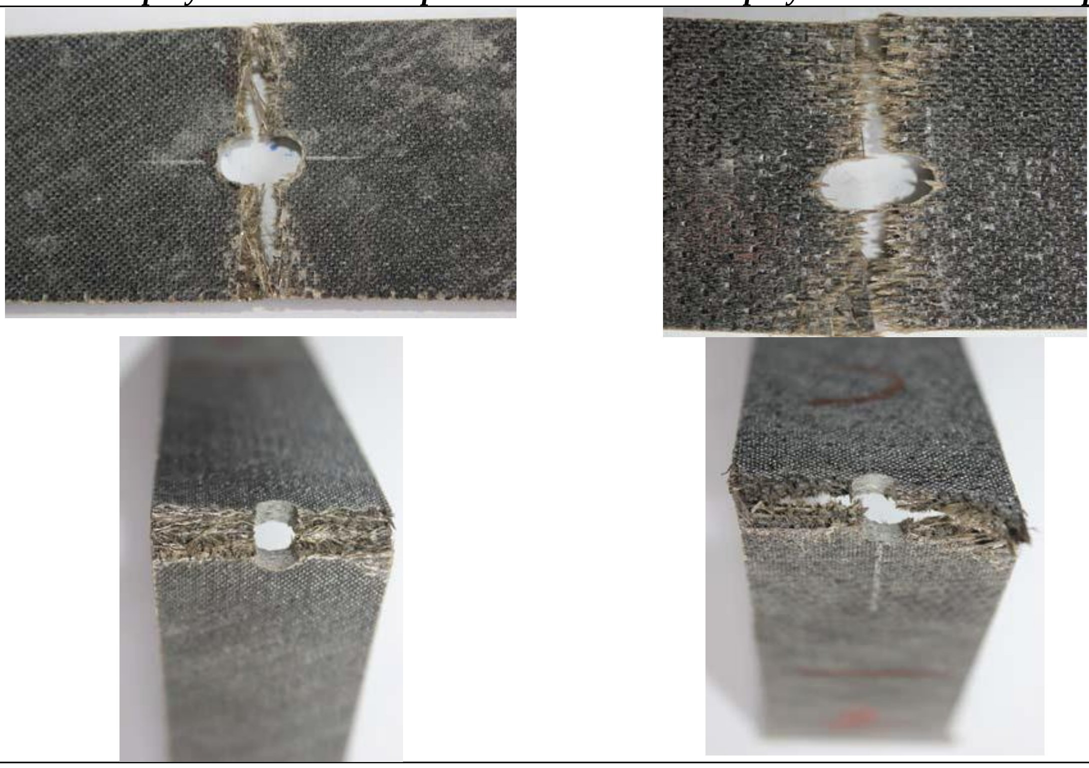


Figure 7. Images of fracture surface after tensile test

CONCLUSION

The standard tensile test and open hole tensile test for HNT-Epoxy nanocomposites were fabricated using casting procedure to steel molding and HNT-Epoxy/Basalt Fiber nanocomposites were manufactured using VARI methods. The following conclusion drawn are:

- HNT nano filler reinforced epoxy nanocomposite have better tensile properties than neat epoxy composite. The maximum tensile strength is found in the 2 wt% HNT-Epoxy nanocomposites as 81,95 MPa.
- The addition of 2 wt% HNT in to epoxy has significantly improved the tensile strength by 22%.
- In open hole tensile test, the addition of 2 wt% HNT is enhanced OHT strength and failure mode of composites is changed from LGM to AGM.
- The experimental results illustrates that Halloysite Nanotube (HNT) reinforced epoxy nanocomposites are better performance compare to neat epoxy composite. Accordingly, it is suggested that HNT particle can be added in the basalt fiber composite to improve tensile strength.

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MECHANICAL BEHAVIOR OF HALLOYSITE-EPOXY NANOCOMPOSITES: EFFECT OF SEAWATER AGING

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Abstract: The aim of this study is to enhance the seawater durability of epoxy resins used for marine applications. Epoxy resin has been reinforced with various amounts of halloysite nanotubes (HNTs. The epoxy nanocomposites have been subjected to seawater aging. Tensile and flexural tests have been performed in order to evaluate the effect of the seawater aging on the mechanical properties. The test results showed that the HNTs modification increased seawater durability of epoxy drastically with respect to the neat epoxy.

INTRODUCTION

Epoxy resins are commonly utilized in polymer industry because of their remarkable good mechanical properties. Although epoxy represents exceptional mechanical performances [1], the environmental factors such as temperature, atmosphere, water, etc. deteriorate of epoxy and result as aging [2, 3]. The high water uptake tendency in humid environment and poor crack initiation or propagation resistance of epoxy resins greatly limits its use in marine applications [4, 5]. The absorbed water would cause numerous undesirable effects in epoxy, such as swelling plasticization, hydrolysis and formation of cracks [6, 7].

Addition of nanostructures into polymers have attracted increasing attention because of the unique properties of the nanostructures [8, 9]. Nanostructures provide superior properties because of their large surface area per unit volume. High aspect ratio of nanostructures results advance properties thanks to the phase interactions that take place between the polymer matrix and the nanoparticles at the interfaces [10]. Several researchers reported that the introduction of nanoparticles into the polymers can provide barrier properties in addition to exceptional mechanical properties [7, 11-13]. Halloysite nanotubes (HNTs) are naturally-occurring tubular clay minerals with unique properties suited to various applications due to their large aspect ratios and ease of processing. However, there is very limited knowledge concerning the seawater durability of HNT modified nanocomposites.

In this study, the effect of seawater aging on the mechanical properties of epoxy nanocomposites reinforced with HNTs has been investigated. The influence of HNTs addition with various on enhancing epoxy mechanical properties in seawater immersed condition has been explored in terms of tensile and flexural properties strength.

MATERIAL AND METHODS

The epoxy system used in this study is a commercially available DGEBA-based resin (Hexion MGS L160) cured with an aliphatic amine hardener (Hexion MGS H160). The halloysite nanotube nano-reinforcements (HNTs) were provided from Eczacibasi Esan Group Company. Nanocomposites were prepared by mixing the HNT and epoxy resin with three different weight percentages (1%, 2% and 3%). The nanocomposite preparation procedures and used standards were detailed published in previous works [14, 15]. The seawater aging of the tensile and flexural test specimens was performed at room temperature by immersing into artificial seawater which was prepared by mixing the 6 wt% sea salt (salt concentration about twice the average concentration in an ocean) and distilled water.

RESULTS AND DISCUSSION

The tensile and flexural strengths of the neat epoxy and HNT modified nanocomposites (without aging) are illustrated in Figure 1a-b. It is clear that the 2 wt% HNT modification results in the highest tensile and flexural strengths. At 2 wt% HNT loading, the epoxy nanocomposite shows ~33% (from 58.83 to 78.05 MPa) and ~25% (from 97.54 to 121.68 MPa) increase in the tensile strength and flexural strength. However, we noticed that both of the tensile and flexural strengths tend to decrease with increasing HNTs content when the epoxy matrix is reinforced more than 2wt% HNT. By comparison, the HNT modified nanocomposites exhibit higher strength values than the neat epoxy over the whole filler contents studied.

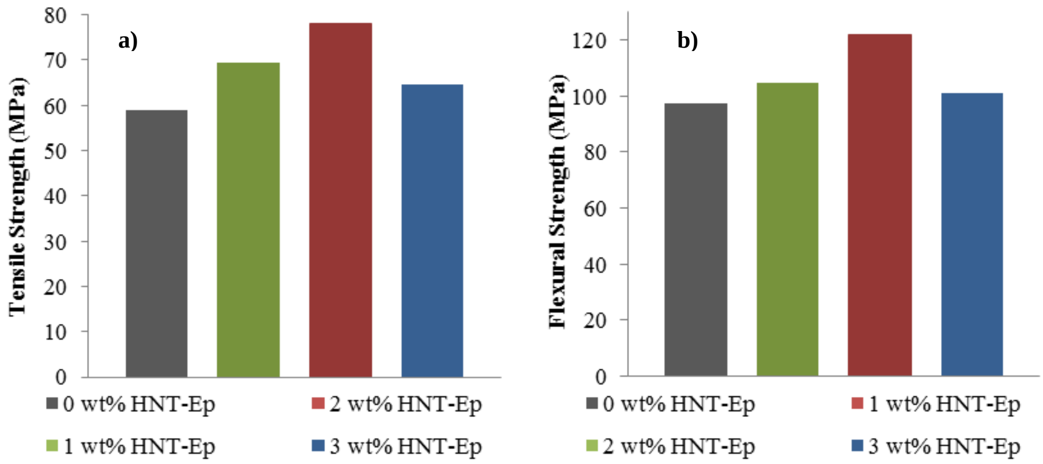

Figure 1. Neat and HNT modified epoxy composites: tensile strength (a) and flexural strength (b)

We have also investigated the impact of seawater aging on HNTs reinforced epoxy nanocomposites. Note that, our seawater experiments were carried out on room temperature with long term aging cycles to simulate natural aging medium for the samples. The mean strength and elasticity modulus values of neat and the 2 wt% HNT modified epoxy after immersed in seawater for 6 months are illustrated in Figure 2a-b. It is clear that the seawater aging causes a reduction in mechanical properties. In the case of the 2 wt% HNT-Epoxy nanocomposites, it can be seen that tensile and flexural properties less affected for all periods of ageing time. Our finding can shows that HNTs limits the diffusion of water molecules and therefore cause relatively less degradation of epoxy [16].

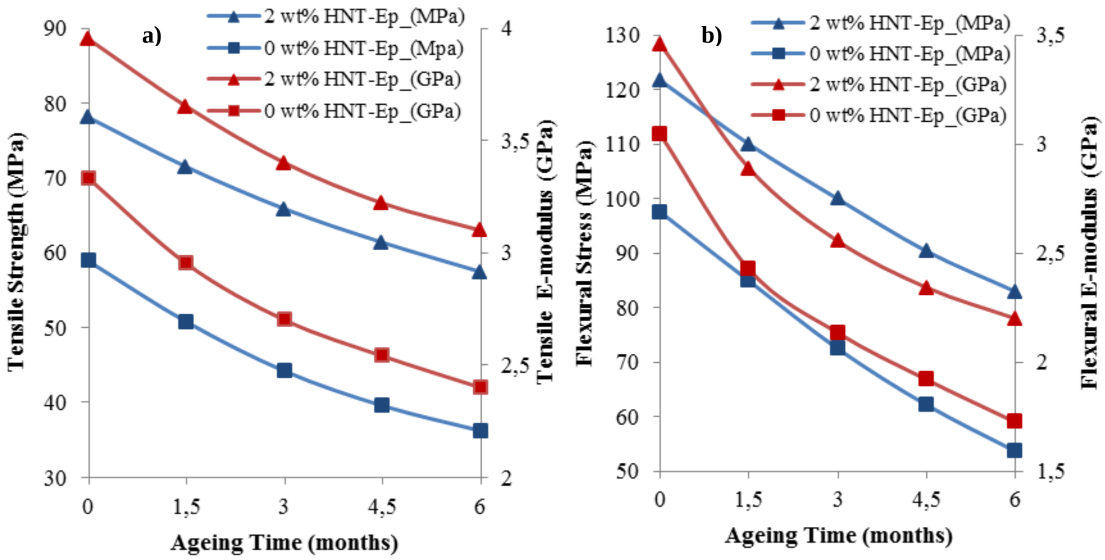

Figure 2. Seawater effect on mechanical properties of treated samples as a function of immersion time: tensile properties (a) and flexural properties (b)

The optical micrographs of fracture surfaces of the dry and water treated tensile specimens are shown in Figure 3. All specimens show different degree of surface roughness depending on immersion time. Initially for dry conditions, the surface of neat epoxy displays smooth fracture area with respect to the HNT-epoxy nanocomposites as seen. However, it is evident that the HNTs loading for epoxy modification increases the roughness of the fracture surfaces. On the other hand, the seawater immersion of epoxy induces an important increase in roughness of the fracture surface due to the plasticization effect of water [6].

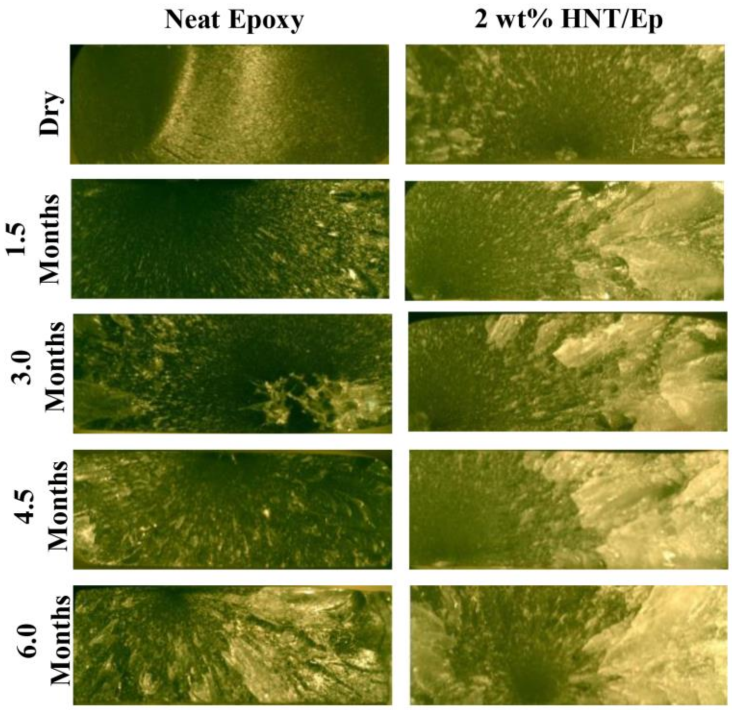

Figure 3. Fracture surface morphology changing with seawater immersion time

CONCLUSION

In this work firstly, the effect of HNT loading in epoxy resins on mechanical properties was studied. The nanocomposites made with the HNT showed dramatic improvement in mechanical properties at 2 wt% HNT loading; that is, tensile strength and flexural strength were increased by 1.32 and 1.25 times respectively over the neat epoxy properties. After the determination of optimum HNT loading (2 wt%) in terms of tensile and flexural performance, the degradation of epoxy was investigated by artificially seawater ageing conditions for 6 months. Seawater ageing resulted in degradation in the tensile and flexural properties of the neat and modified epoxy resins. However, the largest reductions are detected for neat specimens and the smallest reduction was observed in modified epoxy specimens. As a result, seawater ageing has much less severe effect on the 2 wt% modified nanocomposites rather than on the neat epoxy.

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DEVELOPMENT AND MASTERING OF THE COMPOSITION OF ELECTRODE COATINGS FOR WELDING STAINLESS STEEL

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Abstract: Development and mastering of coated electrodes for welding stainless steels involves a very complex technical - technological field and is linked to joining metal parts by welding and surfacing. The coated electrode consists of a metal wire core to which a special coating is applied. The metal core is made of the material that corresponds to the type of base material for which a certain electrode quality is designed. The coating of the electrode is a mixture of powders of mineral and metal origin and is highly important for the quality of the electrode. The paper presents the development of coating formulation for rutile and basic types of electrodes with a metal core of INOX wire 4mm in diameter and AISI 304 quality. Development and mastered formulation of electrode coatings designed for welding stainless steels.
Key words: coated electrodes, welding, stainless steels

INTRODUCTION

Electrode manufacturers allocate high-alloyed electrodes by quality and purpose into several groups: High-alloyed ferritic electrodes, high-alloyed austenitic and austenitic-ferritic electrodes, high-alloyed electrodes for welding heat resistant steels.
High-alloyed ferritic electrodes are used for welding martensitic-ferritic Cr-Ni steels and steel castings (chem. composition of pure weld metal: 0.05-0.15%C, 13-16.5%Cr, 0.5-6%Ni, 0.3-1.1%Mo). Classification: EN 1600: E 13 4 B 43 DIN 8556: E 13.4 MPB 30+130 AWS A-5.4: E 410 NiMo-15 ISO 3581: E 13.4 B 130 36 X JUS C.H3.017: E 13.4 B 130 36 Y INOX B 13/4 Fe REF. E 500- A / SP
High-alloyed austenitic and austenitic-ferritic electrodes are used for welding: stabilized and unstabilized 18/8 Cr-Ni steels, corrosion-resistant (chem. composition of pure weld metal: 0.03-0.06%C, 18-23%Cr, 8-14.5%Ni, 2.7-4%Mo, 8x%C-Nb). Classification: EN 1600: E 19 9 Nb R 12; DIN 8556: E 19.9 Nb R 26; AWS A-5.4: E 347-17; ISO 3581: E 19.9 Nb R 26; JUS C.H3.017: E 19.9 Nb R 26
High-alloyed ferritic-austenitic rutile electrode suitable for welding heat resistant steels 18/8 Cr-Ni steel, (chem. composition of pure metal: 0.03-0.11%C, 20-25% Cr, 5-25%Ni, 0-4.5%Mo, 0.6-2%Mn). Classification: EN 1600: E 25 4 R 43; DIN 8556: E 25.4 MPR 33 160; AISI: 446 ISO 3581: E 25.4 R 160 33 X; JUS C.H3.017: E 25.4 R 160 33 Y INOX R 25/4 Fe REF. E 625 - A / SP
Development and mastering of coated electrodes for welding stainless steels includes selecting and purchasing metal electrode cores of AISI 304 wire, 4mm in diameter. Designed was the formulation for making rutile and basic electrode coatings according to the quality of the selected metal core and the purpose of the high-alloyed electrode [1].

MATERIAL AND METHODS

Selection of metal cores for making coated electrodes

For making metal cores purchased was INOX AISI 304 quality wire, chemical composition shown in Table 1 according to the certificate of the manufacturers from India. Rods for making the electrode metal cores were cut to a length of 350 mm (length tolerance: +/- 1.0 mm) from INOX wire 4 mm in diameter (diameter tolerance: min. 3.90 mm; max. 3.95 mm, usually 3.93 mm).

Table 1. Marking and chemical composition of the electrode core 4 mm in diameter

Chemical composition (wt.%)								
AISI 304	C	Si	Mn	P	S	Cr	Ni	N
	0.027	0.37	1.55	0.039	0.013	18.30	8.05	0.065
Diameter: 4.0 mm	TEST CERTIFICATE (AS PER EN 10204-3.1)							

Designing formulations for basic and rutile type coatings

High-alloyed rutile electrode with low carbon content, intended for welding of high-alloyed Cr-Ni steel, Cr-Ni-Mo steel, and for welding of low-alloyed and unalloyed steels. The welds are resistant to intercrystalline corrosion up to 400°C and oxidation up to 800°C.
The design of formulations for the rutile type coating with a core of AISI 304 wire should ensure the target chemical composition of the weld metal: 0.03% C, 19% Cr, 9% Ni.
The high-alloyed basic electrode with low carbon content is intended for welding of high-alloyed Cr-Ni steels and Cr-Ni-Mo steels. Welds are resistant to crack and pore initiation and have high toughness.
The designed formulation for the basic type coating with a core of AISI 304 wire should provide the target chemical composition of the weld metal: 0.03% C, 19% Cr, 9% Ni, 0.9% Mo and 0.3% Si [1-3].

Mastering production of selected quality of high-alloyed, basic and rutile type electrodes

Experimental production of selected quality of high-alloyed, basic and rutile type electrodes was carried out on the production equipment in the IHIS Research and development center.
The technological process of making the coated electrodes is comprised of these basic technological operations:

- Composing and forming the mass of the coating and making the blocks;
- Continuous application of coating on the metal core and finishing of ends of the electrodes;
- Drying the electrodes as per a defined temperature regime.

The technological production process of coated electrodes begins by composing, weighing and forming of a batch of rutile and basic type coating according to the designed formulation.
The next technological process is homogenization of a dry mix of powders in the V-mixer for 10-15 minutes. After homogenization the mixture is transferred to a W mixer or mixer for wet-mixing of the coating mass by adding water glass as a binder. Due to viscosity the water glass should be kept at a temperature of 18-23°C.
After testing the plasticity of the mixture, in a specially made extrusion tool, a pressing operation of the mass into a coating nozzle is carried out, Figure 1. On the coating line produced is a coated electrode with rutile and basic type coating and a core of AISI 304 quality wire, 4mm in diameter, Figure 1c. Packed electrodes are shown in Figure 1e.
The coated electrode goes to a final drying technological process of electrode coating drying which is performed in a dryer at a defined temperature regime, specific for rutile and specific for basic type coatings, Figure 1d. The rutile coating contains organic matter (cellulose, starch), so the drying temperature should not be greater than 185-190°C and humidity not greater than 0.3-0.4%. The basic electrode coating is dried at a temperature of 355-365°C; humidity should not be more than 0.5-2% [4-6].

a) b) c) d) e)

Figure 1. A W-mixer for wet mixing of the coating mass (a), experimental electrode coating (b), preparing of metal core, a rod 4 mm in diameter and a length of 350 mm (c), the electrodes, after drying, (c) and samples of the electrodes after drying and packaging (d, e)

Test welding of stainless steel with the new rutile and basic type electrode

To perform the test welding and surfacing with a new electrode with rutile and basic type coating selected was a base material of AISI 304 stainless steel strips of a thickness of 15 mm. The investigation of the chemical composition of the base material and the weld metal and also hardness testing of the welded joint were done at the firm Kontrol Inspekt d.o.o. Belgrade. Results of chemical composition of the AISI 304 base material, thickness 15 mm are given in Table 2.

Table 2. Chemical composition of the base material AISI 304 quality, thickness 15mm

Chemical composition (wt.%)										
C	Si	Mn	Cu	Cr	Mo	Ni	V	Nb	Ti	Co
0.049	0.49	1.08	0.55	17.74	0.27	8.19	0.073	0.02	0.28	0.14

Test welding and surfacing with a produced electrode with a rutile type coating was carried out on the ESAB DTB 250 AC-DC device, Figure 2, with the parameters given in Table 3.

a) b)

Figure 2. The ESAB DTB 250 AC-DC device for experimental MMA- process welding with a new electrode

Table 3. Rutile electrode welding parameters

Electrode marking	d [mm]	Welding parameters		
		V, [V]	C, [A]	*в*, [cm/min]
Rutile	4.0	24	110-165	23-30

Welding with a rutile electrode with the new coating formulation gives a good quality of slag and its separation from the weld face after cooling as well as a satisfactory weld metal surface quality, Figure 3a, b, c, d.

a) b) c) d)

Figure 3. Surface appearance of the surfacing obtained experimentally by surfacing AISI 304 stainless steel with the new rutile electrode

Experimental welding with the new basic electrode intended for welding of stainless steels was performed with the ESAB DTB AS 250-DS device and parameters given in Table 4.

Table 4. Parameters for welding with the new basic electrode

Electrode marking	d [mm]	Welding parameters		
		V, [V]	C, [A]	*в*,[cm/min]
Basic	4.0	24	110-140	23-30

The mastered formulation for the coating of the basic electrode with a core of AISI 304 quality wire provides a good quality of weld metal, and the slag forms evenly over the surface of the weld metal and separates well. The appearance of the weld face is of a satisfactory quality, Figure 4 a, b.

a) b)

Figure 4. Experimental surfacing of AISI 304 stainless steel using MMA-process with the basic electrode

RESULTS AND DISCUSSION

In addition to visual control and quality evaluation of the surfacing made with the produced high-alloyed rutile and basic electrodes carried out was the examination of the chemical composition and hardness of weld metal made with the rutile and basic electrodes [2-6].
Test results of the chemical composition of pure weld metal and hardness as per the Brinell test (BH) made by using the produced rutile electrode are given in Table 5.

Table 5. The chemical compositions of pure weld metal made using the rutile electrode

Chemical composition (wt.%)										
C	Si	Mn	Cu	Cr	Mo	Ni	V	Ti	Nb	Co
0.071	0. 46	1.60	0.30	15.17	0.21	9.34	0.079	0.30	0.05	0.18
• Surfacing hardness 151 BH										

Test results of the chemical composition of pure weld metal and hardness as per the Brinell test (BH) made by using the produced basic electrode are given in Table 6.

Table 6. The chemical compositions of pure weld metal made using the basic electrode

Chemical composition (wt.%)										
C	Si	Mn	Cu	Cr	Mo	Ni	V	Ti	Nb	Co
0.068	0. 40	1.52	0.30	15.23	0.21	9.16	0.080	0.02	0.05	0.18
• Surfacing hardness 136 BH										

CONCLUSION

Based on the obtained results of experimental surfacing, of high-alloyed AISI 304 stainless steel made with the mastered rutile and basic type electrodes, reliable conclusions can be made:

- The mastered formulation for coating of rutile and basic type coated electrodes for welding AISI 304 stainless steels shows a satisfactory level of quality and the designed chemical composition of the weld metal;
- The quality of the electric arc and liquid metal transfer is of satisfactory quality;
- Distribution of slag on the surface of the weld metal is good and it separates well from the surface after cooling of the weld metal;
- The surface quality of the weld metal after cooling and removing of slag is satisfactory;
- Splatter of liquid metal in comparison to using electrodes of a known manufacturer demonstrates satisfactory results.

- The mastered formulations for rutile and basic type coatings is a good basis for further successful development of the coating formulation as well as other metallurgical qualities of coated electrodes intended for welding high-alloyed steels and alloys.

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DETERMINING ADHESION / COHESION STRENGTH OF PLASMA SPRAY COATINGS USING THE ROCKWELL - C METHOD

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Abstract: The plasma spray coatings are subject to high influence of surface loads, corrosion, and temperatures which cause damage in the form of separation of the coating from the substrate or flacking of the coating from the substrate edges. Adhesion is the main factor that opposes the influence of the external loads, and defines the quality of the bond of the coating with the substrate. Each type of coating has a determined quality of adhesion as per appropriate standard in order to meet functional properties during operation.
There is no universal coating test for all types of the coatings, the test is chosen depending on the technology used for the production of the coating, the type of material from which it was made and its thickness. One of the many tests that are used for assessment of adhesion / cohesion strength of plasma spray coatings is the scratch test. The aim of this paper was to evaluate the cohesive / adhesive strength of the plasma spray Ni22Cr10Al1Yalloycoating. The testing was conducted using the Rockwell C diamond indenter with a tip radius of 200 µm. The results showed that the scratch test is an efficient method for assessment of adhesion and cohesion of plasma spray coatings.
Keywords: plasma spray coatings, Ni22Cr10Al1Y, scratch test, adhesion strength, cohesion strength

INTRODUCTION

For testing adhesion / cohesion strength of thin and thick coatings a large number of laboratory tests are standardized [1], [2], [3]. The scratch test is a reliable and simple method for determining the coating adhesion bond strength with the substrate. In order for the inorganic oxide ceramics and the organic HA - hydroxyapatite ceramics to be used as functional biomedical coatings on a substrate, the deposited layers of the ceramic coatings must be without defects and detailed adhesion / cohesion strength tests must be performed. For testing the adhesion of coatings using the scratch method used is a micro scratch tester and a nano scratch tester. The micro scratch device uses a Rockwell C diamond with a radius of: 10, 20, 50, 100, 200, 400, 800 µm and the nano scratch device uses a spherical diamond with a radius of: 1, 2, 5, 10, 20 µm (a = 90 ° or 60 °). Most commercial devices use the Rockwell C diamond indenter with a tip radius of 200 µm. This indenter has been used for years for examining the adhesion of coatings a thickness of 0.1 - 30 µm by scratching the surface of the coating. The same indenter can be used for testing thicker plasma spray coatings by scratching the coating surface on the cross section. Depending on the type of the coating material and its thickness other types of indenters may be used, [1]. Adhesion testing of thicker plasma spray coatings is carried out on the polished cross-sectional surface of the sample. Due to the availability of the diamond Rockwell C device with a radius of 200 µm and the simplicity of the test it is frequently used to determine the adhesion of plasma spray coatings. In addition to the normal Fn force in the course of testing the depth of penetration of the indenter and the force of friction can also be determined. The acoustic signal detector is placed above the diamond indenter (needle) and registers the vibrations which occur on the emergence of damage. In addition to the acoustic sensor, the device has sensors that register friction force. The movement of the indenter along the sample leads to the formation of different damages depending on: the stress at the interface, the cohesion strength between the lamellae, the share and size of the micro pores, the presence of unmelted particles, micro-cracks, oxides, micro-hardness and the value of the applied Fn force. Due to the simplicity of the test, the scratch test is very suitable for

optimization of the plasma spray powder deposition parameters in order to produce a coating with optimal mechanical and structural properties, [1].
This paper analyzes the assessment of the adhesion / cohesion strength of plasma spray VPS - Ni22Cr10Al1Y coating using the scratch test on the cross section of the coating, using bulletins describing the screening procedure [4]. For scratch testing used was the plasma spray Ni22Cr10Al1Ycoating deposited on an INCONEL X-750 alloy substrate 20x10x5 mm in size. The results showed that the method is effective and the values were discussed.

MATERIALS AND EXPERIMENTAL DETAILS

For the production of the coating,the powder AMDRY mark 9624 wasused,which is an alloy of nickel with a content of 22 wt% Cr, 10 wt% Al and 1 wt% Y. The powder had a range of granulation from 11 to 37µm, [5]. The deposition of the powder was carried out at low pressure with the vacuum plasma spray system of the company Plasma Technik AG using the control board A-2000 and the F4 plasma gun. As the plasma gas a mixture of Ar / H2 gases was used. Prior to deposition of the powder, cleaning and preheating of the surface of the substrate made of INCONEL X-750 alloy was carried out by transferred arc at a temperature of 850°C [6]. To assess the adhesion / cohesion coating strength using the scratch test, the coating layers were deposited on a sample of the alloy INCONEL X-750 dimensions of 20x10x5 mm. The test specimen was prepared by cutting, grinding and polishing, as in the hardness test, and the scratch load was conducted on the cross section of the sample that was mounted in bakelite. Scratching was conducted using the Rockwell Cmethod with a diamond indenter with a radius of 200 µm with a normal Fnforce, [4]. During the trials, the diamond indenter was moving at a constant speed over the surface of the sample in the direction from the substrate to the interface with the coating and the surface of the coating, as shown schematically in Fig.1.

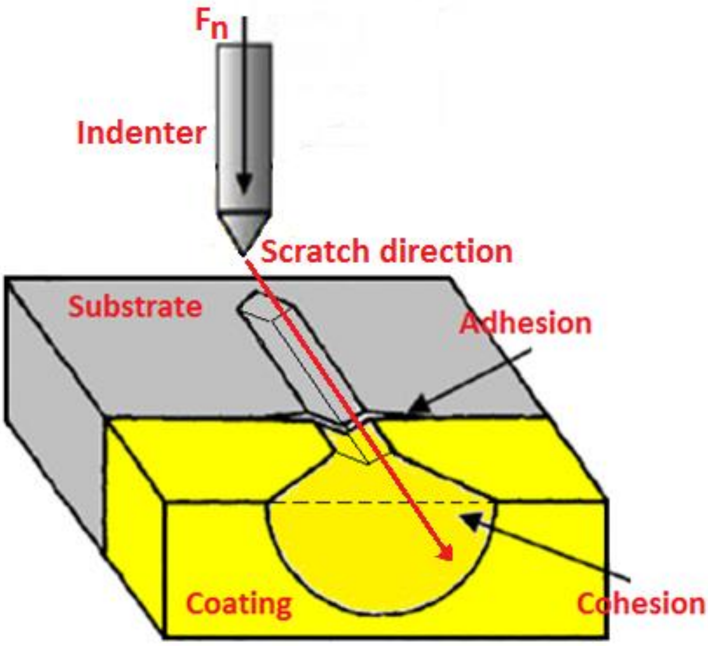

Figure 1. A schematic representation of the scratch test

For the tests used were three different normal Fnforces (10, 25, and 39 N) at a constant speed of the indenter of 1 mm / min. For all the loads applied thelength of scratches was 0.7 mm. The geometry of the indented coating was different and under the influence of the applied normal Fnload.

RESULTS AND DISCUSSION

The microstructure of the Ni22Cr10Al1Y coating deposited in a vacuum was quite homogeneous with a good bond to the substrate. The results obtained by scratch testing show good adhesion and cohesion of the coating for the applied load, as shown in Fig. 2. For the indent made with 10N observed was that the stresses entered with normal Fn force together with residual stresses in the coating did not cause any changes on the interface, such as micro-cracks or plastic deformation of the substrate or coating, as can be seen in Fig. 2b). With increasing the load to 25N changes occur on the interface and coating layers. The channel made with the indenter is wider than the width of the channel made with a load of 10N. Increased stress together with the residual stresses in the interface area cause plastic deformation of the substrate and coating.

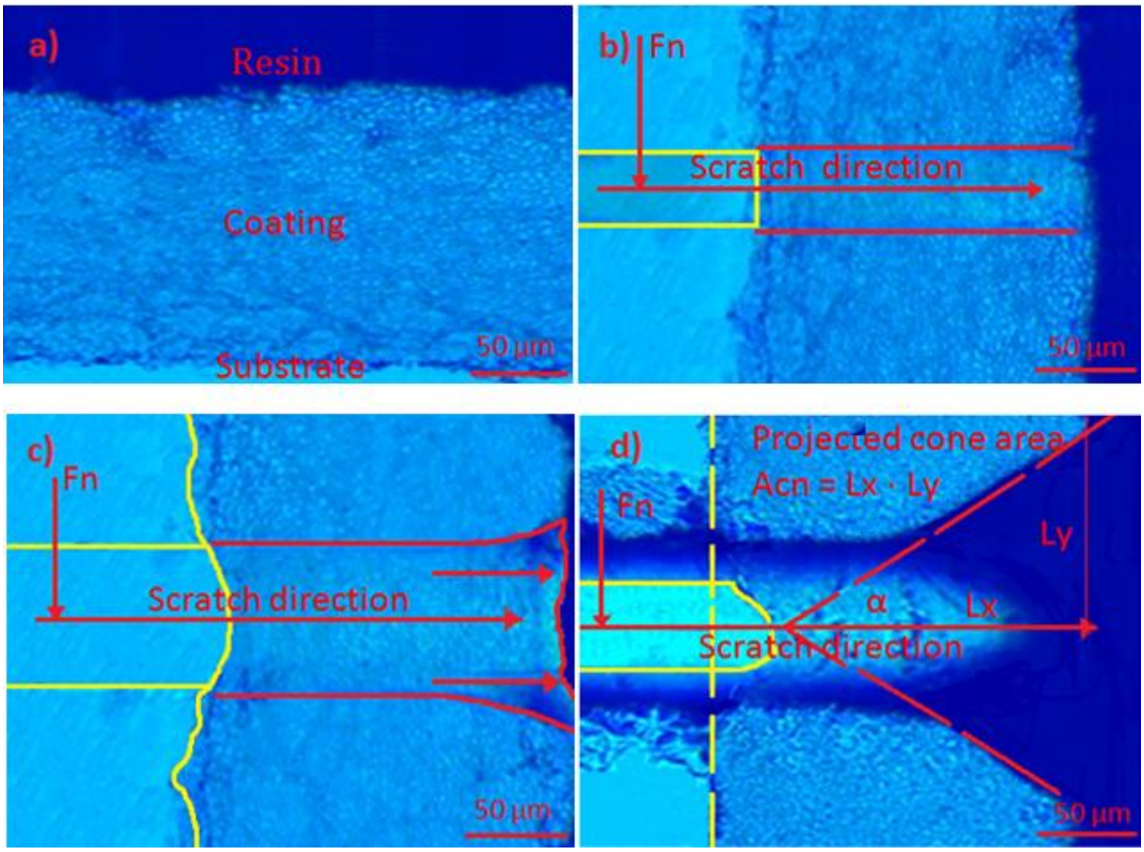

Figure 2. BM microstructure: a) NiCrAlY coating; b) the surface scratch with a load force of 10N; c) the surface scratch with a load force of 25N and d) the surface scratch with a load force of 39N.

The material of the substrate with the primary γ-phase due to plasticity penetrates into the coating in the direction of the normal Fn force, which also plastically deforms the coating which has the same basic structure with the γ-phase. Due to the plastic deformation in the area of the interface and the coating micro or macro cracks do not appear. On the surface of the coating, as a result of the highest stress condition a highest degree of plastic deformation is observed, cone shaped, as shown in Fig. 2c).As the normal Fn force increases to 39N in the interface area the degree of plastic deformation of the substrate and coating increases. On the interface no crack appears indicating very good adhesion strength caused by good adhesion of coating to the substrate. The surface of the formed cone is a function of the load, and its value depends on: the residual stress in the coating layers, coating toughness, hardness and microstructure of the coating. To a certain degree of normal load Fn for materials that are plastic, such as the NiCrAlY alloy characteristic is a linear increase of the longitudinal parts of the cones indicating a good inter-lamellar bond and a good bond of the layers, which are deposited layer by layer to the formation of the final coating thickness. At one point, with an increase of the normal load Fn the stress in the coating exceeds the plastic deformation, and causes the appearance of a cone shaped crack in the coating which extends in the direction of movement of the indenter from the deeper layers of the coating to the surface of the coating. The formed cone surface is calculated as the product of the lengths derived by the equation $A_{cn} = L_x \cdot L_y$, as shown in the Figure 2d). The formed crack in the shape of a cone with a surface of A_{cn} is the main factor for assessing the adhesion / cohesion strength of the coating. The surfaces of the cones or plastic deformation of the material of the substrate and the coating which occur during the test at the substrate / coating interface characterize the coating adhesion and the cone shaped fractures in the coating characterize the coating cohesion. The larger the cone shaped fracture surface, the lower the bond strength of the coating. This is a basic factor for optimizing powder deposition parameters. In the tested coating the cone shaped fracture occurred within the coatings, but not at the interface, which indicates good adhesion and a cohesion fracture caused by the stress state of the layers in the deposited coating.

CONCLUSION

Based on the performed scratch test characterization of plasma spray VPS-Ni22Cr10Al1Ycoatingthe following conclusion can be made:
The scratch test as a mechanical method of testing coatings confirmed that it can be successfully applied for this type of material for the assessment of adhesion / cohesion strength, as expected based on set procedures and standards.
The test analysis shows good adhesion of the coating because at the substrate / coating interface plastic deformation of the substrate and the coating occurred instead of the creation of micro cracks.
The results showed that the scratch test can be successfully used as an effective method for assessing the cohesion of plasma spray coatings.

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DYNAMOMETRIC PROVING RING WITH NONCONSTANT GEOMETRICAL CHARACTERISTICS OF ITS CROSS-SECTIONS

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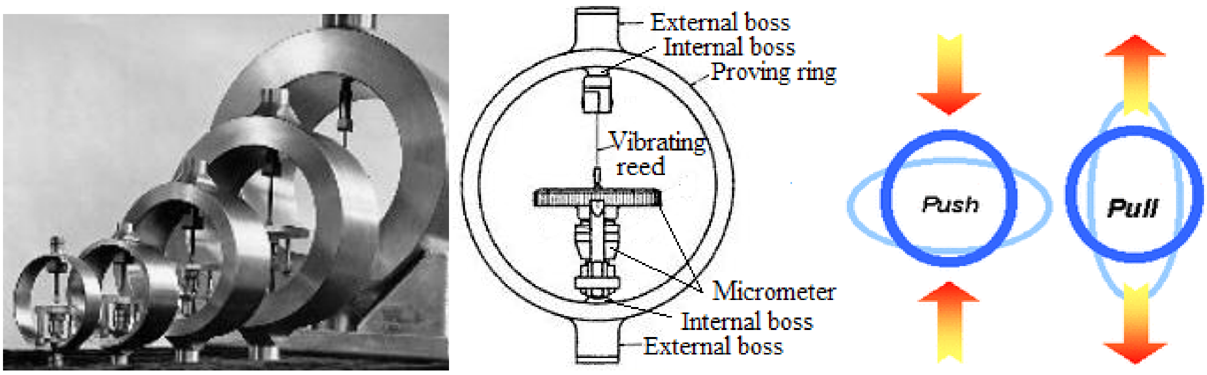
Abstract: This work presents the work of studying separately by means of a theoretical approach and by means of three dimensional modeling (by CAD) of the characteristic - diametrical deformation depending on the diametrical load of a dynamometric ring whose cross-section is not constant in its geometry. The way to obtain this dependence through the theoretical approach is demonstrated by applying the method of numerical integration of the expressions obtained by applying the second Castigliano's theorem in order to find the displacement of the point of application of concentrated force in the direction of its line of action. Also given are the results of the simulation loading of the 3-D model of the investigated ring. Finally, these all results are compared with the experimental ones and some conclusions are made.
Key words: proving ring, deflection characteristic with respect to applied force, Castigliano's second theorem

INTRODUCTION

It is well known that dynamometric proving rings are devices for measuring forces [1]. The dynamometric rings are of different sizes [2] (figure 1a). They are made of alloy steel and their production includes rough machining of forged blanks, thermo-treatment and precise grinding to the final size and roughness of their surfaces. In general every such device consists of two main elements, the elastic ring itself and the diameter-measuring system located in the center of the ring [1][2]. Forces are applied to the ring through the external bosses. The resulting change in diameter, referred to as the deflection of the ring, is measured with a measuring system presented here (Figure 1 b) by a precision micrometer and the vibrating reed mounted diametrically within the ring. The concept and design [1] of proving rings (Figure 1-b) were created originally by Whittmore and Petrenko at the (US) National Bureau of Standards (now called the National Institute of Standards and Technology). To measure the diameter of the ring, the reed is inserted into the vibration mode by tapping it with a pencil slightly. As the reed vibrates, the micrometer screw is adjusted until the tip of the spindle begins to touch the free end of the vibrating reed by extinguishing vibrations. The touch generates a buzzing sound [2], and this is the time to take into account the change of the diameter of the ring. This technique provides repetitive and stable indications with an accuracy of about 1 ÷ 2μm [3]. Nowadays, in the newer systems with dynamometric proving rings, the micrometer and the reed after Whittmore&Petrenko's design are replaced by a built-in metering dial indicator, by a set of electrical resistive strain gauges using a Wheatstone bridge, or by a video camera and software for ring size measurement.



a b c

Figure 1. a) Proving rings in a variety of sizes; **b)** Schematic of a proving ring having external bosses for attachment and internal bosses and the precision deflection-measuring system presented with a micrometer and a vibrating reed; **c)** Proving ring deflections at compression or tension forces.

The proving rings (Figure 1-c) can be used and can be designed to measure compressive forces, tensile forces, or both types of forces. In particular, the tensile force measuring rings [2] are most often made with external threaded bosses and are provided with pulling rods which are screwed into the bosses. Typically, the proving rings are designed to have a deflection of about 0.84 mm to 4.24 mm and are designed in such way to have the relative measurement uncertainty from 0.075% to about 0.0125%.
When loading with the forces for measuring in the rings internal forces arise - bending, shearing and tension, which change along the circular perimeter of the rings. These internal forces can be determined by applying the so-called general theorems of Strength of Materials (e.g. of Castigliano and this of Menabrea) [4], [5], [6]. For example, at load of a thin circular ring according to Figure 2-a, the diagrams of distribution of normal internal force, tangential internal force, and bending moment will respectively be as shown in Figure 2-b, Figure 2-c and Figure 2-d (see [6], page 533).

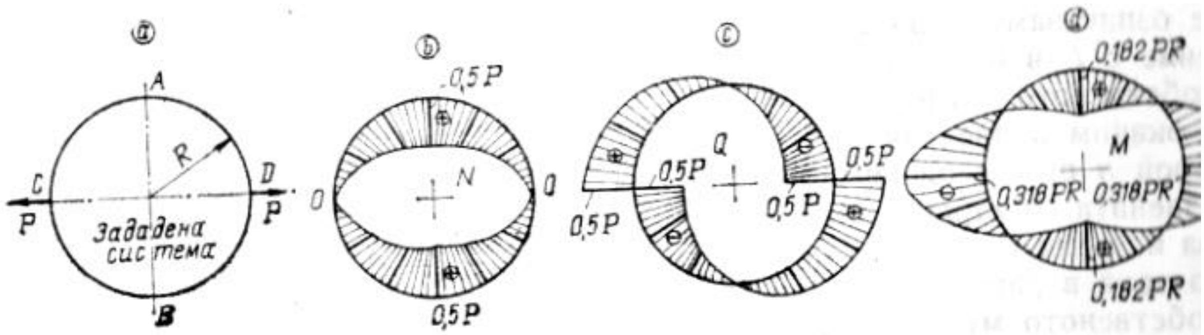
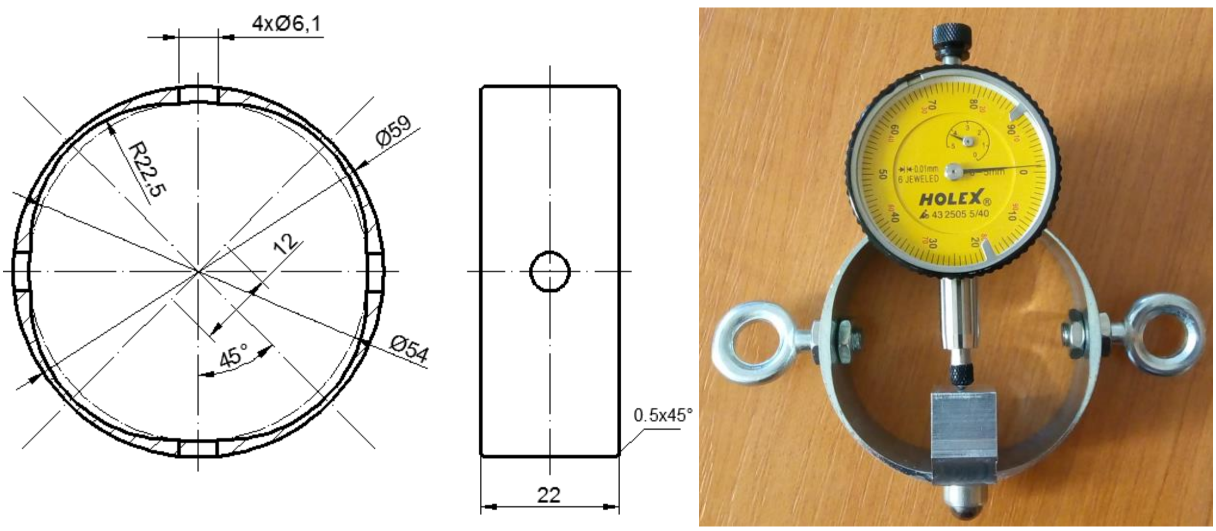


Figure 2. Thin planar circular ring [6, page 533] a) Load scheme; b) Diagram of distribution of the normal internal force; c) Diagram of distribution of the tangential internal force; d) Bending moment distribution diagram.

It is stated in the literature that the bending moment is decisive both for the strength ([7], page 89) and for the magnitude of the deformation ([5], page 170), whereas the influence of the other two internal forces (normal and tangential) is negligible. As the bending moment changes (as it could be seen from its diagram of distribution- Figure 2-d) under a certain periodic law on the circumference of the ring, it could be applied the principle of designing with the uniform strength. According this principle the geometric resistivity characteristics (section modules) of the cross-sections of the ring should be designed to be proportional (on permissible structural degree) to their corresponding internal forces (in this case the bending moment). In the case of a circular proving ring, the maximum bending moments are in the cross-sections passing through the line of applying of the measured two opposing forces as well as through the perpendicular of that direction (see Figure 2-d), whereas the bending moments in the segments of the ring between these two directions are minimal.



a) b)

Figure 3. Design sketch (a) and realization (b) of a dynamometric proving ring.

This gives rise to the idea of constructing and testing a force measuring ring (Fig. 3) with non-uniform cross-section, which under conditions of guaranteed strength provides greater elastic flexibility of the ring and hence its greater sensitivity as a measuring element. Similar designs are known in the literature [8]. In the design under consideration, the aim is to create an elastic element composed of simple and technologically easy to implement surfaces - cylindrical and planar.
In this work are presented the theoretical and model 3D-CAD characteristics of the investigated dynamometric ring and these characteristics are compared with each other and then they are compared to experimentally obtained one.

THIN PROVING RING WITH CONSTANT CROSS SECTION

Internal forces induced by load with diametrical compressive forces

By the name "thin ring" is meant a ring (Figure 4-a) whose dimensions of the cross-section (h = 2.5 mm) in radial direction are negligible in comparisone to the diameter (∅59 mm), and under a ring with constant (or invariable) cross-section is meant a ring, whose cross-section has constant dimensions (here h = 2.5 mm and b = 22 mm). The proving ring has to bear load both compressive and tensile . In here case, let the load is with two equal opposite compressive diametral forces. To determine the internal forces and the elastic characteristic "Diametral deflection - Load", the general theorems from Strength Of Materials can be used - the Castigliano's second theorem which state that first partial derivative of the total internal energy in the structure (in case here - the proving ring) with respect to the force applied at any point is equal to the deflection at the point of application of that force in the direction of its line of action and the Menabrea theorem that the first partial derivative of potential energy U of a elastic body with respect to statically indeterminate in internal force (in case here - the bending moment X1) is zero (Eq.1)(because internal forces do not carry out any work).

$$(\delta U/\delta X_1) = 0 \tag{1}$$

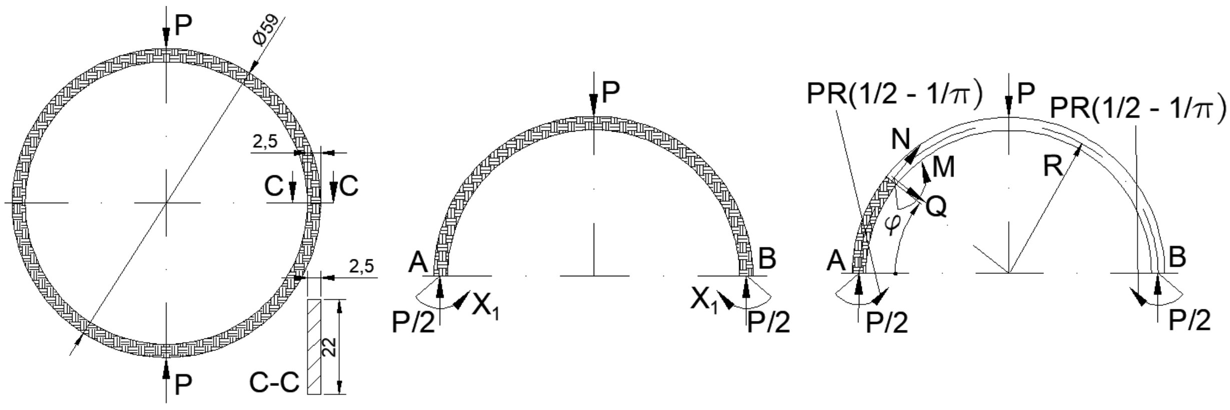


Figure 4. Thin ring: **a)** Dimensions and load scheme; **b)** Scheme for determining of the staticaly undetermined bending moment X1; **c)** Scheme for determining the internal forces (normal force N, tangential force Q and bending moment M) with respect to the angular coordinate of cross-section φ.

The thin ring (Figure 4-a) is a closed planar contour and is three times statically indetermined [6, page 532] and has two planes of symmetry, both - the horizontal and the vertical (the last is where the two compressive forces P act). If the ring is cut off in the horizontal plane of symmetry and the equilibrium of the upper half (Figure 4-b) is checked, then in the cross-sections (left A and right B) the tangential efforts will be zero because they are antisymmetrical [6, page 524] [5, page 209]. Again, from symmetry with respect to the vertical plane in which the forces P act, it follows that $N_A = N_B = P / 2$ and $M_A = M_B = X_1$. Unknown here will be the moments in cross-sections A and B, denoted by X_1. When considering the equilibrium of the shaded part (Fig. 4-c), the internal forces (normal N, tangential Q and bending moment M) can be expressed in any section as functions of the angular coordinate φ (R is the mean radius of the cross-sections):

$$\Sigma F_{ix} = N + (P/2).\cos\varphi = 0 \quad \therefore\rightarrow \quad N = N(\varphi) = -(P/2).\cos\varphi \tag{2}$$

$$\Sigma F_{iz} = Q - (P/2).\sin\varphi = 0 \quad \therefore\rightarrow \quad Q = Q(\varphi) = (P/2).\sin\varphi \tag{3}$$

$$\Sigma M_{iy} = M - (P/2).(R - R.\cos\varphi) + X_1 = 0 \quad \therefore\rightarrow \quad M = M(\varphi) = -X_1 + (PR/2).(1-\cos\varphi) \tag{4}$$

The expression of the potential energy of the defformed elastic ring with an unchangeable cross-sections is given by (5) where: F is the cross-sectional area, E - the modulus of elasticity of the ring's material, G - the modulus of the angular deformations of the material, J – the moment of inertia of the cross-section of the ring, k - characteristic constant [6, page 303] of the cross-section which is related to calculating the potential energy of the deformation caused by the tangential internal force Q:

$$U = 4.\{ \int_0^{\pi/2} [N(\varphi)^2/(2.E.F)].R.d\varphi + \int_0^{\pi/2} [k.Q(\varphi)^2/(2.G.F)].R.d\varphi + \int_0^{\pi/2} [M(\varphi)^2/(2.E.J)].R.d\varphi\} \tag{5}$$

In (5) the integration is performed from 0 to $\pi/2$ radians for one of four similar arcs (all equal to a quarter of a full circle) of the ring and then the result is multiplied by a factor of 4 to obtain the potential energy of the entire ring deformation. For the determination of X_1 he theorem of Menabrea (1) is used, according to which (2), (3), (4) and (5) is obtained (in (6) it should take into account that the partial derivative $\delta M(\varphi)/\delta X_1 = -1 \neq 0$, but $\delta N(\varphi)/\delta X_1 = 0$ and $\delta Q(\varphi)/\delta X_1 = 0$):

$$(\delta U/\delta X_1) = 4. \int_0^{\pi/2} (1/EJ).M(\varphi).(\delta M(\varphi)/\delta X_1) = (4/EJ)\int_0^{\pi/2} (-X_1 + (PR/2).(1-\cos\varphi))(-1)R.d\varphi = 0 \tag{6}$$

,where E = const and J = const. From equation (6) for X_1 is obtained:

$$X_1 = (PR).(1/2 - 1/\pi) \tag{7}$$

Thus the function of the change of the bending moment M from (4) is obtained:

$$M = (PR/2).(2/\pi - \cos\varphi) \tag{8}$$

Characteristic - deflection of the ring's diameter with respect of the applied load P

After obtaining the expressions of the internal forces N, Q and M as functions of the parameter φ in analytical form, the determination of the diameter deflection's (Δ) dependence to the applied load (P) is performed by applying the Castigliano's second theorem [6, page 488], taking into account that $\delta N/\delta P = -(1/2).\cos\varphi$, $\delta Q/\delta P = (1/2).\sin\varphi$ and $\delta M/\delta P = (R/2).(2/\pi - \cos\varphi)$ in the expressions below:

$$\Delta = \delta U/\delta P$$

$$=4.\{\int_0^{\pi/2}[N(\varphi)/(E.F)].(\delta N/\delta P).R.d\varphi+\int_0^{\pi/2}[k.Q(\varphi)/(G.F)].(\delta Q/\delta P).R.d\varphi+\int_0^{\pi/2}[M(\varphi)/(E.J)].(\delta M/\delta P).R.d\varphi\}$$

$$\begin{aligned} &= 4.\{[(P.R)/(4.E.F)].\int_0^{\pi/2}\cos^2(\varphi).d\varphi \\ &\quad + [(P.k.R)/(4.G.F)].\int_0^{\pi/2}\sin^2(\varphi).d\varphi \\ &\quad + [(P.R^3)/(4.E.J)].[(4/\pi^2).\int_0^{\pi/2}d\varphi - 2.(2/\pi).\int_0^{\pi/2}(\cos\varphi).d\varphi + \int_0^{\pi/2}(\cos^2\varphi).d\varphi]\} \end{aligned} \tag{9}$$

Or:

$$\Delta = (\pi/4).[R/(E.F)].P + (k.\pi/4).[R/(G.F)].P + (2/\pi + \pi/4 - 4/\pi).[R^3/(E.J)].P \tag{10}$$

The first two addends in (10) generated from N and Q are negligible with respect to the third addend, which is derived from the contribution of the bending moment M, and therefore we can assume that:

$$\Delta \approx (2/\pi + \pi/4 - 4/\pi).[R^3/(E.J)].P = (0.14877839).[R^3/(E.J)].P \tag{11}$$

This result gives the relationship between the deflection Δ of the diameter of the ring and the applied force P in analytical form and overlaps with the results in [4, page 24], [6, page 508]. The reciprocal of (11) will be the elastic characteristic "Load P - Diameter Change (Deflection) Δ".

THIN PROVING RING WITH NON-CONSTANT CROSS-SECTION

Internal forces induced by load with diametrical compressive forces

Again under the name thin ring is meant a ring (Figure 3-a) whose dimensions in the radial direction of the cross-section are negligible in relation to its diameter. Here, however, the ring has a non-constant cross-section because, although the width b = 22 mm is constant, the other dimension - the thickness h varies from 1 to 2.5 mm through a 90° angle. In addition, this ring has 4 holes ∅6.1 mm (two vertical and two horizontal) to fastening the force-receiving elements, which also cause a non-constant cross-section. Again, to determine the internal forces and the elastic characteristic "Diameter's Deflection Δ - Applied Force P" at load with two opposite, compressive and equal diametrical forces, the general theorems from Strength of Materials are used - the Castigliano's second theorem and the Menabrea theorem. Here again the expressions for the internal forces (normal N, tangential Q and bending moment M) in the cross-section with the angular coordinate φ (it can be used again Figure 4-c) can be given with the expressions (2), (3) and (4), but the mean cross-sectional radii R = R (φ) and axial moment of inertia of the cross-section J = J (φ) are no longer constants, but they change with respect of φ. This makes it practically impossible to solve analytically way the integrals from (6) for determining the moment X_1 in the cross-sections A and B and the integrals from (9) for determining the deflection Δ of the diameter. For this a numerical integration by means of trapezium rule was applied here using the Microsoft Excel program (Figure 5), with predefined characteristics R = R (φ) and J = J (φ) at a step of an interval of a δφ = 5° angle step.

	A	B	C	D	E	F	G	H	I	J
1										
2										
3	fi [deg]	fi [rad]	Rs [m]	Rb [m]	Rav [m]	h [m]	b [m]	J [m^4]	fi cp[rad]	Jcp [m^4]
4	0	0	0.027	0.0295	0.02825	0.0025	0.016	2.08E-11		
5	5	0.087266	0.027	0.0295	0.02825	0.0025	0.01859	2.42E-11	0.043633	2.25E-11
6	10	0.174533	0.02715	0.0295	0.028325	0.00235	0.022	2.38E-11	0.1309	2.4E-11
7	15	0.261799	0.027495	0.0295	0.028498	0.002005	0.022	1.48E-11	0.218166	1.93E-11
8	20	0.349066	0.027795	0.0295	0.028647	0.001705	0.022	9.09E-12	0.305433	1.19E-11
9	25	0.436332	0.028045	0.0295	0.028772	0.001455	0.022	5.65E-12	0.392699	7.37E-12
10	30	0.523599	0.028242	0.0295	0.028871	0.001258	0.022	3.65E-12	0.479966	4.65E-12
11	35	0.610865	0.028385	0.0295	0.028942	0.001115	0.022	2.54E-12	0.567232	3.1E-12
12	40	0.698132	0.028471	0.0295	0.028985	0.001029	0.022	2E-12	0.654498	2.27E-12
13	45	0.785398	0.0285	0.0295	0.029	0.001	0.022	1.83E-12	0.741765	1.92E-12
14	50	0.872665	0.028471	0.0295	0.028985	0.001029	0.022	2E-12	0.829031	1.92E-12
15	55	0.959931	0.028385	0.0295	0.028942	0.001115	0.022	2.54E-12	0.916298	2.27E-12
16	60	1.047198	0.028242	0.0295	0.028871	0.001258	0.022	3.65E-12	1.003564	3.1E-12
17	65	1.134464	0.028045	0.0295	0.028772	0.001455	0.022	5.65E-12	1.090831	4.65E-12
18	70	1.22173	0.027795	0.0295	0.028647	0.001705	0.022	9.09E-12	1.178097	7.37E-12
19	75	1.308997	0.027495	0.0295	0.028498	0.002005	0.022	1.48E-11	1.265364	1.19E-11
20	80	1.396263	0.02715	0.0295	0.028325	0.00235	0.022	2.38E-11	1.35263	1.93E-11
21	85	1.48353	0.027	0.0295	0.02825	0.0025	0.01859	2.42E-11	1.439897	2.4E-11
22	90	1.570796	0.027	0.0295	0.02825	0.0025	0.016	2.08E-11	1.527163	2.25E-11
23										
24										
25	dfi [rad]=	0.087266								
26	X1 за P=1	0.004604								

	K	L	M	N	O	P	Q	R	S	T	U	V
1	I1		I2		I3					IntM1	IntM2	IntM3
2												
3		Rav/J [cp]		Rav*cosFi/J		COS(fi)	COS^2(fi)	SIN^2(fi)	R^3(fi)/J(fi)			
4		1.36E+09		1.36E+09		1	1	0	1082172.75			
5	110090093	1.17E+09	3.1100E+06	1.16E+09	3.1046E+06	0.996194698	0.992403877	0.007596123	931402.0441	4.55304E-08	4.28579E-07	4.27
6	102868255	1.19E+09	2.9099E+06	1.17E+09	2.8821E+06	0.984807753	0.96984631	0.03015369	955134.9436	4.25437E-08	4.0154E-07	3.9
7	136149990	1.93E+09	3.8710E+06	1.86E+09	3.7669E+06	0.965925826	0.933012702	0.066987298	1567262.79	5.63082E-08	5.3688E-07	5.0
8	221653412	3.15E+09	6.3372E+06	2.96E+09	6.0179E+06	0.939692621	0.883022222	0.116977778	2585165.763	9.16702E-08	8.83824E-07	7.97
9	359551135	5.09E+09	1.0328E+07	4.61E+09	9.4917E+06	0.906307787	0.821393805	0.178606195	4213909.181	1.48701E-07	1.44715E-06	1.22
10	567093314	7.91E+09	1.6351E+07	6.85E+09	1.4417E+07	0.866025404	0.75	0.25	6590382.08	2.34535E-07	2.29964E-06	1.78
11	841301058	1.14E+10	2.4325E+07	9.32E+09	2.0392E+07	0.819152044	0.671010072	0.328989928	9527994.039	3.47941E-07	3.43072E-06	2.41
12	1129297712	1.45E+10	3.2712E+07	1.11E+10	2.5822E+07	0.766044443	0.586824089	0.413175911	12188147.4	4.67049E-07	4.62217E-06	2.88
13	1323185463	1.58E+10	3.8363E+07	1.12E+10	2.8208E+07	0.707106781	0.5	0.5	13303090.91	5.47236E-07	5.42568E-06	2.93
14	1323185463	1.45E+10	3.8363E+07	9.32E+09	2.5947E+07	0.64278761	0.413175911	0.586824089	12188147.4	5.47236E-07	5.42568E-06	2.48
15	1129297712	1.14E+10	3.2712E+07	6.52E+09	2.0033E+07	0.573576436	0.328989928	0.671010072	9527994.039	4.67049E-07	4.62217E-06	1.7
16	841301058	7.91E+09	2.4325E+07	3.95E+09	1.3219E+07	0.5	0.25	0.75	6590382.08	3.47941E-07	3.43072E-06	1.01
17	567093314	5.09E+09	1.6351E+07	2.15E+09	7.6808E+06	0.422618262	0.178606195	0.821393805	4213909.181	2.34535E-07	2.29964E-06	5.10
18	359551135	3.15E+09	1.0328E+07	1.08E+09	4.0474E+06	0.342020143	0.116977778	0.883022222	2585165.763	1.48701E-07	1.44715E-06	2.24
19	221653412	1.93E+09	6.3372E+06	4.99E+08	1.9678E+06	0.258819045	0.066987298	0.933012702	1567262.79	9.16702E-08	8.83824E-07	8.67
20	136149990	1.19E+09	3.8710E+06	2.07E+08	8.7657E+05	0.173648178	0.03015369	0.96984631	955134.9436	5.63082E-08	5.3688E-07	2.84
21	102868255	1.17E+09	2.9099E+06	1.02E+08	3.8088E+05	0.087155743	0.007596123	0.992403877	931402.0441	4.25437E-08	4.0154E-07	7.6
22	110090093	1.36E+09	3.1100E+06	2.19E-06	1.2538E+05	1.61557E-15	2.61007E-30	1	1082172.75	4.55304E-08	4.28579E-07	1.50
23	9582380861		2.7661E+08		1.8838E+08					3.96303E-06	3.89524E-05	1.94
24												
25										DeltaMcoef =	1.39065E-06	
26												

Figure 5. Microsoft Excel program for determining the moment X_1 in the cross-sections A and B and the deflection of the diameter Δ by means of numerical integration.

Because of that the expression (6) is recorded in such way:

$$(\delta U/\delta X_1) =$$
$$(4/E)\{X_1.\int_0^{\pi/2}[R(\varphi)/J(\varphi)].d\varphi - (P/2).\int_0^{\pi/2}[R^2(\varphi)/J(\varphi)].d\varphi + (P/2).\int_0^{\pi/2}[R^2(\varphi).\cos\varphi/J(\varphi)].d\varphi\} = 0 \quad (12)$$

Integrals from (12):

$$I_1 = \int_0^{\pi/2}[R(\varphi)/J(\varphi)].d\varphi \quad (13)$$

$$I_2 = \int_0^{\pi/2}[R^2(\varphi)/J(\varphi)].d\varphi \quad (14)$$

$$I_3 = \int_0^{\pi/2}[R^2(\varphi).\cos\varphi/J(\varphi)].d\varphi \quad (15)$$

are solved numerically by means of the trapezium rule and then is found X_1.

$$X_1 = [(I_2 - I_3)/I_1].(P/2) \qquad (16)$$

About function of the change of the bending moment with respect of φ from (4) and (16) it is obtained:

$$M = (P/2).[(I_2 - I_3)/I_1 - R(\varphi) + R(\varphi).\cos\varphi)] \qquad (17)$$

Characteristic - deflection of the ring's diameter with respect of the applied load P

Again, the determination of the dependence of the deflection of the diameter - the applied load P is performed by applying the Castigliano's second theorem [6, page 488], and again it should take into account that $\delta N/\delta P = -(1/2).\cos\varphi$, $\delta Q/\delta P = (1/2).\sin\varphi$, but here from (17) follows:

$$\delta M/\delta P = (1/2).[(I_2 - I_3)/I_1 - R(\varphi) + R(\varphi).\cos\varphi)] \qquad (18)$$

That way the expression for determination of Δ is obtained as:

$$\Delta = \delta U/\delta P = 4.(P/4).\{(1/E).\int_0^{\pi/2}[R(\varphi)/F(\varphi)].\cos^2(\varphi).d\varphi + (k/G).\int_0^{\pi/2}.[R(\varphi)/F(\varphi)].\sin^2(\varphi).d\varphi + (1/E).[((I_2 - I_3)/I_1)^2.\int_0^{\pi/2}[R(\varphi)/J(\varphi)].d\varphi + \int_0^{\pi/2}[R^3(\varphi)/J(\varphi)].d\varphi + \int_0^{\pi/2}[R^3(\varphi).\cos^2(\varphi)/J(\varphi)].d\varphi + 2.[((I_2-I_3)/I_1).\int_0^{\pi/2}[R^2(\varphi).\cos(\varphi)/J(\varphi)].d\varphi]-((I_2-I_3)/I_1).\int_0^{\pi/2}[R^2(\varphi)/J(\varphi)].d\varphi-\int_0^{\pi/2}[R^3(\varphi).\cos(\varphi)/J(\varphi)].d\varphi]\}$$

In the above expression, the integrals are solved by numerical integration by means of trapezium rule. If we neglect the part of Δ, which arises from the internal forces N and Q (and the numerical results have shown that their share is one hundred times smaller than the one generated by the bending moment M), then for deflection Δ it could enroll:

$$\Delta = (P/E).[((I_2 - I_3)/I_1)^2.\int_0^{\pi/2}[R(\varphi)/J(\varphi)].d\varphi + \int_0^{\pi/2}[R^3(\varphi)/J(\varphi)].d\varphi + \int_0^{\pi/2}[R^3(\varphi).\cos^2(\varphi)/J(\varphi)].d\varphi + 2.[((I_2-I_3)/I_1).\int_0^{\pi/2}[R^2(\varphi).\cos(\varphi)/J(\varphi)].d\varphi]-((I_2-I_3)/I_1).\int_0^{\pi/2}[R^2(\varphi)/J(\varphi)].d\varphi-\int_0^{\pi/2}[R^3(\varphi).\cos(\varphi)/J(\varphi)].d\varphi]\}$$

In the case of a selected material 40X for the ring according to the Russian standard (the American analogue is AISI 1045 Steel with $E = 2.05.10^{11}$Pa and $G = 8.10^{10}$Pa) after numerical integration from the above expression, the relationship between Δ in m and P in N is obtained as:

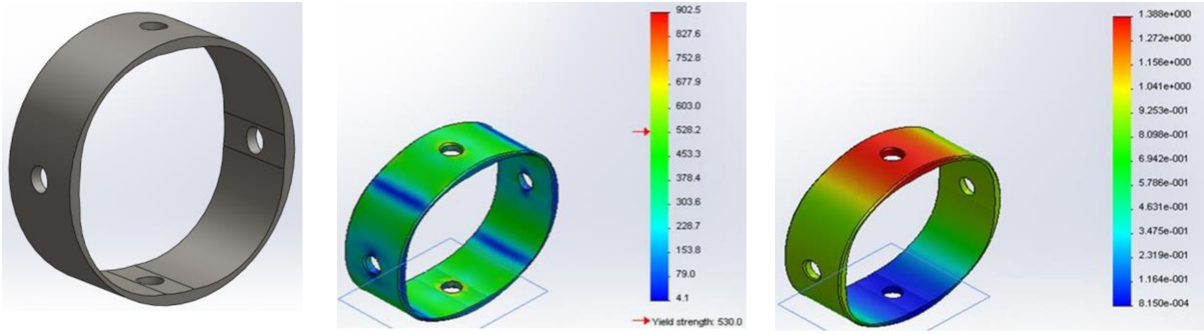
$$\Delta = 1.39065.10^{-6}.P, \ \text{m} \qquad (19)$$

3-D MODELLING OF THE PROVING RING BY MEANS OF CAD

To verify and to compare the results of the above dependence (19), a 3-D model (Figure 6-a) of the dynamometer proving ring it have been constructed by means of the CAD software product SolidWorks 2013 according to the geometric dimensions of Figure 3. Then, using the embedded package Simulation which uses the finite element method, the deflections (Figure 6-c) of the vertical diameter under load according to Figure 4-a, as well as the Von Mises equivalent stresses, were examined. The results are summarized in Table 1 and in graphical way (Figure 8).

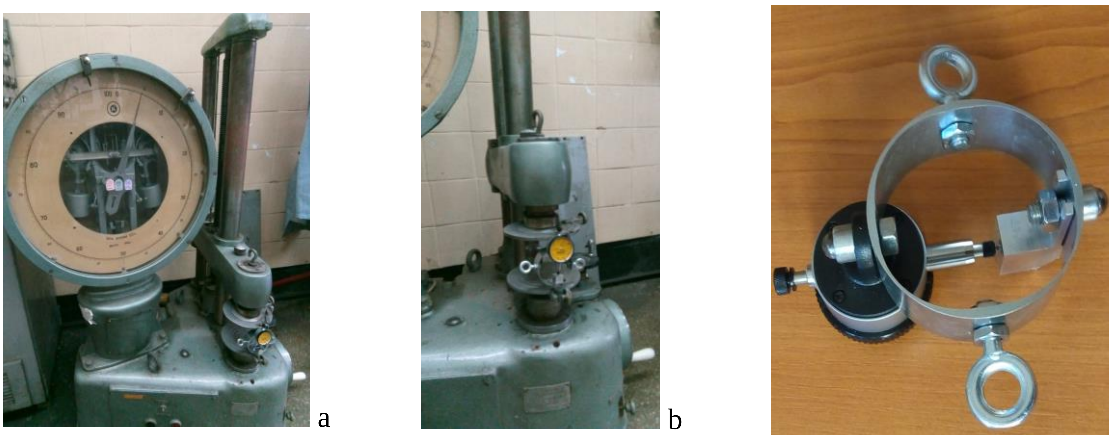
EXPERIMENTAL EXAMINATION

The proving ring (Figure 3-b) is made from steel 40X (Russian standard)) and has been loaded by means of a special spring testing machine (Figure 7-a). Reading of load is done by the indicator of the testing machine, and the ring diameter deflections was measured by means of dial indicator for linear measuring mounted in the ring. The results are summarized in Table 1 and graphical way (Figure 8).



a b c

Figure 6. a) 3-D model, **b)** Von Mises equivalent stresses at P=1000 N, **c)** deflections at P=1000 N.



a b c

Figure 7. Experimental tests - a) spring testing machine, b) ring attachment, c) attaching the dial indicator for linear measuring to the ring.

RESULTS AND DISCUSSION

Table 1 summarizes the results obtained: by means of the theoretical investigation, by means of the simulation of loading of the 3-D model in the SolidWorks 2013 in CAD environment and by means of the experimental tests.

Table 1. Results - theoretical, from 3-D model and experimental

Non Experimental	3-D model	After Castigliano	Experimental	
Load P, N	Deformation Δ, mm		Load P, N	Deformation Δ, mm
0	0	0	0	0
100	0.1388	0.139065084	98.0665	0.15
200	0.2775	0.278130169	196.133	0.29
300	0.4163	0.417195253	294.1995	0.45
400	0.555	0.556260338	392.266	0.6
500	0.6938	0.695325422	490.3325	0.79
600	0.8325	0.834390506	588.399	0.95
700	0.9713	0.973455591	686.4655	1.13
800	1.11	1.112520675	784.532	1.3
900	1.249	1.25158576	882.5985	1.48
1000	1.388	1.390650844	961.0517	1.64

These results are illustrated in Figure 8. It is seen that theoretical rasults and results derived by means of 3-D modeling practically coincide. The experimental results are close to the theoretical and the ones obtained by means of modeling, but the steepness of the experimental "deformation - load" dependence is greater and that steepness of this dependence increases when the loading increases. The reasons for this deviation should be sought in the imperfection of the experimental system: the way of loading application, the way of load reading, the way the ring is attached, etc. Other possible sources are the deviations of the actual dimensions of the ring and of the deviation of the elasticity parameters of the material (E and G) from those of the theoretical or model ones, the deviation of the actual axis of measurement from theoretical axis, influence of the attachment of the dial indicator for linear measuring on the characteristics of the ring itself, etc.

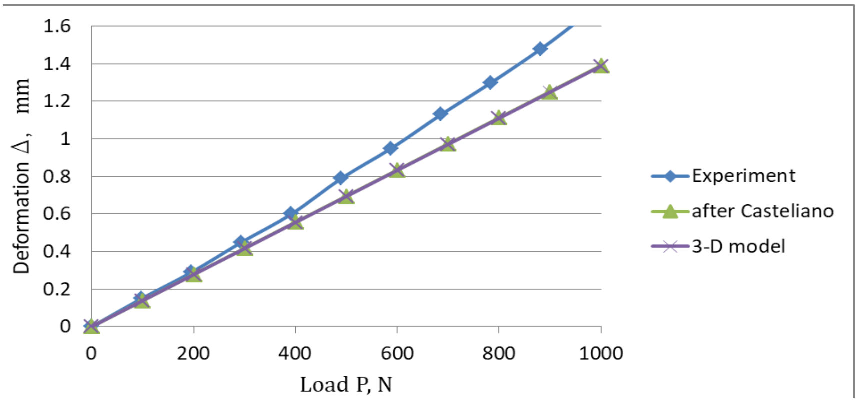


Figure 8. Graphs of the dependences "deflection Δ - loading P".

CONCLUSION

The proving rings with variable cross-sectional geometry are more difficult for theoretically deriving of the "diametrical deformation - diametrical load" dependence. This can be done by applying the general theorems from Strength of Materials, and by means of using numerical integration of expressions derived from these theorems because of the variable geometry of the cross section of these rings. The other easier approach is the use of modern methods of 3-D modeling and load simulation software. Here it is shown that this is achievable on one and the other approach, and the results are comparable. The experimental results concerning the dependence "Diametrical Deflection - Diametrical Load" are relatively close to theoretical and these from modeling, the difference being explained by the deviations of the parameters of the dynamometric ring as geometry and material from those of the theoretical and modeling studies as well as the imperfections of the experimental research.

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THE EFFECTS OF WIDTH/DIAMETER RATIO ON PERFORMANCE OF A DYNAMICALLY LOADED JOURNAL BEARING

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Abstract: In this study, investigation has been made on performance of a dynamically loaded journal bearing under the influence of the bearing width/diameter ratio (B/D), the feature which is quite important to the manufacturers of radial journal bearings. With the increase of 0.5, 1 and 1.5 in the B/D ratio for a dynamically loaded radial journal bearing, corresponding variations of minimum bearing clearance, peak oil film pressure, friction torque, oil flow rate and hydrodynamic power losses on the bearing were investigated. The effects of B/D ratio on the bearing performance are presented graphically.
Key words: dynamically loaded bearing, radial journal bearing, bearing performance

INTRODUCTION

In many important bearing operating situations the load varies in both magnitude and direction, often cyclically. Examples include reciprocating machinery such as steam, diesel and gasoline engines, reciprocating gas compressors and out-of-balance rotating machinery such as turbine rotors. Bearings are generally dynamically loaded. Lubrication theory for the dynamically loaded journal bearing is mathematically complex and, over the last few decades, several analytical approaches have been proposed. The multigrid techniques based on the Elrod algorithm and the finite element methods of analysis are among the most popular [1,2,3,4]. The finite element methods are probably the most accurate and versatile, but tend to be very time-consuming and require high level of knowledge, not accessible to the common designer and, so, remaining confined to research and development. Therefore, based on simplifying premises, engineers and designers prefer to use simpler and still accurate methods, such as the mobility method and the impedance method In general, these two approximate techniques, which belong to the category of rapid methods, are employed to perform analysis of simple journal bearings [5,6,7].
Prediction of performance of the dynamically loaded radial journal bearings by the users and designers of these bearings is very important particularly when considering that these bearings are used to support shafts in such sensitive areas as internal combustion engines, jet engines, compressors, gear and piston pumps, roller mills, mechanical presses and many other machine components.
The bearing width/diameter ratio has direct influence on the performance of a dynamically loaded bearing. For this reason, it is necessary for the researchers engaged in designing journal bearings to predict the effects of the bearing width/diameter ratio on features like minimum bearing clearance, peak oil film pressure, friction torque, oil flow rate and hydrodynamic losses on the bearing. The aim of this study is to provide information to the bearing designers and users on how the bearing width/diameter ratio affects the bearing parameters when the bearing operates under the effect of a dynamic load example. In oder words, this study, the performance of a radial journal bearing under the influence of different width/diameter ratios was investigated. [8,9]

REYNOLDS EQUATION AND SOLUTION

The solution of the Reynolds equation, which is the basic equation of the lubrication problems, which is used in the analysis of hydrodynamic radial plain bearings, by the ORBIT program is summarized below.

$$\frac{\partial}{\partial z}\left(\frac{h^3}{12\eta}\frac{\partial P}{\partial z}\right)+\frac{1}{R^2}\frac{\partial}{\partial \theta}\left(\frac{h^3}{12\eta}\frac{\partial P}{\partial \theta}\right)=\frac{1}{R}\frac{V}{2}\frac{\partial h}{\partial \theta}+\frac{\omega}{2}\frac{\partial h}{\partial z}+\frac{\partial h}{\partial t} \qquad (1)$$

Boundary conditions;

$z = 0 \quad P(z,\theta)=P_{1,j}$ (2)

$z = L \quad P(z,\theta)=P_{n,j}$ (3)

In addition, Half-Sommerfeld boundary conditions were used to solve the Reynolds equation. Here; η oil viscosity, z axial coordinate, R bearing radius, θ circumferential coordinate, h oil film thickness, P oil film pressure, $P_{1,j}$, $P_{n,j}$ pressures at the edge of the bearing (z = 0 and z = L), V linear velocity, ω angular velocity. The terms in the Reynolds equation using the finite difference formulation are considered as follows.

$$\left[\frac{h^3}{12\eta}\frac{\partial P}{\partial z}\right]_{i,j} \equiv \frac{\left[0.5\left(h_{i+1,j}+h_{i-1,j}\right)\right]^3}{12\eta}\frac{\left[P_{i+1,j}-P_{i-1,j}\right]}{2\Delta_z} \tag{4}$$

$$\left[\frac{h^3}{12\eta}\frac{\partial P}{\partial \theta}\right]_{i,j} \equiv \frac{\left[0.5\left(h_{i,j+1}+h_{i,j-1}\right)\right]^3}{12\eta}\frac{\left[P_{i,j+1}-P_{i,j-1}\right]}{2\Delta_\theta} \tag{5}$$

$$\left[\frac{\partial h}{\partial z}\right]_{i,j} \equiv \frac{\lfloor h_{i+1,j}-h_{i-1,j}\rfloor}{2\Delta_z} \tag{6}$$

$$\left[\frac{\partial h}{\partial \theta}\right]_{i,j} \equiv \frac{\lfloor h_{i,j+1}-h_{i,j-1}\rfloor}{2\Delta_\theta} \tag{7}$$

$$\left[\frac{\partial h}{\partial t}\right]_{i,j} \equiv \frac{\lfloor h_{i,j}-h_{i,j}^{eski}\rfloor}{2\Delta_t} \tag{8}$$

The Reynolds equation is written at each node using the finite difference formulation as above and the results are arranged in the form of a linear equation system.

$$[L].\{P\}=\{R\} \tag{9}$$

Where {P} is the array of nodal oil film pressures to be solved for, [L] contains entries for pre-multipliers of the pressures involving h^3, η, Δ_z , Δ_θ, R and the entries for the and the terms on the right side. In order to solve this equation system. Gauss Elimination method was used in the program. The calculation time is very long because the finite difference method calculates for each node in the solution. Figure 1 shows a hydrodynamic mesh pattern on an unwrapped bearing surface.

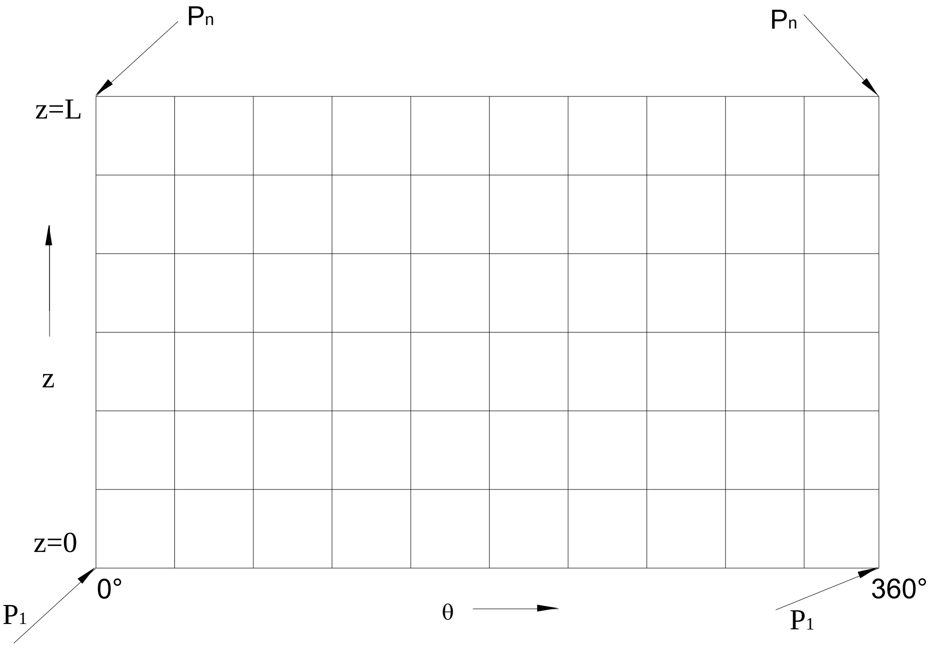

Figure 1. Hydrodynamic mesh on an unwrapped bearing surface

From the solution of oil film pressures, the force components on the bearing due to it are calculated using

2-2

$$F_{x,oil} = \int_A P\cos\theta dA \tag{10}$$

$$F_{y,oil} = \int_A P\sin\theta dA \tag{11}$$

and the force components due to contact pressures using

$$F_{x,asp} = \int_A P_{asp}\cos\theta dA \tag{12}$$

$$F_{y,asp} = \int_A P_{asp}\sin\theta dA \tag{13}$$

The friction force components arising due to fluid flow are given by

$$F_{x,fhyd} = \int_A \left\{-\frac{\eta}{h}V + \frac{h}{2}|\nabla P|\right\}\sin\theta dA \tag{14}$$

$$F_{y,fhyd} = \int_A \left\{-\frac{\eta}{h}V + \frac{h}{2}|\nabla P|\right\}-\cos\theta dA \tag{15}$$

while the boundary friction force components are expressed

$$F_{x,fbdy} = \int_A \mu P_{asp}\sin\theta dA \tag{16}$$

$$F_{y,fbdy} = \int_A \mu P_{asp} \text{-}\cos\theta dA \tag{17}$$

where dA is the elemental bearing surface area, C_f is the friction coefficient associated with the contact surfaces, and $|\nabla P|$ is the pressure gradient in the circumferential direction.
As a result, the force balance on the bearing is expressed as

$$F_{x,app} = F_{x,oil} + F_{x,asp} + F_{x,ine} + F_{x,fhyd} + F_{x,fbdy} \tag{18}$$

$$F_{y,app} = F_{y,oil} + F_{y,asp} + F_{y,ine} + F_{y,fhyd} + F_{y,fbdy} \tag{19}$$

where $F_{x,app}$, $F_{y,app}$ are components of the applied bearing force. The associated power losses for journal bearings due to hydrodynamic and boundary lubrication are denoted by L_{hyd} and L_{bdy} respectively. In turn, the hydrodynamic power loss has two components; one due to Couette and the other due to Poisseuille flow. The hydrodynamic power loss is expressed as

$$L_{hyd} = \int_A \frac{\eta}{h} V^2 dA + \int_A \frac{\eta}{h} \omega^2 dA + \int_A \frac{h^3}{12\eta R^2} \frac{(\partial P)^2}{\partial \theta} dA + \int_A \frac{h^3}{12\eta} \frac{(\partial P)^2}{\partial \theta z} dA \tag{20}$$

while the boundary friction component of power loss is given by

$$L_{sınır} = \int \mu P_{sınır} (V^2 + \omega^2)^{1/2} dA$$

Calculation of the oil film temperature is of some significance in journal bearing analysis due to the high dependence of lubricant viscosity on temperature. Within ORBIT there is an iterative thermal solution option that is activated when the user specifies an input block titled ‘TBAL’. If this is not activated then ORBIT performs the journal bearing simulation by using either a) a user-supplied constant oil viscosity value or b) a viscosity value computed based on the user-specified oil type and user-specified inlet oil temperature. Within the thermally balanced solution scheme, the iterative procedure for calculating the effective oil temperature is based on the assumption that all the energy dissipated by bearing friction goes in increasing the oil temperature such that

$$T_{oil} = T_{inlet} + \frac{(L_{hyd} + L_{bdy})}{\rho C_p Q} \tag{21}$$

Where: T_{oil} Effective oil temperature, T_{inlet} Inlet oil temperature, L_{hyd} Cycle averaged hydrodynamic friction power loss, L_{bdy} Cycle averaged boundary friction power loss (W), Q Cycle averaged oil flow-rate through the bearing, ρ Oil density and C_p Specific heat capacity of the oil

Table 1 Journal bearing data

Nominal bearing length, (m)	0.250E-01, 0.450E-01, 0.600E-01
Nominal bearing diameter, (m)	0.500E-01
Nominal radial clearance, (m)	0.250E-04
Rotational speed, (RPM)	0.150E+04
Axial velocity, (m/s)	0.00
Avg. shaft temperature, (K)	350
Avg. bearing temperature, (K)	373
Avg. oil inlet temperature, (K)	400
Oil viscosity, (Pa-s)	0.150E-01
Oil density, (kg/m^3)	860

Bulk modulus, (Pa)	0.500E+09
Cavitation pressure, (Pa)	0.100E+06
Thermal conductivity (W/m-K)	0.680
Specific heat (J/kg-K)	0.200E+04
Bearing asperity height, (m)	0.150E-06
Journal asperity height, (m)	0.150E-06
Density of asperities, ($1/m^2$)	0.600E+08
Curvature of asperities, (m)	0.500E-02
Elastic modulus of bearing, (N/m2)	0.200E+12
Elastic modulus of journal, (N/m2)	0.200E+12
Friction coefficient	0.120
Analysis type	Dynamic
Solution type	Finite Difference Method

RESULTS AND DISCUSSION

Variation of bearing load (horizontal, vertical and resultant load) with crank angle for a dynamically loaded radial journal bearing is given in Figure 1. ($F_{sum} = \sqrt{F_x^2 + F_y^2}$)

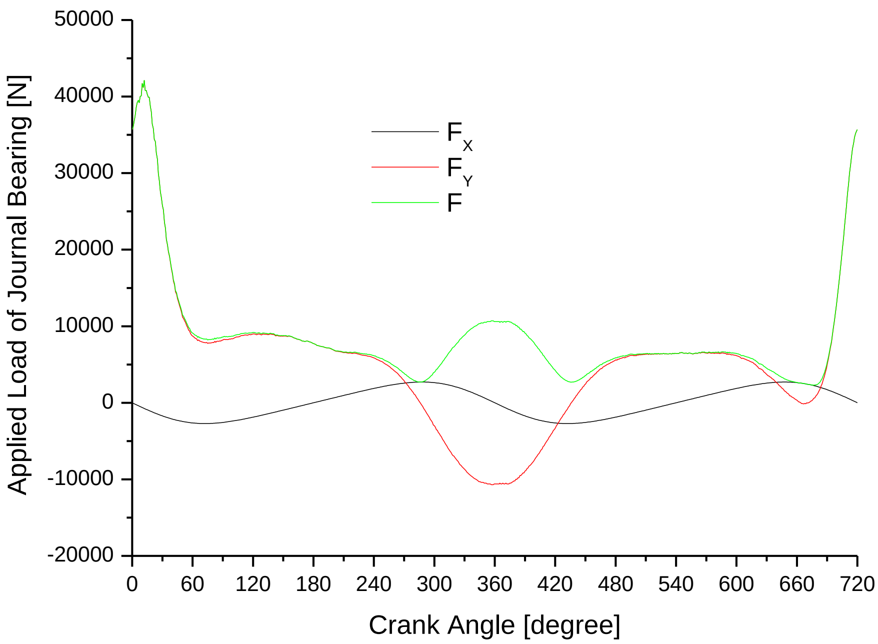

Figure 1. Variation of vertical, horizontal and total load applied onto bearing with respect to crank angle

When the figure is studied, it is found that the maximum value of the total load on the bearing is 42106 N which occurs at 12° crank angle whereas the minimum total bearing load occurs at 677° crank angle with a value of 2302 N.
The graph of minimum bearing clearance with crank angle for the journal bearings subjected to same dynamic load but with different the bearing width/diameter ratios is given in Figure 2.

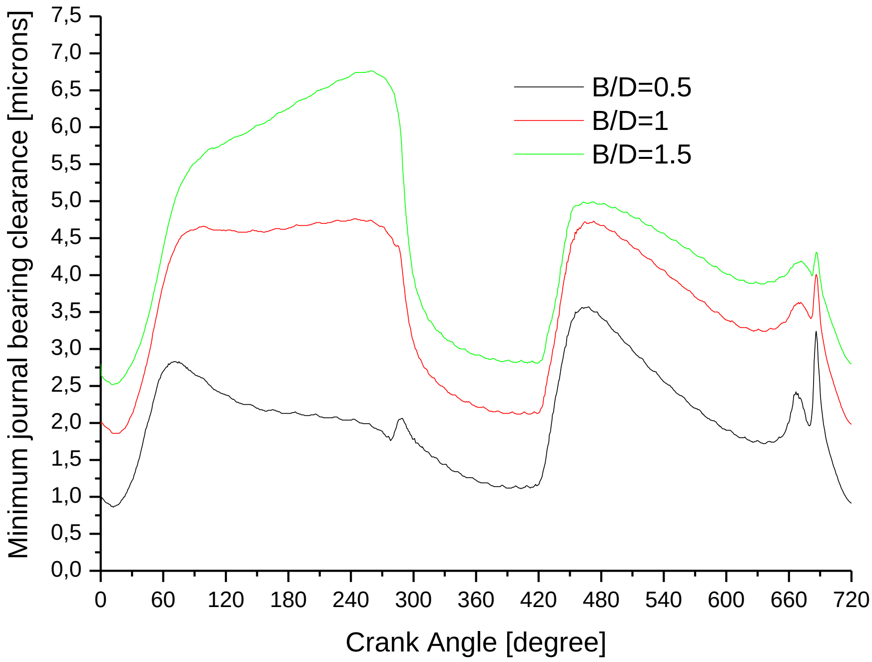

Figure 2. Effects of B/D ratio on the bearing minimum clearance

It is clearly seen from Figure 2 that, as the B/D ratio increases the minimum journal clearance increases just above the 12º crank angle. The figure shows that at 0.5 the bearing width/diameter ratio, the smallest value of the minimum journal bearing clearance is 0,86 µm and at crank angle of while the highest value of the minimum journal clearance is 3,57 µm and occurring at crank angle of 467º. At B/D ratio of 1, the smallest value of minimum bearing clearance occurs at crank angle of 11,5º and with a value of 1,86 µm. As for the highest value of minimum bearing clearance, it was found that the crank angle of 242º is where this value of 4,76 µm exists. It was also found that as the bearing width/diameter ratio becomes 1.5, the smallest value of minimum journal clearance changes to 2,52 µm and shifts to crank angle of 10,5º, and the highest value of minimum journal clearance is 6,76 µm taking place at crank angle of 258º. An increase in B/D ratio leads to corresponding increases in the smallest and highest values of the minimum journal bearing clearance. In short, as the B/D ratio increases, the minimum journal clearance increases too. In other words, an increase in journal bearing's minimum clearance means an increase in the oil film thickness. The thicker the oil film, the better the performance of the journal bearing. This is so because as the oil film is thick, the risk of metal to metal contact between the shaft and journal is reduced and hence safer operation of the bearing. Consequently, it can be said that the best B/D ratio in terms of minimum journal bearing clearance is 1.

The graph of variation of maximum oil pressure at same dynamic load but different B/D ratio is shown in Figure 3.

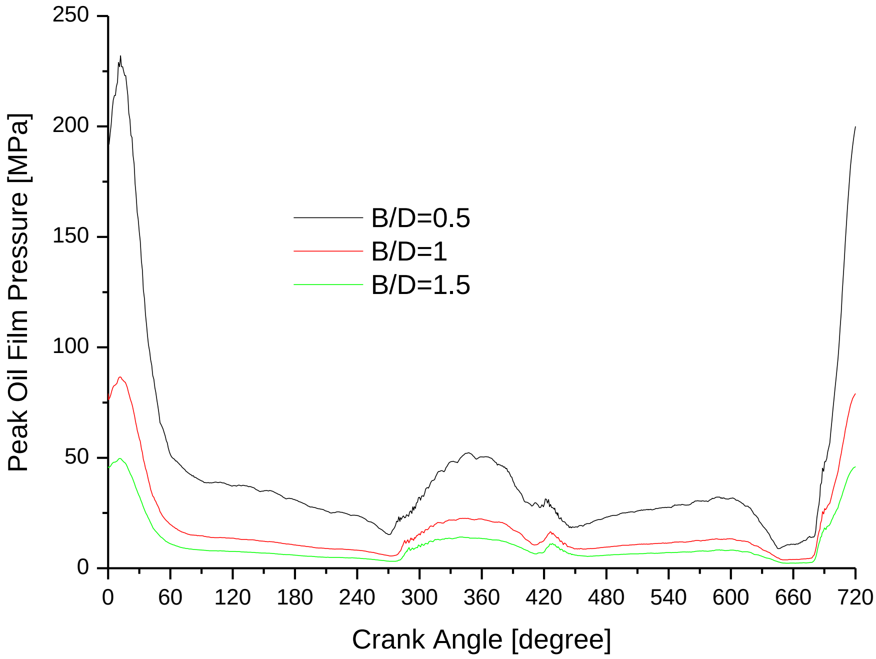

Figure 3. Effects of changes in B/D ratio on oil film pressure

It is seen from the figure that, at the same crank angle, as the B/D ratio increases the maximum value of oil film pressure generally decreases. When the figure is studied, it is found that at the bearing width/diameter ratio of 0.5 the smallest value of oil film pressure is 8,83 MPa and occurs at 645^o crank angle, while the maximum oil film pressure is 232 MPa taking place at 12^o crank angle. When the bearing width/diameter ratio is 1, the smallest value of oil film pressure occurs at crank angle of 652^o and with the value of 3,78 MPa, while the maximum oil film pressure is 86,6 MPa and occurs at crank angle of 12^o. At the bearing width/diameter ratio of 1.5, the smallest oil film pressure is again at crank angle of 653^o with the value of 2,26 MPa while the maximum oil pressure occurs at crank angle of 12^o with the value of 49,7 MPa. As the B/D ratio increases, the minimum oil film thickness increases also. An increase in oil film thickness means reduction in oil film pressure. In terms of journal bearing performance, it is important to have lower oil film pressure for the same load influence but different B/D ratios. In other words, the lower the maximum pressure of oil film is, the lesser the constrain the journal bearing experiences and hence the larger its load carrying capacity becomes. And this is an important aspect for bearing designers. According to Figure 3, the best journal bearing is the one with the bearing width/diameter of 1. Figure 4 is the graph showing variation of B/D ratio and its effects on friction torque.

From Figure 4, it is seen that at the same crank angle frictional torque increases with the B/D ratio. By looking at the figure, it is seen that, at B/D ratio of 0.5, the lowest frictional torque is 0,464 Nm and exists at crank angle of 460^o, whereas the highest value is 0,838 Nm and at 720^o crank angle. The figure also shows that at B/D ratio of 1, the lowest frictional torque exists at crank angle of 217^o and has a value of 0,758 Nm, while the highest frictional torque is 1,15 Nm at crank angle of 410^o. The bearing width/diameter ratio of 1.5 gives the lowest frictional torque of 0,982 Nm at 235^o, and the highest value of 1,51 Nm at 414^o. An increase in frictional torque leads to impairing of the journal bearing performance. Therefore; based on figure 4, we find that the best journal bearing is the one with the bearing width/diameter ratio of 0.5.

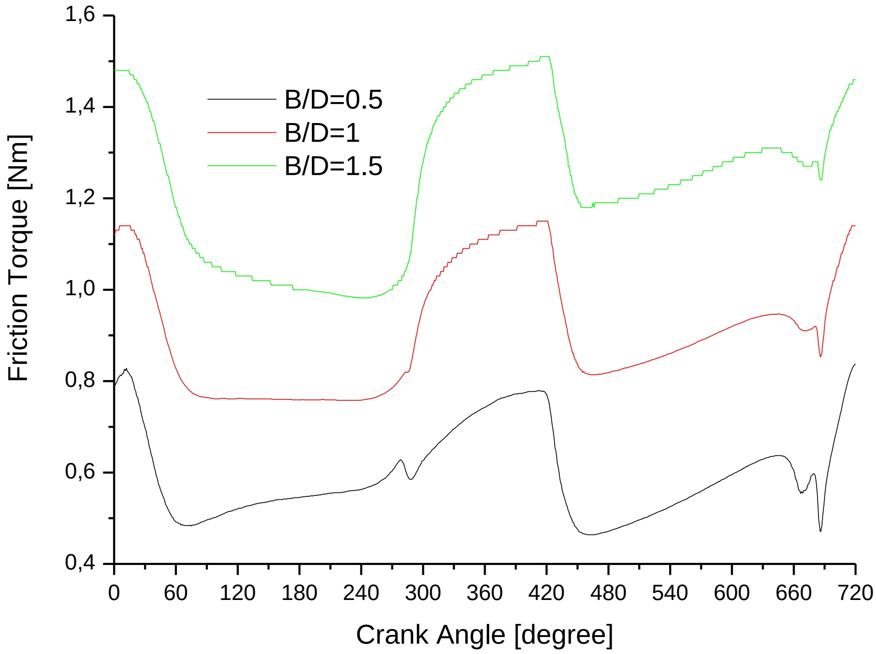

Figure 4. Variation of B/D ratio with friction torque

The effects caused by variation of the B/D ratio on hydrodynamic power losses are presented in Fig. 5. Figure 5 shows that, the increase in B/D ratio generally, leads to an increase in the power loss on the journal radial bearings. The figure indicates that at the bearing width/diameter ratio of 0.5 an average of 0,07 kW power loss is experienced on the bearing while the power losses are 0,125 kW and 0,161 kW for the bearing width/diameter ratios of 1 and 1.5 respectively. An increase in B/D has led to a corresponding increase in the minimum oil film thickness and the increase in oil film thickness has negatively affected the power losses. Under same load operating conditions, as the B/D ratio increases the power losses experienced on the journal bearing tend to increase. The power losses on radial journal bearings are directly proportional to the frictional torques on the bearings. When the two graphs are studied they are found to bear the same trend.

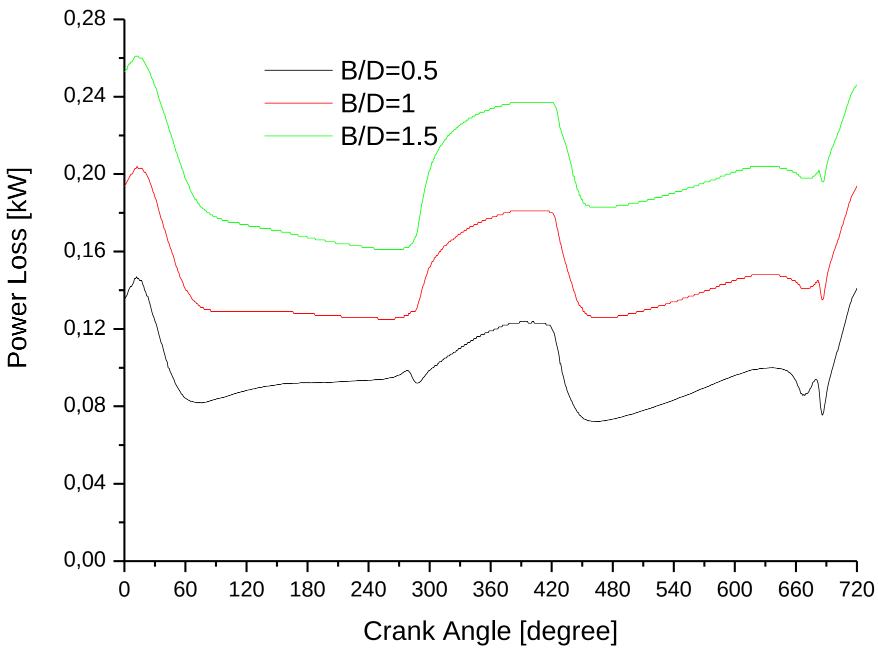

Figure 5. Influence of B/D ratio on hydrodynamic power losses

CONCLUSIONS

In this study, changes encountered in the minimum bearing clearance, maximum oil film pressure, frictional torque, oil flow rate and hydrodynamic power losses as the B/D ratio increases on the radial journal bearings operating under the same dynamic loading were investigated and the following results are summarized

The increase in B/D ratio leads to an increase in both minimum and maximum values of the bearing minimum clearance. That is, B/D ratio increases with the minimum bearing clearance. The best result in terms of minimum bearing clearance is found on a bearing with B/D ratio of 1.5. When the maximum values of oil film pressure are studied under different B/D ratios, it is again found that the best result is achieved with the bearing with B/D ratio of 1.5. An increase in frictional torque is no good for journal bearing performance. Therefore, the best result in terms of frictional moment is obtained with the B/D ratio of 0.5. An increase in the average oil flow rate acts in favor of the bearing performance. Under the same loading conditions, the increase in B/D ratio generally leads to corresponding increase in the power losses in the radial journal bearings.

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BRIDGE CRANE MECHANISMS CALCULATION AND ANALYSIS OF THE SIGNIFICANCE OF USE IN PRAXIS

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Abstract: The crane is made up of a bridge and a cart. Bridge cranes have wide application in praxis in various factory departments. They are used to manipulate various types of loads in production halls, workshops, warehouses, energy facilities, rolling mills, foundries, performing technological processes, assembling or dismantling equipment, etc. In the paper is given a technical description of the bridge crane, the calculation of the mechanisms for moving, lifting and carrying capacity of the bridge crane and analysis of the significance of use in praxis.
Key words: bridge crane, mechanism for moving, mechanism for lifting, carrying capacity

INTRODUCTION

Cranes can be defined as cyclic-acting devices for the transportation of bulk and piece goods within a limited working space, which is determined by the construction characteristics of the crane. When lifting crane works, in the process of transshipment process, the lifting and lowering operations of load are dominant. The cranes are classified according to different criteria, and for the choice of transshipment technology or designing of the transshipment process, the most appropriate classification according to the type of drive and construction. According to the type of drive, the cranes are divided into two groups: with electric and internal combustion engine. Electric – powered cranes, as a rule, move along the rails, while the cranes powered by the internal combustion engines have a wearing frame and a drive system similar to a road vehicle.

TECHNICAL DESCRIPTION OF BRIDGE CRANE

The bridge crane has a bridge shape, which is why it got its name, which moves along high lifted rails above the operating surface. The rails on which the bridge is moving in closed buildings rely on the construction structure of the building, and when working on the open path, it is performed as a special construction of reinforced concrete or steel. Load capacity can range from 2.5 to 5000 kN, and range from several meters to several tens of meters (50 m). The bridge of the crane serves to move the cart carrying the catching device with a mechanism for lifting and lowering the load. The construction of the bridge should ensure the positioning of the hoisting device of the crane at the shortest path in each point of the operating surface. The main elements of the bridge crane beside the bridge and cart are the drive devices as well as the control system.
The construction of the cart depends on the purpose of the crane:
Standard cranes for handling piece load and spill load, with so – called free hanging load, have cart where the piece load is most commonly hanged on the hook, and in certain cases special catch devices (electromagnets, pliers, pneumatic devices, etc.) are used. To handle with spill load, specially customized cart are used, usually with multiple ropes for grabbing and putting off using a grapple.
The bridge consists of one or two main and two frontal carriers. In the frontal carriers are located drive and free wheels over which the bridge relies on the track and realizes the translational movement. The control of the bridge crane can be from the work hall, cabin or automatic.

Drive of bridge

The bridge in light-weight cranes is over four wheels on the track, and with heavy cranes in order to reduce the specific pressure on the track, the number of wheels is significantly higher.

In light-weight cranes, the drive is performed over two symmetrically distributed drive wheels on the frontal carriers, and in heavy duty, drive is performed at four points. The conventional constructions of drive group are performed with the so-called central drive, consisting of a centrally positioned engine and reducer with transmission of the drive force to the drive wheels via the shaft.
Today, the principle of single drive with the installation of an electric motor and reducer is directly used on the drive wheel. In order to avoid sideling the bridge when moving, electric motors are synchronized.

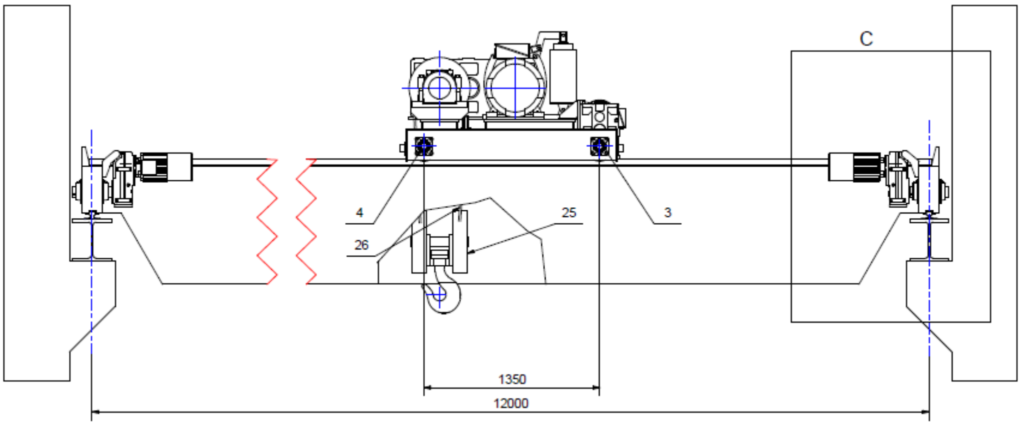

Figure 1. Bridge crane set

Cart

Cart represents the most important working part of bridge cranes. Load lifting mechanism is located on the cart.

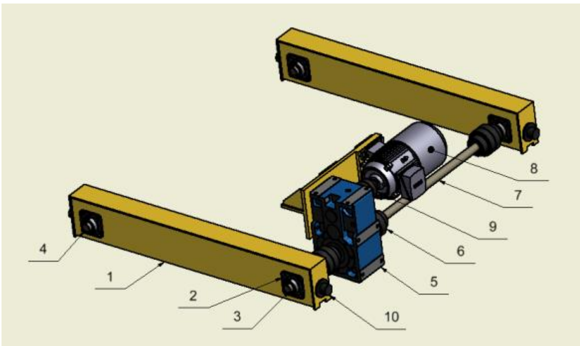

Figure 2. Mechanism for cart movement

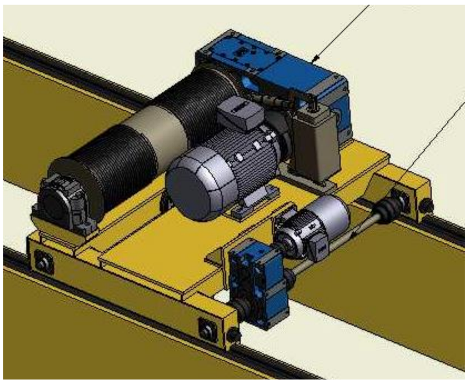

Figure 3. Load lifting mechanism

MECHANISMS CALCULATION FOR MOVEMENT, LIFTING AND CARRYING CAPACITY OF BRIDGE CRANE

Example 1:

The following data are known:
$H = 25$ m – the height at which the load is lifted
$t_{diz} = 1$ min – load lifting time
$M_{dob} = 12$ kNm – moment on winch
$n_{EM} = 945$ min^{-1} – electromotor frequency
$\eta_m = 0{,}85$ – mechanism efficiency for drive lifting (efficiency of reducer)
$i_m = 45$ – transmissional mechanism ratio for lifting (transmissional ratio of reducer)
$\eta_{kot} \approx 1$ – efficiency of coil

It is necessary to determine: electromotor power P_{EM} , force in the rope F_u and carrying capacity m_Q.

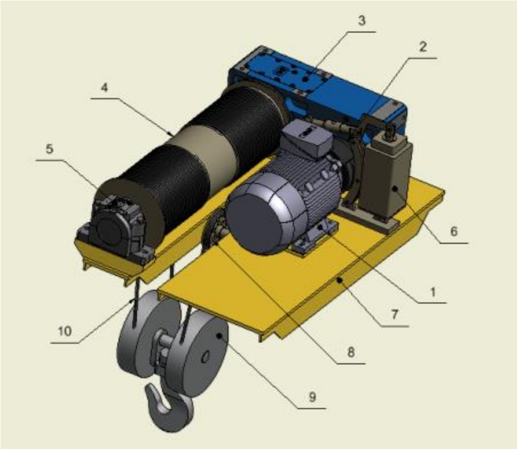

Figure 4. Load lifting mechanism

Calculation:

Load lifting velocity:
$$V_{diz} = \frac{H}{t_{diz}} = \frac{25}{1} = 25\ \frac{m}{min}$$

Winch frequency:
$$n_{dob} = \frac{n_{EM}}{i_m} = \frac{945}{45} = 21\ min^{-1}$$

Mechanism efficiency for drive lifting:
$$\eta_m = \frac{P_{dob}}{P_{EM}} = \frac{M_{dob} \cdot \omega_{dob}}{M_{EM} \cdot \omega_{EM}} = \frac{M_{dob}}{M_{EM}} \cdot \frac{1}{i_m}$$

Moment on electromotor shaft:
$$M_{EM} = \frac{M_{dob}}{i_m \cdot \eta_m} = \frac{12}{45 \cdot 0{,}85} = 0{,}31\ kNm$$

Electromotor power:
$$P_{EM} = M_{EM} \cdot \frac{\pi \cdot n_{EM}}{30} = 0{,}31 \cdot \frac{\pi \cdot 945}{30} = 31\ kW$$

Selecting standard electromotor power:
$$P_{EM} = 37\ kW$$

Winch velocity:
$$V_{dob} = i_{kot} \cdot V_{diz} = \frac{z}{z_{dob}} \cdot V_{diz} = 2 \cdot V_{diz} = 2 \cdot 25 \frac{m}{min} = 50\ \frac{m}{min}$$

Winch diameter:
$$D_{dob} = \frac{V_{dob}}{\pi \cdot n_{dob}} = \frac{50}{\pi \cdot 21} = 0{,}758\ m$$

Selecting standard winch diameter:
$$D_{dob} = 800\ mm$$

Force in the rope:

$$F_u = \frac{2M_{dob}}{D_{dob}} = \frac{2 \cdot 12}{0{,}8} = 30\ kN$$

Load weight:

$$Q = F_u \cdot z \cdot \eta_{kot} = 30 \cdot 4 \cdot 1 = 120\ kN$$

Carrying capacity:

$$m_Q = 12\ t$$

Example 2:

Poznati su sledeći podaci:
l = 32 m – the distance that the crane crosses along the crane track
t = 40 s – the time during which the crane crosses the given distance
G_{ko} = 30 kN – cart weight
G_{mo} = 65 kN – bridge weight
β = 3 – coefficient of sideling
d = 70 mm – shaft wheel diameter
μ = 0,01 – coefficient of slip friction between shaft and hub
f = 0,04 cm – coefficient of wheeling friction on rail
η_m = 0,8 – transmissional mechanism efficiency for movement bridge crane (efficiency of reducer)
i_m = 20 – transmissional mechanism ratio for drive movement of bridge crane
(transmissional ratio of reducer)
n_{EM} = 980 min^{-1} – electromotor frequency for drive movement of bridge crane
P_{EM} = 4 kW – electromotor power for drive movement of bridge crane
It is necessary to determine carrying capacity m_Q.

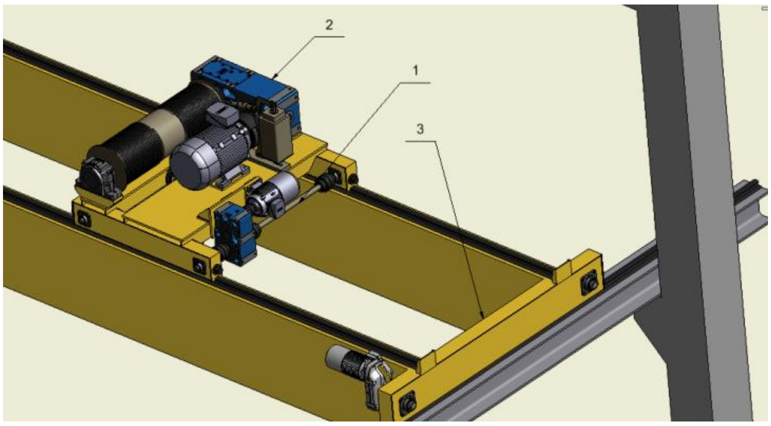

Figure 5. Mechanism for bridge movement, cart movement and load lifting

Calculation:

Bridge velocity:

$$V_{mo} = \frac{l}{t} = \frac{32}{40} = 0{,}8\ \frac{m}{s} = 48\ \frac{m}{min}$$

Bridge wheel frequency:

$$n_t = \frac{n_{EM}}{i_m} = \frac{980}{20} = 49\ min^{-1}$$

Bridge wheel diameter:

$$D_t = \frac{V_{mo}}{\pi \cdot n_t} = \frac{48}{\pi \cdot 49} = 0{,}311\ m$$

Selecting standard wheel diameter:

$$D_t = 315\ mm$$

Force to overcome resistance of bridge movement on horizontal path:

$$F_w = \frac{P_{EM} \cdot \eta_m}{V_{mo}} = \frac{4 \cdot 0{,}8}{0{,}8} = 4\ kN$$

Load weight:

$$Q = \frac{F_w}{\left(\frac{2 \cdot f}{D_t} + \frac{\mu \cdot d}{D_t}\right) \cdot \beta} - G_{ko} - G_{mo}$$

$$Q = \frac{4}{\left(\frac{2 \cdot 0{,}4}{315} + \frac{0{,}01 \cdot 70}{315}\right) \cdot 3} - 30 - 65$$

$$Q = 185\ kN$$

Carrying capacity:

$$m_Q = 18{,}5\ t$$

ANALYSIS OF THE SIGNIFICANCE OF USE IN PRAXIS

The crane is made up of a bridge and a cart. Bridge cranes have wide application in praxis in various factory departments. They are used to manipulate various types of loads in production halls, workshops, warehouses, energy facilities, rolling mills, foundries, performing technological processes, assembling or dismantling equipment, etc. Example: Each thermal power plant has a bridge crane for the needs of repair, e.g. when it comes to repair turbine and generator, it is necessary to remove the turboaggregate housing.

Bridge cranes for special purposes have carts that are specially adapted and are significantly different from the systems used for general purpose cranes. This group consists of: cranes adapted to the needs of the process in metallurgy, bridge cranes for stack, special cranes for automated warehouses of profiles and bars, hanging cranes.

In metallurgy, there are traditionally used several purpose – built forms of bridge cranes that have been named according to the type of processes in which they participate: casting cranes, clip cranes, traverse cranes, etc. For this type of crane, it is characteristic that they possess mainly extremely high loads, that they are exposed to the influence of high temperatures and that they are strictly designed for purpose, i.e. constructively maximally adapted to the realization of specific requirements in the processes they serve.

CONCLUSION

The construction of a bridge crane has been designed so that the drives for the movement of the bridge and cart provide the positioning of the catching device of the crane at the shortest path in each point of the operational surface. The bridge of the crane serves to move the carts which carrying the catching device with a mechanism for lifting and lowering the load. Working velocities of individual movements at bridge crane with hook are: lifting velocity 20 – 25 m/min, velocity cart 25 – 40 m/min, and bridge velocity 40 – 100 m/min. In order to make the bridge crane work in the open space, it is necessary to make a lifted track on the pillars, which is often unprofitable. The main disadvantage of the use of bridge cranes in warehouses is the need for another means of transport that would enter load, or exit load from the warehouse. Their advantage is in the large utilization of the storage area, because the bridge crane does not require space, as if another appliance moving on the floor would be used.

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ON THE SPATIAL CHAOS APPEARANCE IN CASCADE CONNECTED NONLINEAR TRANSPORTATION SYSTEMS WITH TRAPEZOIDAL NONLINEARITY TRANSITION

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Abstract: The system consisting of a series of cascade connected transporters with trapezoidal nonlinearity transition for rubber strip transportation is analyzed in this paper. One characteristic of this system is the possibility of spatial chaos appearance. Simulation of bifurcation diagrams and „escape-time“ diagram of this nonlinear cascade system is done in steady state using M-files in program package Matlab.
Key words: spatial chaos,bifurcation diagram, „escape-time“ diagram, cascade nonlinear systems

INTRODUCTION

Convergent, oscillatory and chaotic dynamics of SISO (Single Input Single Output) cascade connected nonlinear systems were analyzed in [1-6]. These SISO systems can be found in the tyre industry for rubber strip transportation [4], and in cascade connected nonlinear electrical circuits, [5]. They consist of a small number of nonlinear SISO subsystems of the same structure. These SISO systems are described by equation $x_{k+1} = f(x_k, r)$, where x_k and x_{k+1} are input and output of the *k*-the cascade respectively, Fig. 1. Nonlinear function *f* and its parameter- amplification, *r*, are common for all cascades.

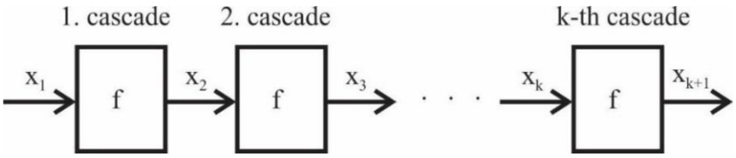


Figure1. Block scheme of SISO cascade connected nonlinear system

It was noticed that in these systems for certain values of parameter *r* very complex oscillations can appear, as well as, spatial chaos. Spatial chaos appearance in SISO cascade connected nonlinear systems is not the consequence of signal iteration in time, as is the case with appearance of chaos in nonlinear continuous and discrete systems, [7]. The appearance of spatial chaos in SISO cascade connected nonlinear systems is consequence of signal propagation through space, i.e., through subsystems of SISO cascade connected nonlinear systems, [4, 5].
Let the equation $x_{k+1} = f(x_k, r)$ describes the nonlinear cascade system in steady state. Bifurcation diagram of this cascade system shows outputs of all cascades in steady state for different values of control parameter, i.e., amplification *r*. In this case, as in the case of nonlinear discrete systems described by (1), parametric axis is devided into a series of close points, but equation (2) is iterated only once in each point of parameter *r* for each cascade particularly. „Escape-time“ diagrams represent a procedure for examining the chaotic behavior of system (1) and visually show the degree of expansion for each point in the area of which we are examining. For example, each point with coordinates (r, x_1), (x_1 is the input into the first cascade, i.e., the input of the nonlinear cascade system), in Descartes plane, can be drawn in a different color or shades of one color. The color point is determined depending on the number of iterations needed for point to exceed a certain pre-given value of cascades outputs. Since we have only eight available colors, points corresponding to a larger number of iterations, will be colored the same as the points corresponding to a small number of iterations. For example, point with nine iterations is associated with the same color as the point corresponding to one iteration, point with ten iterations is associated with the same color as the point corresponding to two iterations, etc.

RUBBER STRIP TRANSPORTATION SYSTEM

One of important process in tyre industry is the process of extrusion of protector - rubber strip, forming external protective part of a tyre. After the extrusion, it is necessary to cool down the rubber strip to the room temperature in order to cut it into pieces of certain length depending on tyre dimension. For the cooling of protector the cascade transportation system is used, Fig. 2. This system consists of 7 - 13 cascades and enables the protector cooling in the natural way without any additional tensions such that rubber strip relaxes on the transition from one transporter to another. However, in order to accomplish these requirements it is necessary to determine the velocity of each transporter and the whole line should have certain velocity, also. The velocities of the individual transporters are regulated on the basis of the measured tyre length between the transporters. The measuring is done by especially constructed measurer, and the information about the error is led to the thyristor controlled by DC motor controlling the next transporter. The statical error of each cascade depends on the system input velocity and on the product of the rubber strip compression coefficients of the former cascades and the current one.

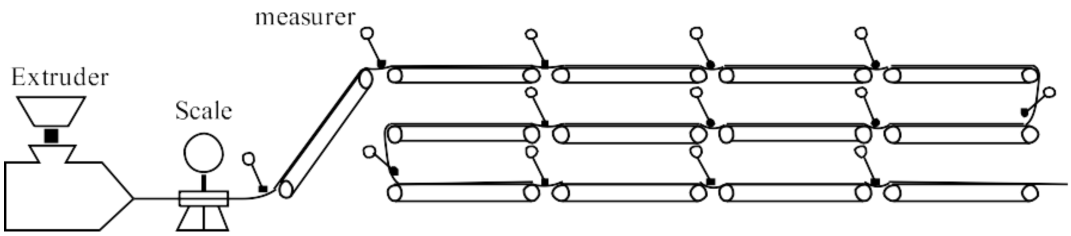


Figure 2. Rubber strip transportation system

The structural scheme of rubber strip transportation system is given in Fig. 3 with the next notations:

- l_i - is the length of the rubber strip between the *i*-th and the *(i+1)* - th transporters,
- V_i is the velocity of the *i*-th transporter,
- $V_{p,i}$ is the transition velocity of the *i*-th transporter,
- $V_{g,i}$ is the rubber velocity of *i*-th transporter,
- μ_i is the rubber strip compression coefficient in the *i*-th transporter,
- $W(s)$ is the transfer function of the motor with the load and amplification k,

$$W(s) = \frac{k}{T_1T_2s^2 + (T_1 + T_2)s + 1}$$

- T_1, T_2 are the time constants of the subsystem loaded with rubber strip material,
- $\Phi(V_i)$ is transition nonlinearity.

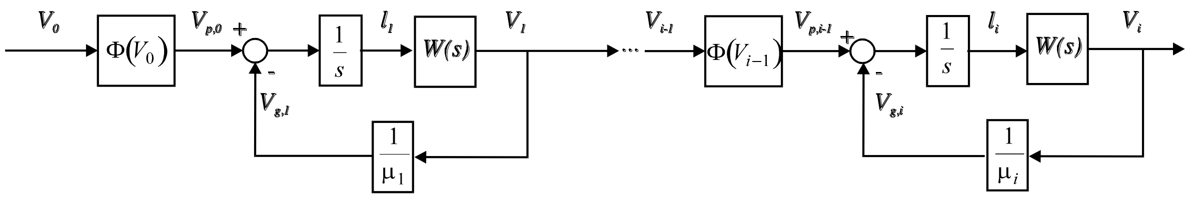


Figure 3. The structural scheme of rubber strip transportation system

System dynamics is described by the next set of equations:

$$\frac{dl_i}{dt} = \Phi(V_{i-1}) - \frac{1}{\mu_i}V_i, \; i = 1,2,\ldots,13 \tag{1}$$

$$T_1T_2\frac{d^2V_i}{dt^2} + (T_1 + T_2)\frac{dV_i}{dt} + V_i = kl_i \tag{2}$$

The characteristic of these systems is a great sensitivity to the parameters variations and external influences. The consequence is the appearance of chaotic dynamics.
For these systems next cases are of interest, [4]:

1. Chaotic motion as a result of complex oscillations in the system,
2. Chaotic change of quazy steady states in individual subsystems.

In earlier works for analysis of chaos appearance the next transition nonlinearity of cascade system, Fig. 3, were used:

1. Parabolic nonlinearity

$$\Phi(V_i) = 5V_i - V_i^2 \tag{3}$$

2. Triangular nonlinearity:

$$\Phi(V_i) = \begin{cases} 0 & V_i < 0, \\ 3V_i & 0 \le V_i < 2, \\ -1.5V_i + 9 & 2 \le V_i \le 6, \\ 0 & V_i > 6. \end{cases} \tag{4}$$

Next in the paper, the analysis of chaos appearance in transportation systems is done with trapezoidal nonlinearity transition.

THE ANALYSIS OF TRANSPORTATION SYSTEM DYNAMIC WITH TRAPEZOIDAL NONLINEARITY TRANSITION

Let the trapezoidal nonlinearity is given by:

$$\Phi(V_i) = \begin{cases} 0 & V_i < 0 \\ 2.5V_i & 0 \le V_i \le 2, \\ 5 & 2 < V_i < 3, \\ -2.5V_i + 12.5 & 3 \le V_i \le 5, \\ 0 & V_i > 5. \end{cases} \tag{5}$$

The transfer function of the motor with the load is given as:

$$W(s) = \frac{k}{(s+1)(2s+1)} \tag{6}$$

Let us analyze the system in Fig. 3 consisting of 13 cascades whose transfer function for the *i*-th cascade is described by:

$$W_{pi}(s) = \frac{k}{\mu_i s(s+1)(2s+1)} \tag{7}$$

In the quazy steady state for the *i*-th cascade the next relations are given:

$$\lim_{s \to 0} sW_{pi}(s) = \frac{k}{\mu_i} \tag{8}$$

$$V_{i,s} = \frac{k\mu_i}{\mu_i + k}\Phi\left(V_{i-1,s}\right) \tag{9}$$

where $V_{i,s}$ is the velocity of the the *i*-th transporter in the quazy steady state. For $\mu_i = 1$ and $V_0 = 1$, equation (9) becomes:

$$V_{i,s} = \frac{k}{1+k}\Phi\left(V_{i-1,s}\right), i = 1,\ldots,13 \tag{10}$$

Fig. 4 shows the behavior of trajectories of cascade system (10) for six characteristic values of parameter *k*. This figure is obtained using the next M-file:

```
% the appearance of bifurcation and chaos in system (10) with trapezoidal nonlinearity transition, (5)
y=zeros(14,1);
k=6.8;
y(1)=1;
for i=2:14
   if y(i-1)<0,
      y(i)=0;
   elseif 0<=y(i-1)&y(i-1)<2,
         y(i)=(k*2.5*y(i-1))/(1+k);
   elseif 2<=y(i-1)&y(i-1)<=3,
         y(i)=(k*5)/(1+k);
   elseif 3<=y(i-1)&y(i-1)<=5,
         y(i)=(k*(-2.5*y(i-1)+12.5))/(1+k);
   else
         y(j,i)=0;
   end;
end;
for i=1:13
     x(2*i)=y(i);
     x(2*i-1)=y(i);
 end;
 for i=1:12
     z(1)=0;
     z(2*i)=y(i+1);
     z(2*i+1)=y(i+1);
     z(26)=y(14);
end;
   a=[0:0.01:2]; b=(k*2.5*a)/(1+k);
   SUBPLOT(3,2,4)
   plot(a,b,'k')
   hold on
   plot(a,a,'k')
   a=[2:0.01:3]; b=(k*5)/(1+k);
   plot(a,a,'k')
   plot(a,b,'k')
   a=[3:0.01:5];
   b=k*(-2.5*a+12.5)/(1+k);
   plot(a,b,'k')
   line(x(:),z(:))
   xlabel('x');
   ylabel('f(x)');
   plot(a,a,'k')
```

For $k = 1$ system (10) is stable if the nonlinearity transition is given with (5), i.e., the outputs of almost all cascades are equal to 2.5. For $k = 2$ bifurcation appears. The value of even cascades outputs is

2.7778, and the value of odd cascades outputs is 3.3333, only the first cascade output is 1.6667. The second bifurcation appears for $k = 4.4$. The cascades outputs have approximately one of the next four values: 1.8861, 2.3586, 3.8421 and 4.0741

System, then, enters the chaotic regime, the outputs of all cascades are different and shown in Fig. 4 for $k = 6.8$. For $k = 10$, cascades outputs have approximately one of the next three values: 1.0331, 2.3479 and 4.5455. Chaos appears, again, in system (10), which is shown in Fig. 4 for $k = 19.9$.

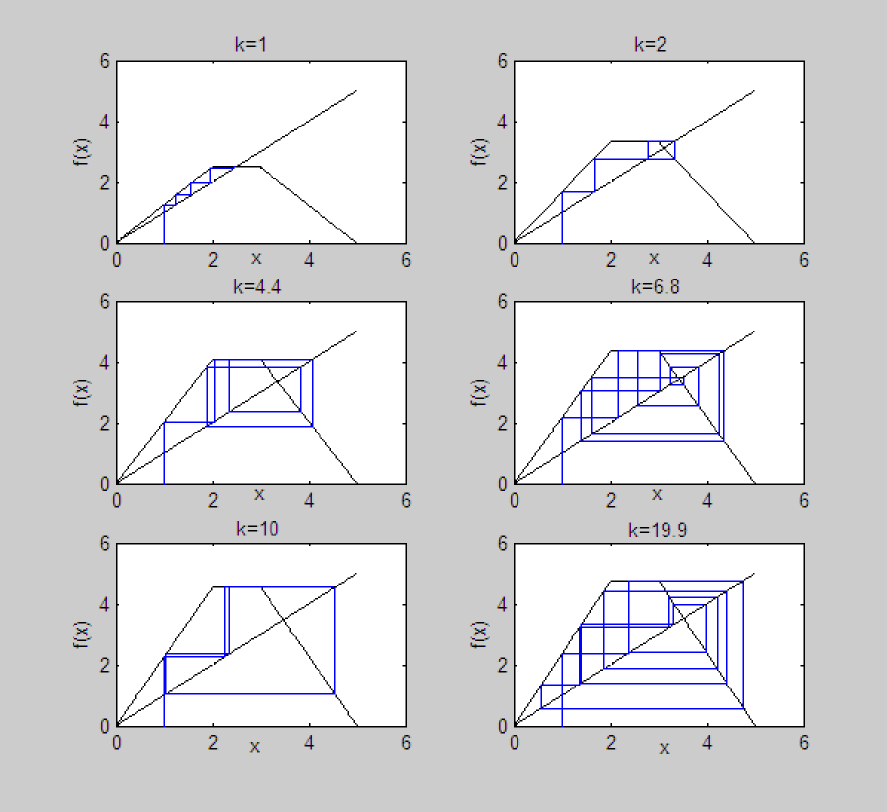


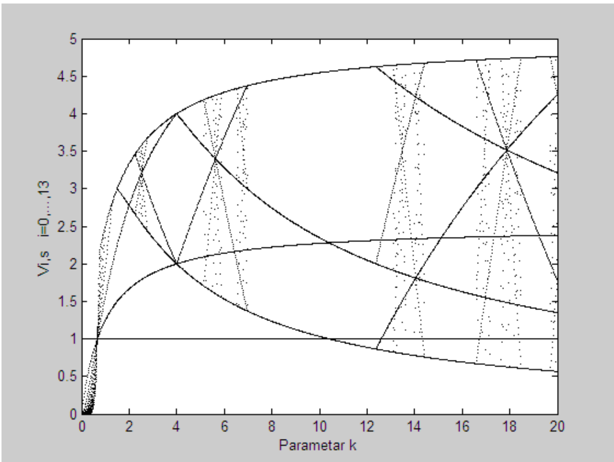
Figure 4. Bifurcation and chaos appearance in system (10) with nonlinearity transition (5)

Generating the bifurcation diagram of cascade system (10), and the phase portrait $(V_{i,s}, V_{i+1,s}), i = 0, \ldots, 12$ as a function of implicit parameter *k* is done using the next M-file (Figs. 5a and 6):

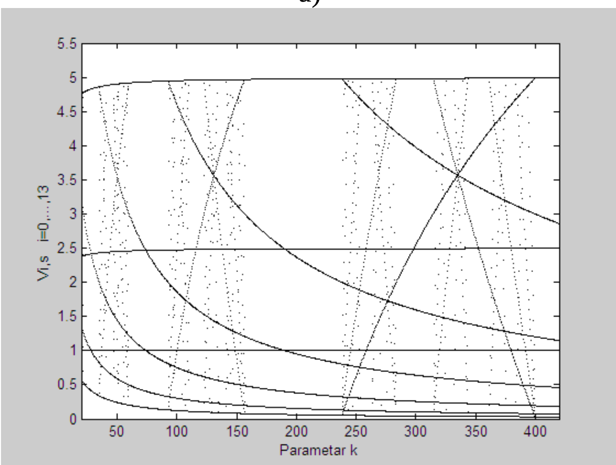
```
% generating the bifurcation diagram and the phase portrait (Vis, Vi+1,s) %i=0,...,12
% of system (10) for trapezoidal nonlinearity transition, (5)
V=zeros(1001,14);
k=[0:0.02:20]';
for j=1:1001,
V(:,1)=1;
end;
figure(1)%bifurcation diagram
plot(k,V(:,1),'k')
xlabel('Parametar k');
ylabel('Vi,s   i=0,...,13');
for i=2:14
   for j=1:1001,
      if V(j,i-1)<0,
        V(j,i)=0;
      elseif 0<=V(j,i-1)&V(j,i-1)<2,
            V(j,i)=(k(j)*2.5*V(j,i-1))/(1+k(j));
      elseif 2<=V(j,i-1)&V(j,i-1)<=3,
            V(j,i)=(k(j)*5)/(1+k(j));
         elseif 3<=V(j,i-1)&V(j,i-1)<=5,
```

```
            V(j,i)=(k(j)*(-2.5*V(j,i-1)+12.5))/(1+k(j));
         else
            V(j,i)=0;
         end;
        hold on
        figure(1)
        plot(k(j),V(j,i),'k')
        hold off
        hold on
        figure(2)%phase portrait
        plot(V(j,i-1),V(j,i),'k')
        hold off
     end;
end;
figure(2)
xlabel('Vi,s   i=0,...,12');
ylabel('Vi+1,s');
hold off
```

In Figs. 5a and 5b, the dependences of cascades velocities, $V_{i,s}(i = 0,\ldots,13)$ in steady state, on amplification *k* are shown. It can be seen that for the small amplification (Fig. 5a), all cascades have approximately the same outputs. At higher amplification, the first bifurcation appears and the consequence is the chaos appearance in transportation system (Figs. 5a, 5b). Transportation system, in the case of trapezoidal nonlinearity transition, (5), does not become unstable not even for the higher values of amplification *k*. This is shown in Fig. 5b.



a)



b)

Figure 5. Bifurcation diagram of cascade system (10) with nonlinearity transition (5) for: a) $k \in [0, 20]$ and b) $k \in [0, 450]$

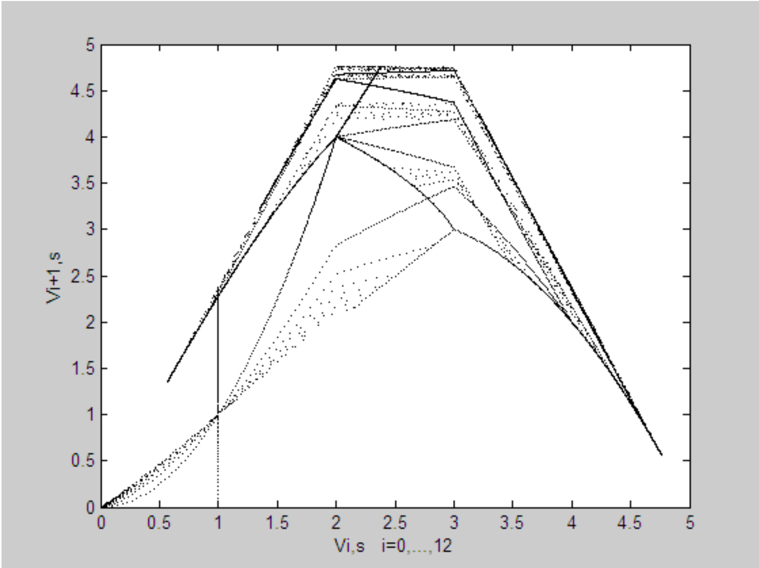


Figure 6. Phase portrait $(V_{i,s}, V_{i+1,s})$, $i = 0,\ldots,12$ as a function of implicit parameter k, ($0 \le k \le 20$), of cascade system(10) with nonlinearity transition (5)

In Fig. 7 the „escape - time" diagram is given which shows the degree of expansion for each point in the region (k, V_0), i.e., in the plane of control parameter k and the input velocity, V_0, of cascade system described by (10), (5). The point color is determined depending on the number of iterations required for point to exceed the value of cascade output 4.5. This diagram is obtained using the next M-file:

```
%„escape - time" diagram of cascade system (10), with
% trapezoidal nonlinearity transition (5)
v=[0.5:0.01:2.5]';%input velocities vector
k=[8:0.06:20]';%gain vector
maxbrit=13;%the cascade number
for i=1:201
   for j=1:201
      gotovo=0;
      l=0;
      a=v(i);
      b=k(j);
      while a<=4.5&gotovo<maxbrit,
      if a<0,
         a=0;
      elseif 0<=a&a<2,
         a=(b*2.5*a)/(1+b);
      elseif 2<=a&a<3,
         a=5*b/(1+b);
      elseif 3<=a&a<=5,
          a=(b*(-2.5*a+12.5))/(1+b);
       else
           a=0;
        end;
         gotovo=gotovo+1;
         l=l+1;
         if l>7,
          l=l-8;
      end;
       end;
       scatter(k(j),v(i),45,l)
       hold on
    end;
end;
```

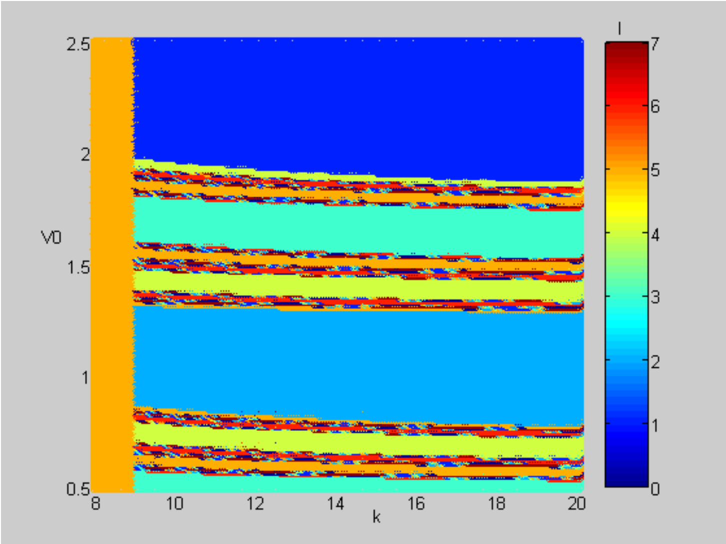


Figure 7. “Escape-time” diagram of cascade system (10) with trapezoidal nonlinearity transition (5)

CONCLUSION

In this work was examined the occurrence of bifurcations and chaos at cascade connected nonlinear transportation systems with trapezoidal nonlinearity transition. Simulation of bifurcation and „escape-time“ diagrams is done for these nonlinear cascade systems in steady state (when $t \to \infty$). Cascade system does not have to become unstable after the chaotic regime, when each cascade has diffrent outputs. Whether the system will remain stable or not, depends on the choice of nonlinear function. The paper confirmed that in the case of trapezoidal nonlinearity transition cascade system remains stable for all values of amplification *k*.

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DETERMINING OF CORRECTIONAL VALUES OF WORKING RELIABILITY OF INTEGRAL PARTS OF CIRCUIT – THE SPINNING BOX OF ROTOR SPINNING MACHINE

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Abstract: Based on exploitational values of reliability of parts the correctional values of reliability are obtained. Optimal model of safety includes working values of parts with allowed risk, and the band of absolute safe work of analyzed circuit is clearly visible and it is placed between the values of showed curve of dependability $M_{\xi}(t)_{BP} = f(t)$.

Key words: box spinning, OE spinning machine, reliability, exploitation.

1. INTRODUCTION – DESCRIPTION OF CIRCUIT OF THE SPINNING

The system of power transfer in the circuit – the spinning box is shown in image 1 and consists of the following integral parts which are divided based on processing stream of carded tape (raw material which is being processed). When we determine the exploitational values of reliability which express approximate values of working reliability of integral parts of analyzed circuit with maximal security (area of their time of safe work and area of decreasing of their reliability) for their more precise determination a determination of their correctional values is used. This had for a goal to determine total transfer function of working reliability of parts of analyzed circuit to get the most accurate values of reliability. Correctional values of reliability from exploitational data are shown on images 2 and 3.

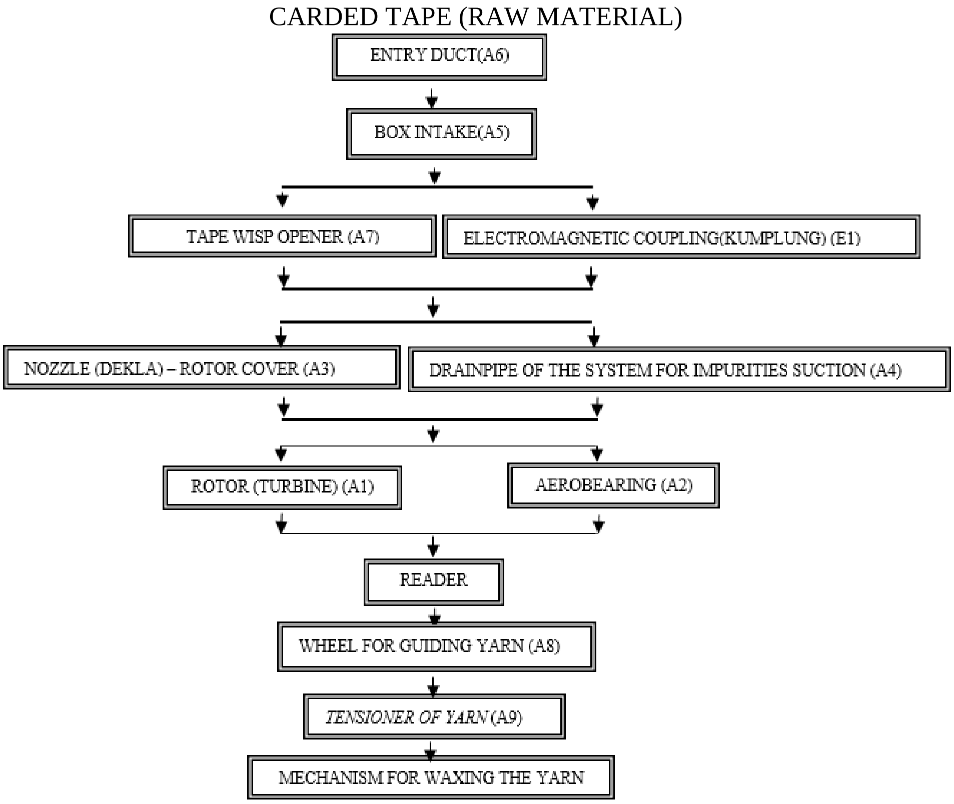

Figure 1. The system of power transfer in the circuit – the spinning box

Correctional values of reliability are get as a quotient of an empirical function of density of distribution from empirical values ($f_e(t)$) and function of intensity of breakings ($\lambda_e(t)$) in a time interval of exploitational work of parts of circuits (analysis included exploitational working time of integral parts of the circuit in a period of $13000 \leq \Delta t_i \leq 21000$ hours) and it is determined with the expression:

$$P_i\ (t) = \frac{f_{e_i}(t)}{\lambda_{e_i}(t)} \tag{1}$$

The obtained correctional values will further to be used in forming of value tables of transfer functions of circuit of the spinning box $G_{BP}(t)$ based on which shapes of curves are determined $f\,(G_{BP}(t), t)$ which determine the shape of statistical distribution of reliability i.e. from the shape of the curve the distribution of reliability which corresponds mostly to the shape is taken.

Conclusion

From the shape of curves of correctional values of reliability of integral parts of analyzed circuit $P_i(t)$, i.e. according to the inclination of the curve, intervals of reliability can be analytically predicted, which will be used later as a basis in determining of proper reliability (reliability obtained from statistical distribution). Analysis showed the following conclusions:

I) Analysis of working reliability of integral parts of analyzed circuit without the application of procedures of technology for preventive maintenance:
  - The highest working reliability have integral components A8, A9, A10, whose reliability is maximal and is the result of $P_{A8}(t)$ = $P_{A9}(t)$ = $P_{A10}(t)$ = 1,0 and lasts in time interval of over $\Delta t_i \geq 20000(h)$.
  - Based on the shape of the curve $f(P_i(t),t)$, i.e. according to their inclination in table 1 sequence of values of reliability and working time components is shown. Analysis included the intervals of reliability after the first lesser value of maximal value.

Table 1. Values of intervals of correctional reliabilities in dependence of analyzed working time interval of integral parts of analyzed circuits on which the procedures of technology of preventive maintenance were not implemented

Mark of integral part	Time interval of analyzed work of integral part $\Delta t_1 \leq \Delta t_i \leq \Delta t_2$	Interval of reliability for analyzed time interval $\boldsymbol{\Delta} P_{i1} \leq \Delta P_i \leq \Delta P_{i2}$
The circuit of the spinning box		
A6	13000÷14000	1,0÷0,828
A5	13000÷14000	1,0÷0,9÷0,868
A7	13000÷16000	1,0÷0,514
E1	13000÷14000	1,0÷0,615
A3	13000÷14000	1,0÷0,72
A4	13000÷16000	1,0÷0,523
A1	13000÷14000	1,0÷0951÷0,927
A2	13000÷14000	1,0÷0,952÷0,927
E2	13000÷16000	1,0÷0,806

II) Analysis of working reliability of integral parts of analyzed circuits on which the procedures of technology of preventive maintenance were implemented:

- The highest working reliability have integral parts A8, A9, A10, which reliability is maximal and is $P_{A8-0}(t) = P_{A9-0}(t) = P_{A10-0}(t) = 1{,}0$ and lasts in time interval of $\Delta t_i \geq 20000(h)$.
- Based on the curve shape $f(P_{i-0}(t),t)$, i.e. according to their inclination, order of reliability values and working time of parts during the time of these reliabilities is shown in table (table 2). Analysis included intervals of reliability after the first lesser value of maximal value.

Table 2. Values of intervals of correctional reliabilities in dependence of analyzed working time interval of integral parts of analyzed circuits on which the procedures of technology of preventive maintenance were implemented

Mark of integral part	Time interval of analyzed work of integral part $\Delta t_{1-0} \leq \Delta t_{i-0} \leq \Delta t_{2-0}$	Interval of reliability for analyzed time interval $\boldsymbol{\Delta} P_{i-01} \leq \Delta\ P_{i-0} \leq P_{i-02}$
The circuit of the spinning box		
A6	13000÷15000	1,0÷0,8
A5	13000÷15000	1,0÷0,88
A7	13000÷16000	1,0÷0,7
E1	13000÷15000	1,0÷0,475
A3	13000÷15000	1,0÷0,831
A4	13000÷16300	1,0÷0,67
A1	13000÷15000	1,0÷0,376
A2	13000÷15000	1,0÷0,552
E2	13000÷16300	1,0÷0,88

2. DETERMINATION OF STATISTICAL METHOD OF RELIABILITY DISTRIBUTION OF ANALYZED CIRCUIT

In order to determine statistical method of reliability distribution it is necessary to form models and determine transfer functions of reliability of analyzed circuit. For determining of tables of transfer functions of circuit of the spinning box of spinning $G_{BP}(t)$ correctional reliability values were used $P_i(t)$.

2.1. Forming models and determining transfer functions of reliabilities of analyzed circuit based on empirical data

Forming models included the layout of parts of circuits according to the processing of yarn i.e. according to marks in order of parts in the fault tree.
Parts are respectively arranged in circuit, from the entry duct to the mechanism for waxing the yarn in the spinning box. For these reasons a model of a block diagram is shown. The model is more complex and includes the layout of the parts in the spinning box including their functionality and purpose, and for that reason a reduction of more complex structure of block diagrams.
Based on obtained final expressions of transfer functions of analyzed circuits ($G_p(t)_{BP}$- for the spinning box), and in them by changing the values of reliability of parts$P_i(t)$ for time intervals $13000(h) \leq \Delta t_i \leq 20000(h)$ tabular values for zones of reliability significance are obtained, from which the curves of reliability of functions of analyzed circuit are constructed (table 3)
I) A model of block diagram of transfer function of reliability in the circuit of the spinning box
For completion – reduction of this model its final completion in obtaining the transfer function of circuit reliability will be implemented $G_p(t)_{BP}$.As seen on image 2 it is an open system of automated control of reliability. The model is shown on image 2.
I Step: Determining of partial blocks of reliability

P_{p1}(t) = P_{E1}(t) • P_{A7}(t), P_{p2}(t) = P_{A4}(t) • P_{A3}(t), P_{p3}(t) = P_{A1}(t) • P_{A2}(t),P_{p4}(t) = P_{A8}(t) + P_{E2}(t), P_{p5}(t) = P_{A9} (t) + P_{A10}(t)

II Step (Figure 3)

Values of partial blocks of reliability are: P_{p6}(t) =P_{A6}(t) +P_{p1}(t),P_{p7}(t)=P_{p4}(t) + P_{p1}(t).

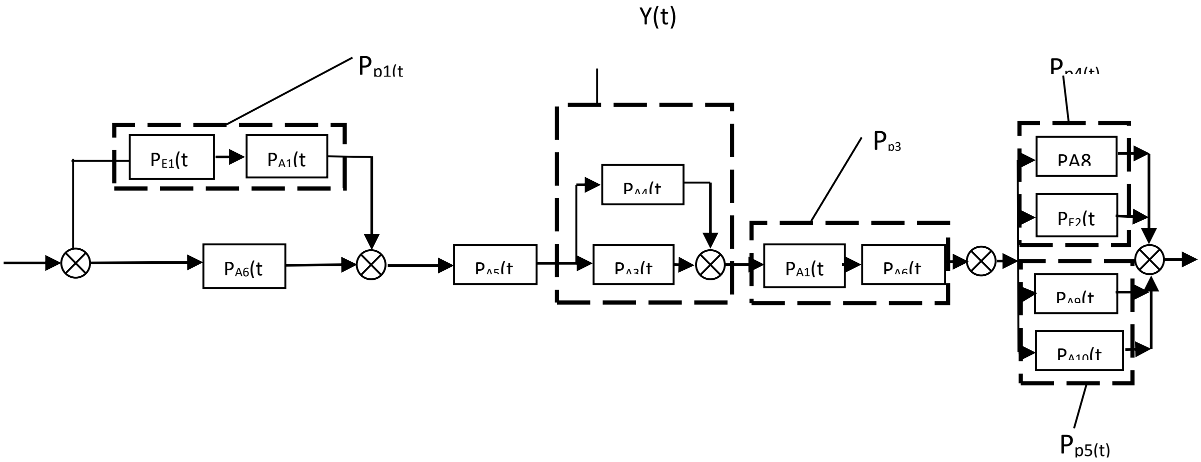

Figure 2. Initial model of a block diagram of the transfer function of reliability in a circuit of the spinning box

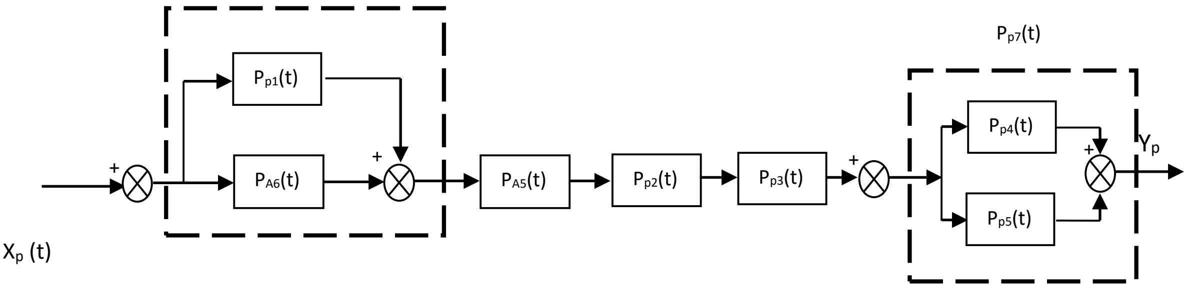

Figure 3. Reduction of a block diagram in the II step for the circuit of the spinning box

The final equation of reliability value based on partial reliability values for the circuit of the spinning box is:

G_{BP}(t)=$\frac{Y_p(t)}{X_p(t)}$=(P_{A6}(t)+P_{p1}(t))·P_{A5}(t)·(P_{A4}(t)+P_{A3}(t))·P_{A1}(t)·P_{A2}(t)·(P_{p4}(t)+P_{p5}(t))=(P_{A6}(t)+P_{E1}(t)·P_{A7}(t))·P_{A5}(t)·(P_{A4}(t)+P_{A3}(t))·P_{A1}(t)·P_{A2}(t)·(P_{A8}(t)+P_{E2}(t)+ P_{A9}(t)+P_{A10}(t)=P_{A1}(t)·P_{A2}(t)·P_{A5}(t)·{(P_{A6}(t)+P_{E1}(t)·P_{A7}(t)}·(P_{A4}(t)+P_{A3}(t))·(P_{A8}(t)+P_{E2}(t)+P_{A9}(t)+ P_{A10}(t))

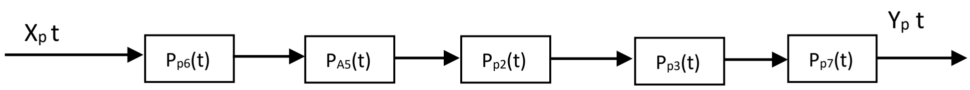

Figure 4. Reduction of a block diagram in the III step for the circuit of the spinning box

$G_{BP}(t)_p$=P_{A1}(t)·P_{A2}(t)·P_{A5}(t)(P_{A4}(t)+P_{A3}(t))· {(P_{A6}(t)+P_{E7}(t)·P_{A7}(t))}·(P_{A8}(t)+P_{E2}(t)+P_{A9}(t)+P_{A10}(t))

2.2. Forming of value tables of transfer functions of the circuit of the spinning box $G_p(t)_{BP}$

Tables are formed based on final expressions of transfer reliability functions in dependence of working time interval of circuits.

Based on obtained values, a diagram of dependability is completed *f*($G_p(t)_{BP}$,*t*) (image 6.).

A display of transfer function of reliability values of the circuit of the spinning box is shown in tables (table3.)

Table 3. Values of transfer functions of reliabilities of the circuit of the spinning box in dependance of the values of its reliability

Values of Reliabilit $P_i(t)$	Transfer function of reliability of the subsystem of spinning box $G_p(t)_{BP}$	
1,0	Shaded areas present the final limit of satisfying reliability in analysis	16
0,9		8,078
0,8		3,775
0,7		1,6
0,6		0,5972
0,5		0,1875
0,4		0,0458
0,2		0,0006
0		0

Note: Shaded areas $P_i(t)$ included values P_i (t)≥0,5 because values below this limit are not taken into consideration (they include areas in which there is a necessity to repair the circuit which will be further elaborated at determining reliability values in cases of chosen statistical distribution).

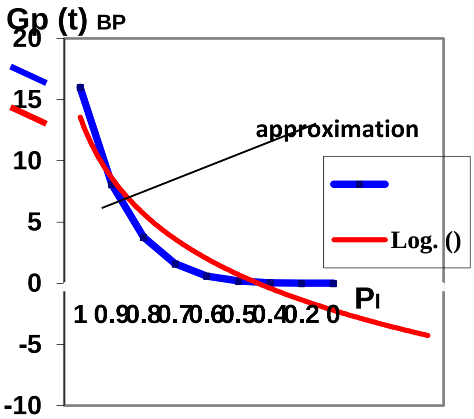

Figure 5. The graph of transfer function of spinning box with approximation $G_p(t)_{BP}$

Conclusion: Curves*f*($G_p(t)_{BP}$,*t*) correspond according to their shape to lognormal curves, and for that reason for a choice of statistical distribution of reliability a lognormal distribution will be chosen. According to this distribution a correction of reliability of every integral part of the analyzed circuit will be executed.

2.3. Determining of correctional values of working reliability of parts of the circuit in case of lognormal statistical distribution

On displayed graph of transfer functions $G_{BP}(t)_P$, a statistical distribution of reliability is determined on which basis further corrections of working reliability of integral components of analyzed circuits will be carried out and values of relevant reliability will be obtained.
In order to obtain as accurate as possible results for determination of reliability of safe work of parts of analyzed circuit of OE – spinning machine (circuit of the spinning box) correctional values of reliability based on lognormal statistical distribution of reliability as a chosen distribution will be used.

Correctional values of reliability are obtained with a chosen statistical distribution of reliability in the form of:

R_i = 1 – $F(t)$ = 1 - $\int_0^t \frac{1}{\sigma \cdot t \cdot \sqrt{2\pi}} e^{\frac{1}{2}\left(\frac{\ln t-\mu}{\sigma}\right)} dt$.

Introducing the substitution: $z = \frac{x-\mu}{\sigma} = \frac{\ln t-\mu}{\sigma}$ and by differentiating$t$,

$z = \left(\frac{\ln t-\mu}{\sigma}\right) \Rightarrow \frac{dz}{dt} = \frac{\frac{1}{t}\sigma}{\sigma} = \frac{1}{t.\sigma} \Rightarrow z = \frac{dt}{t.\sigma}$

Since $R_i(t)$ = 1 - $\int_{-\infty}^{z} \varphi(z)dz$, $\varphi(z)$ = t·σ ·$f(t)$

then the final expression for calculating the working reliability of parts of analyzed circuits:

$R_{i(t)} = \frac{f(t)}{\lambda(t)} = \frac{\varphi(z)}{\lambda(t) \cdot t \cdot \sigma}$

It should be pointed out that σ is a standard deviation of a natural logarithm, and its values are read from tables for normal statistical distribution.

3. TESTING OF A MODEL ON THE CIRCUIT OF THE SPINNING BOX

Testing of a model on the circuit of the spinning box is performed according to the obtained numerical values of a constituent of the optimal model of safety of functioning of its work.

Figure 5 displays curves of dependability of frequency of safety from exploitational working time of integral parts of spinning box for the optimal model of safety. The optimal model of safety includes working values of parts with allowed risk. The displayed image clearly shows area of absolute safe work of the analyzed circuit and it is placed among the values of displayed curves of dependability $M_\xi(t)_{BP}$ = f (t). From the obtained diagram it is easy to conclude that the risky area of functioning safety of work of the circuit of the spinning box in the period of its work of 13 300 (h). For that it is necessary to pay attention in this exploitational period i.e. around this period to conduct a continuous control of values of amplitudes of mechanical oscillations on the chosen measuring points. Also, on a displayed diagram periods of time of changing of all necessary integral parts of the circuit are marked in order to obtain the highest values of safe functioning.

It has to be mentioned that the optimal model of safe functioning of work of spinning box formed in the working areas of integral parts with allowed risk, because with the risk that is not allowed we are entering in a risky working field of the circuit and there should be an immediate intervention in a form of replacement of warn out integral parts or circuit repair.

Image 6 displays curves of dependability of frequency of safety in dependence of exploitational working time of integral parts of the spinning box for the optimal model of safety. The optimal model of safety includes working values of parts with the allowed risk. Shown image clearly displays the area of absolute safe work of the analyzed circuit and it is placed among the values of the shown curves of dependability $M_\xi(t)_{BP}$ = f (t). From the obtained diagram we can clearly conclude that the risky area of functioning safety of work of the spinning box in the time of its work of 14 250 (h). For that reason it is necessary to pay attention in this exploitational period i.e. around this period to perform continuous control of values of amplitudes of mechanical oscillations on chosen measuring points. . Also, on a displayed diagram periods of time of changing of all necessary integral parts of the spinning box are marked in order to obtain the highest values of their safe functioning.

It has to be mentioned that the optimal model of safe functioning of work of spinning box formed in the working areas of integral parts with allowed risk, because with the risk that is not allowed we are entering in a risky working field of the circuit and there should be an immediate intervention in a form of replacement of warn out integral parts or circuit repair.

h	$M_{\xi}(t)_{BP}\cdot 10^{10} \Rightarrow \lambda_{\max}$	$M_{\xi}(t)_{BP}\cdot 10^{6} \Rightarrow \lambda_{\min}$
13000	8.274	5.517
13023	11.37	7.59
13068	7.145	5.69
13080	11.3	7.537
13300	3.184	2.123
13600	11.7	7.803
15000	19.524	13.015
15040	19.836	13.222
15060	20.062	13.491
15080	20.15	13.437
15190	21.053	14.033
15400	22.863	15.243

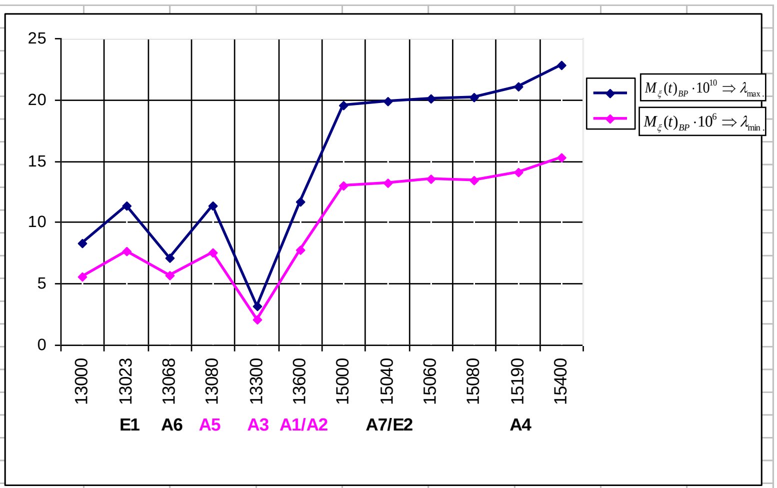

Figure 6. Diagram of frequency of safety in dependence of exploitational working time of integral parts of the circuit of the spinning box on which the procedures of technology of preventive maintenance were not implemented – optimal model

h	$M_{\xi}(t)_{BP}\cdot 10^{12} \Rightarrow \lambda_{\max}$	$M_{\xi}(t)_{BP}\cdot 10^{8} \Rightarrow \lambda_{\min}$
13983	4.89	5.05
14001	4.9	4.95
14100	4.69	4.842
14128	4.7466	4.9
14151	5.938	6.124
14200	5.048	5.211
14250	4.0571	4.153
14251	9.818	10.138
14300	15.09	15.57
14301	6.399	6.6
14450	6.81	7.023
14600	8.7	8.97
14962	13.442	13.86
15000	7.519	7.837
15630	9.624	10.031
15730	13.777	14.36
15805	19.224	20.037
15905	10.673	11.15
15995	11.04	11.53
16000	11.06	11.55
16150	14.983	15.648
16300	20.658	21.577
17000	15.295	14.97

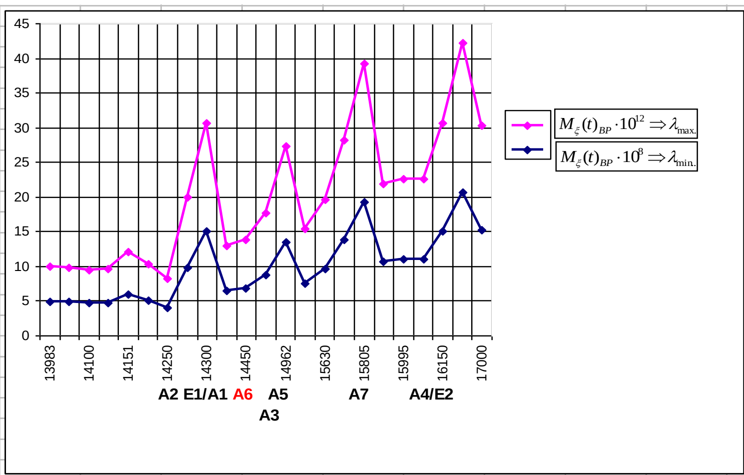

Figure 7. Diagram of the frequency of safety in dependence of exploitational working time of integral parts of the circuit of the spinning box on which the procedures of technology of preventive maintenance were implemented – optimal model

4. CONCLUSION

The optimal model of safe functioning of work of spinning box is formed in the working areas of integral parts with allowed risk, because with the risk that is not allowed we are entering in a risky working field of the circuit and there should be an immediate intervention in a form of replacement of warn out integral parts or circuit repair.
Further examination of the model will be suggested based on spatial plan of the spinning machine and it will include location measuring points with the aim of influencing of mechanical oscillations on them, and it will include two spinning points one opposite the other.
All these components together with analyzed integral parts of the circuit of the spinning box and the circuit for winding spools with the finished yarn make a total power transfer per one point of spinning of a section (as it was already mentioned one section has 20 spinning boxes). By introducing of an additional model which is based on the analyzed circuit models, an overall influence of mechanical

oscillations per every section unit of OE spinning machine can be carried out and in that way contribute in carrying out a full diagnostics of unwanted consequences which occur under the influence of an increased level of mechanical oscillations.

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OPTIMIZING OPERATIONS SEQUENCE USING MODERN PARTICLE SWARM OPTIMIZATION ALGORITHM

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Abstract: Operation sequencing as a part of the process planning problem has shown to be a complex optimization challenge in the literature belonging to the class of non-deterministic polynomial problems. Here, operation sequencing problem is represented on a simplified example from the literature and optimized using a metaheuristic approach. Precedence relationships among operations for appropriate features are defined and adjacency matrix is formed. The optimization methodology is based on the modern particle swarm optimization algorithm (mPSO) whose performances are enhanced by chaotic maps and genetic components, such as crossover and two mutation operators. The main focus of this work is on reducing the optimal cost of operation sequence with determination of an appropriate tool and TAD candidate for each operation in a sequence. One case study was conducted in order to test the performances of the proposed algorithm which proved to be very efficient for the simplified operation sequencing problem with excluded machines alternatives.
Key words: operation sequence, particle swarm optimization, chaotic maps

INTRODUCTION

Computer aided process planning (CAPP) is a key technology between computer aided design (CAD) and computer aided manufacturing (CAM). Its main focus is on generating all the required information for converting a raw material block into a finished product. Generally, most important activities of process planning are the following [1, 2]:

- Acceptance and analysis of the input data, definition of machining faces or extraction of manufacturing features,
- Selection and definition of raw materials,
- Definition of a process plan,
- Selection and definition of machining processes, setups and setup sequences,
- Selection and definition of machining operations and their sequences,
- Selection and definition of machines, tools, fixtures, measuring instruments and other manufacturing resources,
- Selection and definition of cutting parameters and cutting strategies,
- Generating programs for NC manufacturing systems,
- Determination of machining time and cost, and
- Generating appropriate technological documentation (routing sheet, operation sheets, programs, etc.)

This paper is focused on a single activity of process planning which is the determination of optimal machining sequences. Operation selection joined with operation sequencing together form a famous process planning optimization problem that has been widely and thoroughly studied in the literature. Assuming the fact that we already have manufacturing features and machining operations selected and used as the input data for a part we want to optimize, the next necessary step of process planning is to find the best possible sequence of the given operations.

On one side, the operation selection is a task based on form-feature geometry, its technological requirements as well as mapping these specifications to appropriate operations or series of operations [3]. On the other side, operation sequencing may be formulated as an optimization problem, considering the fact that a number of possible sequences may grow with the increase of a number of operations and manufacturing resources required to perform those operations. These resources are considered to be appropriate machines and tools and are defined as the operation method as expressed in [4].

As an important segment of operation sequencing, precedence relationships among operations should be defined according to the geometrical and manufacturing interactions between features. These relationships form precedence constraints which make sure these interactions are not violated and machining process can be performed effectively.

Accordingly, numerous optimization techniques have been used and implemented so far in order to optimize operation sequences in process planning. Since the operation sequencing is very complex to formulate using classical techniques such as branch and bound, linear programming, dynamic programming and so on, metaheuristic algorithms have proved to be most effective for solving hard optimization problems which operation sequencing surely is. Literature is enriched with many different sources focusing on these intelligent implementations on process planning or operation sequencing problems. Authors have performed different case studies in the past in which some of the proposed prismatic parts are still used as benchmark models in the studies being conducted today. The following are some of the proposed methodologies for optimization of operation sequencing activity.

Authors in [5] developed simulated annealing technique for solving operation sequencing problem in which machining cost was used as an optimization criterion. Precedence cost matrix and reward-penalty matrix were used by the algorithm in order to ensure the feasibility of operation sequences. The authors tested this methodology on three case studies in which the SAT proved its efficiency.

Another example of metaheuristic implementation can be found in [6] which expressed the ant system algorithm for operation sequencing problem. The ASA methodology represents the advanced ant colony optimization algorithm emphasizing the improvement in precedence checks and ant cycles which largely influenced decrease in computational time of the algorithm. The authors demonstrated the efficiency of ASA on two interesting case studies.

Authors in [7] implemented modified clustering algorithm on operation sequencing problem whose main characteristic is that the precedence constraints are firstly checked for selecting all possible next operations of the last operation in the sequence and their traveling costs are compared to choose the optimal feasible operation which has the minimum traveling cost in the sequence. Cost matrices are also used to determine precedences among operations and machining cost that is optimized.

Two important aspects of process planning, operation sequencing and setup planning were emphasized in case studies conducted in [8, 2]. Authors in [8] used genetic algorithm for optimizing integrated setup planning and operation sequencing including machining cost as an objective function and constraint matrix for generating feasible operation sequences. In [2], authors applied interesting approach which is not based on metaheuristics but on a simulation technique performed within SolidCAM system. Here, matrix of anteriorities was introduced and the machining time was optimized. The results of the simulation experiment showed to be very good in terms of setup plans and operation sequences for one case study.

The concept of our methodology is concerned with the implementation of particle swarm optimization algorithm for operation sequencing problem which is enhanced by adding chaotic behavior and genetic components such as crossover and mutation. The following section puts an emphasis on this methodology whose efficiency and robustness were proved on later described case study.

MODERN PARTICLE SWARM OPTIMIZATION ALGORITHM

Kennedy and Eberhart [9] are the founders of particle swarm optimization algorithm who was firstly introduced in 1995 and since then, numerous engineering problems have been solved using this method. The PSO is a population-based metaheuristic algorithm belonging to the field of swarm intelligence, one of the branches of artificial intelligence, Figure 1. It is an evolutionary algorithm that is inspired by social behavior of organisms in swarms, flocks or schools, such as flocks of birds or schools of fish. It imitates the natural process of foraging, of how for instance birds or fish behave during this intelligent process of search for food. Each individual’s velocity and position are the crucial elements which affect personal and social experience of the swarm (i.e. flock or school). Their mutual collaboration towards achieving their goal as a group largely inspired the authors to create a computational method for solving different problems in the world.

The classical PSO starts with the initialization of a number of individuals called particles which are encoded in a predetermined way depending on the problem type. This population is then evaluated using appropriate fitness function which determines how good each particle is. Particles move in the search space of the problem with appropriate velocity which defines diversity of the search. Their positions are being updated across generations and they represent potential solutions to the problem. These solutions are evaluated in each generation of the particle swarm search where the local best position represents the best position achieved by a single particle so far while the global best position represents the best position achieved by a single particle in entire population. The global best is therefore the optimal solution found by the algorithm. Figure 2 illustrates the movement of particles and updating of their velocities.

Figure 1. Swarm intelligence in illustrated form

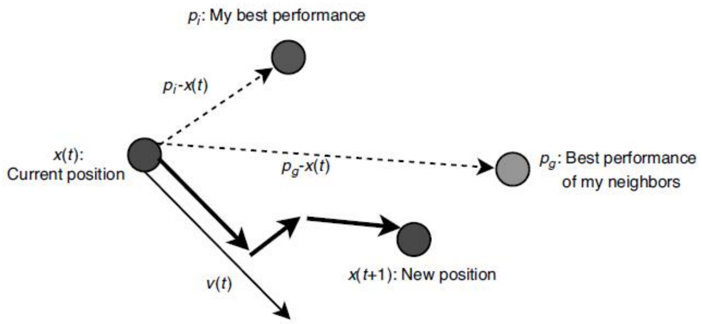

Figure 2. Movement of a particle in the search space and particle velocity update [10]

Taking into account the complexity of operation sequencing problem, even though the example in this paper is quite simplified, the classical PSO methodology showed to be very obsolete and inefficient for the given conditions. As many other instances in the literature, when approaching complex engineering problems classical metaheuristics require additional modifications in order to make them more robust and efficient for the search. This affects better algorithm convergence and much greater probability of finding the optimal solution.

Here, the classical PSO's performance is enhanced by adding chaos and genetic components. On one side, chaotic behavior has already been introduced in [11]. These authors developed the chaotic PSO for solving complex process planning problem whose capabilities were greatly improved by chaotic maps that were used to express stochasticity, ergodicity and certainty, properties which are crucial for the effective search. So, in that name, chaotic maps are included in this concept of the modern PSO and their representation is given in Figure 3. There are ten different chaotic maps which greatly influenced diversity of the mPSO. They are adopted from [12].

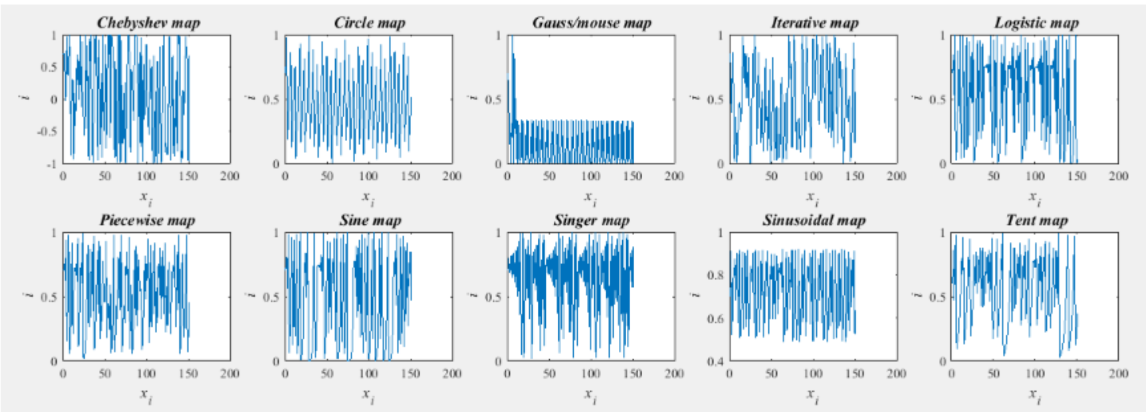

Figure 3. Chaotic maps generated in Matlab environment

The second modification that was done to the classical PSO was the introduction of the standard components of genetic algorithm, crossover and mutation. Genetic algorithm is one of the most famous evolutionary algorithm and metaheuristics whose components are still very adaptable to many novel algorithms. The purpose of crossover is to generate new individuals (offsprings) from the old ones (parents) and in that case provide new solutions and hopefully better ones. Mutation, on the other

side, has the diversity properties, whose purpose is similar to the one of chaotic maps, to enable diversification, spreading the search and making sure as many neighborhoods of the search space are traversed. Two mutation operators are introduced in this study. One is shift mutation, based on the random selection of two operations in the sequence and exchanging their position in the sequence. The other mutation operator is concerned with changing tool and TAD candidate of a randomly selected operation from the sequence.
The next chapter will discuss the case study that was selected for testing the proposed mPSO algorithm.

CASE STUDY – RESULTS AND DISCUSSION

In order to test performances of the proposed algorithm, a case study has been conducted. The prismatic housing part illustrated in Figure 4a is adopted from [8] and represents the model used in our study.
According to the rules for recognizing and extracting manufacturing features for the observed part, features for the given housing part are extracted and illustrated in Figure 4b [2]. Based on the extracted features, appropriate machining operations are recommended and listed in Table 1. Associated tools with their cost indices for performing these operations are also proposed and given in Table 2.
Following the defined machining operations and recommended tools, potential tool and TAD candidates are defined according to the study conducted in [2]. These alternatives are represented in Table 3.
The notable difference from the study in [8] that we adopted is the omission of machine candidates which assumes the fact that all operations for machining the defined features are performed on a single machine. Therefore, the entire machining process consists of alternative sequences of operations, their selected tool candidates and alternative setups on one machine.

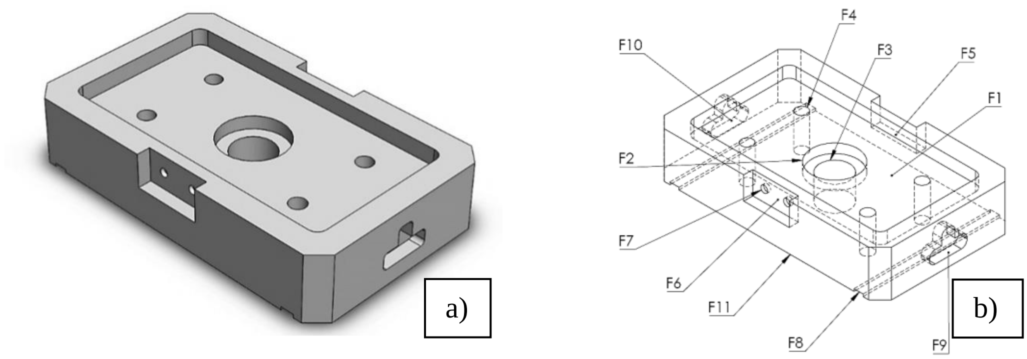

Figure 4. Prismatic housing part, a) 3D solid model b) Extracted features of the model [2]

Table 1. Recommended machining operations for housing part [2]

Features	Rough machining	Semi finish	Finish
F1	Rough turning		
F2	Counter boring		
F3	Drilling	Core drilling	Reaming
F4	Drilling		
F5	Rough milling		
F6	Rough milling		
F7	Drilling		
F8	Rough milling		
F9	Rough milling		
F10	Rough milling		
F11	Rough milling	Finish milling	

Table 2. Recommended cutting tools with cost indices [2, 8]

Tool ID	Tool name	Cost index
T1	Drill 1	7
T2	Drill 2	5
T3	Drill 3	3
T4	Counterbore drill	8
T5	End mill cutter 1	7
T6	End mill cutter 2	10
T7	End mill cutter 3	15
T8	Core drill	30
T9	Reamer	20
T10	Slot cutter	15

Table 3. Available tool and TAD candidates for the defined operations [2]

Features	Operation ID	Tool candidates	TAD candidates
F1	Rough milling (op1)	T5, T6, T7	-z
F2	Counter boring (op2)	T4	-z
F3	Drilling (op3)	T2, T3	+z, -z
	Boring (op4)	T8	+z, -z
	Reaming (op5)	T9	+z, -z
F4	Drilling (op6)	T2	+z, -z
F5	Rough milling (op7)	T5, T6, T7	-y, -z
F6	Rough milling (op8)	T5, T6, T7	+y, -z
F7	Drilling (op9)	T1	+y
F8	Rough milling (op10)	T6, T7	+z
		T10	+y, -y
F9	Rough milling (op11)	T5, T6, T7	-x
F10	Rough milling (op12)	T5, T6, T7	+x
F11	Rough milling (op13)	T5, T6, T7	+z / +x, -x / +y, -y
	Rough milling (op14)	T5, T6, T7	+z / +x, -x / +y, -y

Considering the given input data for optimization of operations sequence, an appropriate precedence relationships may be primarily defined based on which an adequate adjacency matrix can be formed. The following Table 4 represents the precedence relationships for the housing part. Table 5 represents the adjacency matrix for the housing part with associated numbers referring to precedencies among operations in a sequence. The number of machining operations for the housing model matches the number of rows and columns in the represented adjacency matrix. Each number 1 represents the precedence relationship meaning that operation in the observed row has to be performed prior to the operation in the observed column. Number 2 in the matrix means that the observed operations has to be performed in the same setup.

Table 4. The precedence relationships between operations for the housing part

Operations	Precedence relationships
op1	op1 must be performed prior to op3 and op6
op3	op3 must be performed prior to op4
op4	op4 must be performed prior to op2 and op5
op8	op8 must be performed prior to op9
op13	op13 must be performed prior to op14
op14	op14 must be performed prior to op6 and op10

Table 5. Adjacency matrix of the housing model

	Op1	Op2	Op3	Op4	Op5	Op6	Op7	Op8	Op9	Op10	Op11	Op12	Op13	Op14
Op1	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Op2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Op3	0	2	0	1	0	0	0	0	0	0	0	0	0	0
Op4	0	1	0	0	1	0	0	0	0	0	0	0	0	0
Op5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Op6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Op7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Op8	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Op9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Op10	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Op11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Op12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Op13	0	0	2	0	0	0	0	0	0	0	0	0	0	1
Op14	0	0	2	0	0	1	0	0	0	1	0	0	0	0

The problem of optimizing operation sequence of the housing part contains 14 machining operations with the total of 10 tool candidates and 6 tool approach direction (TAD) candidates which vary for each feature (Table 3). According to the defined input data for the mPSO algorithm, the required parameters are set as follows: population size is 80 individuals, maximal number of generations is 200, the inertia coefficient is set to be 0,5 with linear decrease to 0,2 during generations, personal and social acceleration coefficients are set to 1, probability of crossover is 60% and probabilities for two mutation operators, shift mutation and candidate mutation, are both 40%.

The algorithm was coded in Matlab programming environment and tested on the laptop with Windows 7 OS, Intel Core i3 2,10 Ghz and 3 GB RAM. The mPSO was run 10 times for each chaotic map resulting in total of 100 runs. The best operation sequence with associated tool and TAD is the one with the least total machining cost and is represented in Table 6.

Table 6. Optimal operation sequence with tools and TADs

11	8	1	7	12	13	14	10	3	4	5	9	6	2
5	5	5	5	5	5	5	1	3	8	9	1	2	4
-x	-z	-z	-z	+x	+z	+z	+z	+z	+z	+z	+y	-z	-z
Total machining cost: 869 Fitness: 0,0012 Chaotic map: Iterative													

Taking into account chaotic character of the mPSO, the most suitable results were obtained by using Iterative and Circle map, with the slight emphasis on the latter which provided better average result in 10 runs.

Also, as included in [2, 8], setup planning may also be mentioned in this case study. The setup planning strategy for the observed housing part is represented in Table 7. Comparing to the study in [8], the number of setups for the housing is the same, six different fixture setups. On the other side, authors in [2] obtained better results focusing on setup planning and obtained five different setups by using the simulation technique developed in CATIA software. Worth mentioning is the thing that CATIA software only provides estimation of machining times which is not included in the optimization performed in this study.

The algorithm performed well assuming the fact the operation sequencing problem was simplified and machine candidates are excluded from the study meaning that the entire machining process for the housing is performed on a single machine but in different setups as shown in Table 7.

Table 7. Setup planning strategy for the housing part

Setup number	Tools	TADs	Executing operations
1	5	-x	Op11
2	5	-z	Op8, Op1, Op7
3	5	+x	Op12
4	5,5,1,3,8	+z	Op13, Op14, Op10, Op3, Op4
5	1	+y	Op9
6	3	-z	Op6, Op2

CONCLUSION

This paper introduced the modern particle swarm optimization algorithm for solving the operation sequencing problem which belong to the group of complex optimization problems in the literature. The task is to find the optimal operation sequence for performing machining operations in an appropriate order while generating manufacturing features on an observed part. Among sequences, algorithm is also employed in determining appropriate cutting tools and tool approach directions for each machining operation in a sequence. Chaotic maps as well as genetic components, crossover and mutation were adopted in order to improve the performance of the algorithm. The case study focusing on the housing, a prismatic part adopted from the literature, was conducted in order to test the performances of the proposed mPSO algorithm. Precedence relationships among features and were defined for the given problem and the appropriate precedence matrix was formed to ensure feasibility of the sequence. Machining cost was used as an objective of optimization and the results showed that the mPSO performed very well in the search process for finding optimal operation sequences using different chaotic maps. Machining process for the housing used a single machine with different number of setups which is also represented in this study. The future research will be focused on process planning optimization and the implementation of novel metaheuristic algorithms that have been recently introduced in the field of swarm intelligence.

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Session 2.

Energetics and Process Technique

COMPUTER SIMULATION FOR SELECTION OF THE ORDER FOR THE LAYERS FROM THE WALL OF INDUSTRIAL COOLERS

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Abstract. In this paper a mathematical model and computer software for calculating the thickness of the insulation layers (panels) from the walls of the industrial coolers based on the order of their installation was developed. A numerical example is given that is tested on an existing industrial cooler in Bitola, Macedonia. In order to calculate the thickness of the thermal insulation it is necessary to consider a multilayer barrier (wall) where for each layer the thickness is known, except for the insulation material which should be calculated. With the determined geometric and physical characteristics of the wall, it is necessary to determine the temperature at each point of the construction. By connecting these points, the temperature change through the construction creates dependency with its thickness. After calculating the actual specific heat flux, the temperatures between each layer of the wall are calculated. For improved monitoring of the change in the partial pressure of the saturated water vapor through the layers of the wall, the thickness of the insulating material is divided into approximately five parts, and then a table of temperature changes and the corresponding value of the partial pressure of the saturated aqueous vapor is created. In order to avoid condensation of the water vapor when it passes through the wall, a certain condition must be fulfilled. With certain measurements adopted, a computer simulation was created and measurements calculated. The computer simulation enables swift and accurate calculation of thickness of the insulation at multilayer bulkheads found at industrial coolers, and allows selection of the location for the insulation and steam barrier in the bulkhead.
Keywords: Insulation coolers, industrial cold storage, panels, multilayer bulkheads, steam barrier.

CALCULATION OF THICKNESS OF THE HEATING INSULATION

A multilayer wall is considered, where for each layer the thickness is already known, except for the insulating material. The insulating material thickness is calculated by Equation (1),

$$\delta_{iz} = \lambda_{iz} \cdot \left[\frac{t_n - t_v}{q} - \left(\frac{1}{\alpha_n} + \sum \frac{\delta_i}{\lambda_i} + \frac{1}{\alpha_v}\right)\right] \quad \text{m} \tag{1}$$

where,

λ_{iz} W/mK - coefficient of thermal conductivity of the insulation,
α_n W/m^{2}K - coefficient of passage of heat from the external air to the outer side of the compartment,
α_v W/m^{2}K - coefficient of heat transfer from the inner side of the barrier of the internal air.

The recommended value for the specific heat flux is: $q=11$ W/m^2, [1].

CHANGE OF TEMPERATURE

With the determined geometric and physical characteristics of the compartment, it is necessary to determine the temperature at each point of the construction. By connecting these points we determine the change of temperature through the construction depending on its thickness, Fig. 2. If we use the heat resistance of each junction instead of the thickness of the construction, then the change in temperature is a straight line.
The designed temperature of the external air is Equation (2),

$$t_{sp} = 0{,}4 \cdot t_{sm} + 0{,}6 \cdot t_{mm} \quad {}^{o}\mathrm{C}, \tag{2}$$

where,

t_{sp} ^{o}C - average monthly temperature for the warmest month of the last 10 years,
t_{mm} ^{o}C - the average value of the maximum temperatures of the warmest month of the last 10 years.

The external air temperature is,

$t_n = t_{sp} + 6$ ^{o}C, - for outer bulkheads on the south side,
$t_n = t_{sp} + 15$ ^{o}C, - for ceilings with a flat roof,
$t_n = t_{sp} + 10$ ^{o}C, - for ceilings under roof with ceiling space,
$t_n = t_{sp} + 15$ ^{o}C, - for floors on the ground.

After calculating the thickness of the isolation, it is adopted and then the true specific thermal flux is calculated by Equation (3),

$$q = \frac{t_n - t_v}{\frac{1}{\alpha_n} + \sum \frac{\delta_i}{\lambda_i} + \frac{\delta_{iz}}{\lambda_{iz}} + \frac{1}{\alpha_v}} \quad \mathrm{W/m^2}, \tag{3}$$

After calculating the actual specific heat flux, the temperatures between each layer in the compartment are calculated by Equation (3),

$$t_x = t_n - q \cdot R_x \quad {}^{o}\mathrm{C}, \tag{4}$$

where,

R_x m^{2}K/W - heat resistance for each layer of the compartment.

CHANGE OF PARTIAL PRESSURE OF SATURATED WATER STEAM

To better monitor the change in the partial pressure of saturated water steam through the layers of the compartment, the thickness of the insulating material is divided into approximately five parts. A table of temperature changes and the corresponding value of the partial pressure of saturated steam is then made [2].
The specific water vapor flux is Equation (5),

$$W = \frac{p_n - p_v}{H_v} \quad \mathrm{kg/m^{2} \cdot K}, \tag{5}$$

where,

p_n Pa - the partial pressure of the water steam of the external air,
p_v Pa - the partial pressure of the water steam of the internal air,
H_v m^{2}sPa/kg - resistance to diffusion of water steam through the barrier.

The resistance of water steam diffusion through the compartment is calculated by Equation (6),

$$H_v = \sum \frac{\delta_i}{\mu_i} \quad \mathrm{m^2sPa/kg}, \tag{6}$$

where,

μ_i kg/msPa - coefficient of steam permeability of the layer.

The partial pressure of the water steam between each layer in the compartment is calculated by Equation (7),

$$p_x = p_n - W \cdot H_x \quad \text{Pa,} \tag{7}$$

In order not to condense the water steam, when passing through the barrier, the dependency must be fulfilled,

$p_x < p_x''(t_x)$ i.e., $t_x < t_x''(p_x)$, Fig. 3

For a stationary heat flux through a multilayer barrier it is calculation by Equation (8),

$$q = k \cdot (t_{sp} - t_v) = k' \cdot (t_{sp} - t_x) \quad \text{W/m}^2\text{,} \tag{8}$$

where,

$$k = k' \cdot \frac{t_{sp} - t_x}{t_{sp} - t_v} \quad \text{W/m}^2\text{K,} \tag{9}$$

In order not to condensate the water steam, to the contact of the steam barrier and the compartment, the temperature t_x, which is at that place, must be greater than the amplitude of saturation t_x'',for the partial pressure that governs in that place,

$$k < c \cdot k' \cdot \frac{t_{sp} - t_x}{t_{sp} - t_v} \quad \text{W/m}^2\text{K,} \tag{10}$$

where,

c = 0,95 - coefficient of safety.

NUMERIC EXAMPLE

According to the mathematical model, a computer program was created, which was tested on an existing industrial refrigerator in Bitola.
The thickness of the insulation on the southern outer wall composed of several layers is calculated, Fig. 1, with the following features.
- The insulation material which is going to be used is polystyrene and it is going to be installed after the bituminous steam boiler. Its features are given in Table. 1.
- Average monthly temperature of the warmest month of the last 10 years, [4], t_{sm} = 25 °C.
- Average value of the maximum temperatures of the warmest month of the last 10 years, [4], t_{mm} = 30 °C.
- Coefficient of passage of heat from the external air on the outside side of the compartment, [1], α_n = 30 W/m²K.
- Coefficient of heat transfer on the inside of the internal air compartment, [1], α_v = 8 W/m²K.
- Inner temperature, t_v = 20 °C.
- Relative humidity of the external air, [4], φ_n = 40 %.
- Relative humidity of the internal air, [4], φ_v = 70 %.

Table 1. Characteristics of the compartment [1].

Type of layer	**δ mm**	**λ W/mK**	**$\mu \cdot 10^{12}$ kg/msPa**
1. facade plaster	20	0,870	37,500
2. brick wall	250	0,870	29,200
3. cementene mortar	20	1,280	25,000
4. bituminous steam barrier	5	0,760	0,012
5. insulating material		0,041	3,000
6. intertwined network			
7. cement mortar	20	1,280	25,000

Table 2. Change the temperature across the barrier

Starting layer number	**δ m**	**R mK/W**	**t °C**
1	0,000	0,000	34,660
2	0,020	0,023	34,425
3	0,270	0,310	34,490
4	0,290	0,326	34,330
iz	0,295	0,333	34,263
6	0,495	5,211	-18,564
7	0,515	5,226	-18,723

Comparison of the calculated and accepted sizes,
- Calculated outdoor temperature, t_n = 34 °C.
- Accepted external temperature, t_n = 35 °C.
- Calculated insulation thickness, δ_{iz} = 184 mm.
- Accepted insulation thickness, δ_{iz} = 200 mm.
- True specific heat flux, q = 10,2 W/m.

The thickness of the isolation is divided into five equal parts, and the temperature change through the insulating layers is shown in Table. 3.

Table 3. Change of the temperature through the insulation layer.

Serial Number	**δ m**	**t °C**
1	0,000	31,263
2	0,040	21,297
3	0,080	11,332
4	0,120	1,376
5	0,160	-8,598
6	0,200	-18,564

Table 4. Penetration of moisture through the compartment

Starting layer number	**δ m**	**$H_v \cdot 10^{-9}$ m²sPa/kg**	**p Pa**	**p" Pa**
1	0,000	0,000	2251	5522
2	0,020	0,533	2249	5450
3	0,270	9,095	2211	4619
4	0,290	9,895	2207	4577
iz	0,295	426,562	370	4559
6	0,495	493,228	76	118
7	0,515	494,028	72	116

Table 5. Moisture penetration through the insulating layer

Starting layer number	δ m	$H_v \cdot 10^{-9}$ m^2sPa/kg	p Pa	p'' Pa
1	0,000	426,562	370	4559
2	0,040	439,895	311	2534
3	0,080	453,228	252	1342
4	0,120	466,562	193	674
5	0,160	479,895	134	294
6	0,200	493228	76	110

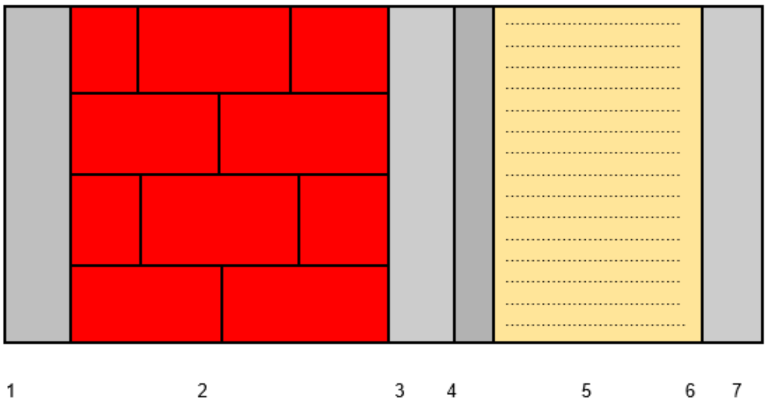

Figure 1. Construction of an external wall

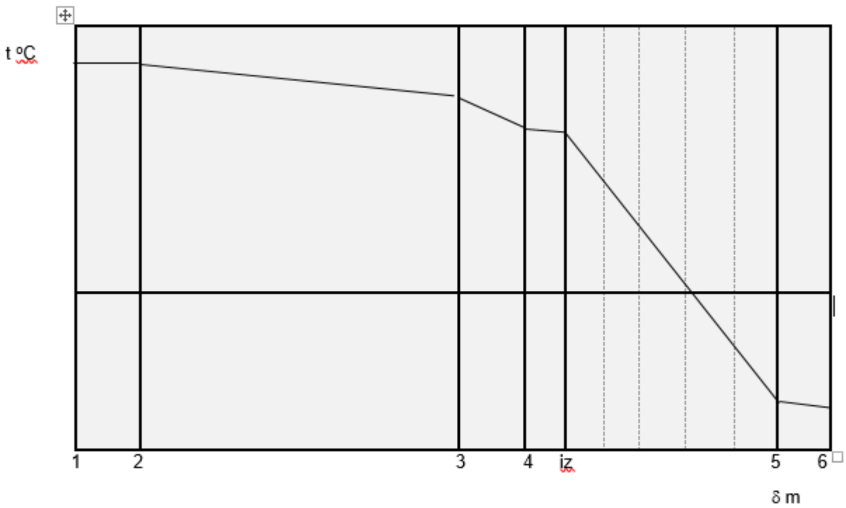

Figure 2. Change in temperature depending on the thickness of the compartment

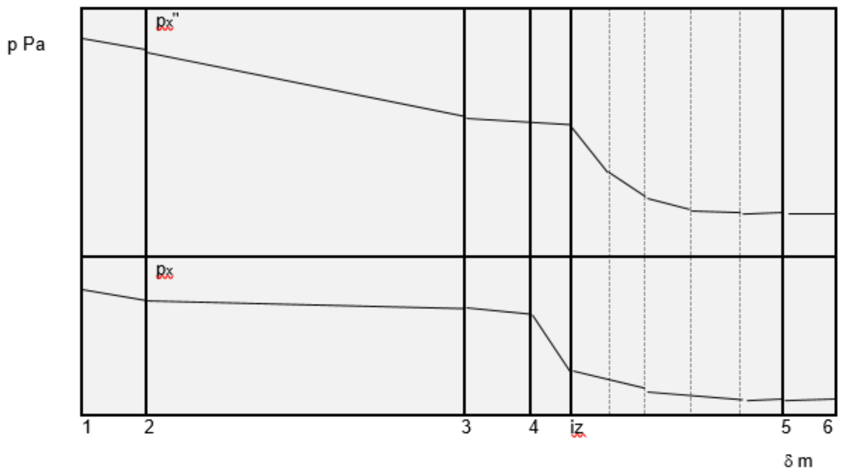

Figure 3. Change in the pressure depending on the thickness of the compartment

CONCLUSION

The aim of the paper is to provide a quick and accurate calculation of the insulation thickness at industrial coolers with multi- layered compartments. In addition it allows selecting the location of the insulation and the steam barrier in the compartment, in order to prevent the condensation of the steam somewhere between the layers of the compartment.

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ECONOMIC – ECOLOGICAL ESTIMATION OF HEAT PUMP PERFORMANCE – EXAMPLE FROM PRACTICE

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Abstract: Increasing energy efficiency is the fastest and cheapest way to meet the growing demand for energy, while at the same time meeting the environmental and economic challenges that arise with its consumption. The heat pump is notable as one of the solutions for these needs. Beside other adventages, heat pump is characterized by economic and ecological characteristics such as lower price of heat energy and strengthening the ecological profile.
Based on the example from the practice paper presents economy and ecology projection of heat pump performance which function in the bivalent system in coordination with the gas central heating boilers.
Key words: heat pump, economy, environmental protection, CO_2

INTRODUCTION

Rational consumption of primary energy, increased energy efficiency of the system, environmental protection, reducing CO2 emissions and protecting the ozone layer, reduction of fossil fuel consumption as well as cooling functions are characteristics of the heat pump which makes that mentioned device uses renewable energy sources in the most efficient techno-economic way [1].
Economic analysis refers to the application of scientific and technical principles for the cost problems, estimation and cost control, business and time planning and managing, as well as the analysis of profitability.
The aim of economic analysis (process, evaluation) in the field of engineering is to eliminate non-profit projects or identifying financial causes that obstruct the normal and profitable operation of the plant [2].
In economy analysis of energy systems in general, and especially in comparison of heat pumps with boilers on liquid fuels, there is a two basic parameters - investment and exploitation costs [3].

TECHNOLOGICAL DESCRIPTION OF HEATING SYSTEM

Plant for using geothermal energy with heat pump water-water/well function in the bivalent system in coordination with the system of the gas boilers using a floor heating system.
Implemented heat pump with capacity 233kW satisfies total heat demand, except in exceptional cases, when the external temperature decreases continuously below -18 °C for longer period.
Groundwater from a one drilled well of 35m deep is using as a heat source.
Heat pump is located in the substation and it is connected to the central floor heating system in the object. Heating by central heating with the gas boilers works in cases when the outdoor temperatures are low, i.e. when it is necessary that the temperature of the heating fluid be more than 45/35 °C and than heat energy is provided through two gas boilers with a total capacity of 250kW.
Underfloor heating works in heat mode 45/35 °C. In this mode, heat pump has the highest utilization, savings are about 75% [4].

INVESTMENTS

Investments or investment costs present total costs of some plant that are ready for commissioning and include following costs:

- Creation of complete technical documentation of the plant (projects, construction documentation and other) and equipment which include control of technical documentation,

- procurement and montage of whole equipment for plant,
- procurement and montage/production of pipeline system, measuring instruments and and measuring and control systems, construction of supporting structures, etc. and
- arranging the location of the building and construction of buildings, auxiliary (temporary) facilities, access roads, etc.

It is a one-time expense, which is not returning at the end of the plant's operating life (except in the amount of equipment residual value).
Else to the investment costs, there are operational and additional costs.
Operating costs are related to the continuous operation of the plant.
Additional costs are necessary for putting plant into operation and exploiting until the first profit is realized. These costs are called working capital and include initial expenses.
The value of an investment represents a static category, i.e. it does not depend on the operating time of the plant. Based on the value of the investment, a decision can be made to continue the work on the project, especially in cases of smaller investments or in cases of investing in non-profitable activities.
Also, investments in environmental protection or fire protection are investments that do not produce direct profits because there are no products that could be marketed.
The size of the investment does not provide data on the economic efficiency of investments but indicates the necessary financial sources for the realization of the project.

Investment of the bivalent system - upgrading the heat pump system to the existing gas central heating boilers system

Investment value of heat pump could be reduced with using bivalent system in heating [3].
With this bivalent system investment (upgrading heat pump system to the existing gas boiler system) it is anticipated using of sub-geothermal energy, respectively renewable energy, thus achieving significant effects of energy savings by about 75%.
Also, ecological effects are important, which will be presented in the further part of the paper.
Beside energy savings, important thing is qulity improvement of heating in objects without which money savings would have no real effect.
With this investment is predicted and realized following:

- Three heat pumps with heating capacity 233kW (COP = 4.44),
- submersible pump 7,5kW,
- drilling and construction of wells 35m depth, 150mm diameter,
- various types of pipes, pipe armature, pipe thermal insulation, arches of supporting elements, elbows, bonding materials,
- valves (ball, non-returnable, safety) and taps,
- container with valve,
- measuring instruments (manometer, thermometer),
- filling of excavation, instalation test, unexpected jobs, preparatory finishing works and
- other.

INVESTMENT ECONOMIC VALIDITY OF INSTALLED PLANT

As it can be seen from the above mentioned with this investment, a substation of the heat pump plant was added, which enabled the use of renewable energy and, consequently, an increase in energy efficiency.
The total value of the investment amounted 5,259,768.00 din.
With mentioned investment it has been realized:

- Numerous positive energy effects including on the first place worthwhileness and increased quality of heating and maintenance of the building,
- the installed system meet all conditions of the environmental protection,
- better terms from the aspect of safety work and working conditions,
- profit over the entire lifetime of the project (total earnings will be higher than total expenditures).

The above indicates that this investments meets the basic criteria and that the adoption of a positive decision on financing justified expected.

Economic winningness

By unit of power, the boiler plant has a lower investment value than a heat pump. However, while costs of power for the boiler plant is increasing every day, the energy consumption for the heat pump is very small, because the most of the heat is uses from the "environment".
The economics of the heat pump can be observed in several ways. The leading one is the one which is based on two basic data, amount of investment costs of implementing heat pump and maintenance costs, which is used in the next part [3].
The annual price of energy consumption for heat pump is: 371,322.18 din.
The annual price of energy consumption for heating on the gas is: 2.192.208,3 din.
Based on the above costs, the total annual savings is: 1,820,886.12 din.
While for the exploitation period of 15 years the total savings will amount: 27.313.291,8 din.
Remark: Shown energy prices correspond to the current prices with value-added tax (VAT). With the rising prices of energy, savings are linearly increasing [4].
The main characteristic of the investment is that the existing and additional factors are used in its process, and the effects after the completed works will be the results of both of them.
The effects of additional investments are results from a "without the project" and "with the project" analysis. The status "without the project" is the result of only the existing situation, and the status "with the project" presents both, existing and additional, so the difference between these two cases is the result of additional investments.
This difference presents basis for estimation of project efficiency, i.e. applying identical methods for estimation.

Profitability

Benchmark for this assessment are cash flows (financial and economic flow) for the whole economic period.
In the profitability analysis, the following criteria were used:

- Returning period of investments and
- the net value of the project.

Returning period of investments – time for returning the total amount of funds invested for the project realization is the necessary time that project income cover investments.
Based on the total value of the investments, which amounted 5,259,768.00 din. and the annual difference between the costs of heating on the gas and heating on the heat pump, which amounts 1,820,886.12 din., the repayment period of the investment is: 2 years and 9 months [4].
Remark: The repayment period of the investment is reflected in the current market prices of energy, with a constant trend of rising energy prices, the period of repayment of investments are decreasing.

ECOLOGICAL EFFECTS

Traditional heating methods have a very low degree of efficiency from 0.6 to 0.9, regarding to much of the heat goes with combustion products, a large storage space for fossil fuels is needed, and a huge amount of combustion products are releasing [5]. In addition fossil fuels are using irrational and their sources are exhaustive.

CO_2 emissions at the global, continental and national level

Table 1 shows CO_2 emissions from fuel combustion database from 2016. This database contains a wide range of CO_2 emissions for more than 150 countries and regions.

Table 1. CO_2 emissions from fuel combustion in millions of tons (1990.-2014.) [6]

Year	World	OECD Europe	NON-OECD Europe	Republic of Serbia
1990.	20502,5	3900,6	3940,1	62,0
1991.	20617,7	3931,0	3795,5	52,3
1992.	2059,6	3844,6	3423,3	48,1
1993.	20676,6	3790,2	3098,4	42,8
1994.	20781,3	3773,3	2737,0	39,0
1995.	21362,0	3824,2	2634,8	44,6
1996.	21822,7	3958,8	2537,2	51,7
1997.	22109,1	3885,5	2386,1	56,4
1998.	22254,9	3896,8	2364,1	56,3
1999.	22398,3	3859,9	2346,3	40,1
2000.	23144,5	3893,2	2377,0	43,0
2001.	23482,2	3938,8	2389,5	45,1
2002.	23884,1	3927,2	2402,0	48,6
2003.	24932,7	4032,6	2498,4	52,2
2004.	26110,2	4043,6	2482,5	56,4
2005.	27037,7	4027,7	2470,7	49,6
2006.	27890,3	4051,8	2565,1	51,7
2007.	28989,7	4017,9	2590,4	50,2
2008.	29164,8	3942,6	2641,2	48,3
2009.	28748,6	3672,5	2403,9	45,7
2010.	30450,4	3792,9	2536,7	45,9
2011.	31354,4	3648,6	2672,3	50,0
2012.	31592,9	3638,6	2605,5	44,6
2013.	32129,4	3560,4	2568,8	45,4
2014.	32381,0	3391,6	2446,1	38,1

Remark: OECD - Organisation for Economic Co-operation and Development)
Republic of Serbia is a member of OECD.
Emissions data are based on the IEA (International Energy Agency) world energetics balance sheets from 2016. and based on the methodologies list on the greenhouse effect of the intergovernmental panel for climate change IPPC (Intergovernmental Panel on Climate Change) from 2006. год.

CO_2 emissions of implemented bivalent system and its projections

The difference of impact of the heat pump with using geothermal energy on the environment in relation to heating on the fossil fuels, based on the described installed plant is shown through reduction of CO2 emissions as following:
The reduction of CO2 emissions into the atmosphere at an annual level is: 180 tons
Reduction of CO2 emissions in the atmosphere for a 15 year exploitation period is 2700 tons.
Remark: Data is received from official data of International Energy Agency (IEA) [4].

CONCLUSION

When it comes to renewable energy sources and the derivation of energy in a more economical way, heat pumps are not considered as "permanent" and the best solutions, but are "offered" as one of the solutions, which from an economic point of view should be analyzed, whenever their application is technically justified.
The dimensioning of the heat pump in extremely low temperature conditions would be uneconomical, because of that heat pump is upgrading to existing heating systems is practiced, creating a bivalent system. Since the heat pump is still most expensive heating source, its size should be determined

according to an optimum, which must include the meterological conditions and purpose of the pump, as well as the seasonal dynamics of its use.

ACKNOWLEDGMENT

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CRITICAL ANALISYS OF FORMULAS FOR THE LENGTH OF ELASTIC CABLES WITH SUPPORTS ON SAME OR DIFFERENT LEVELS

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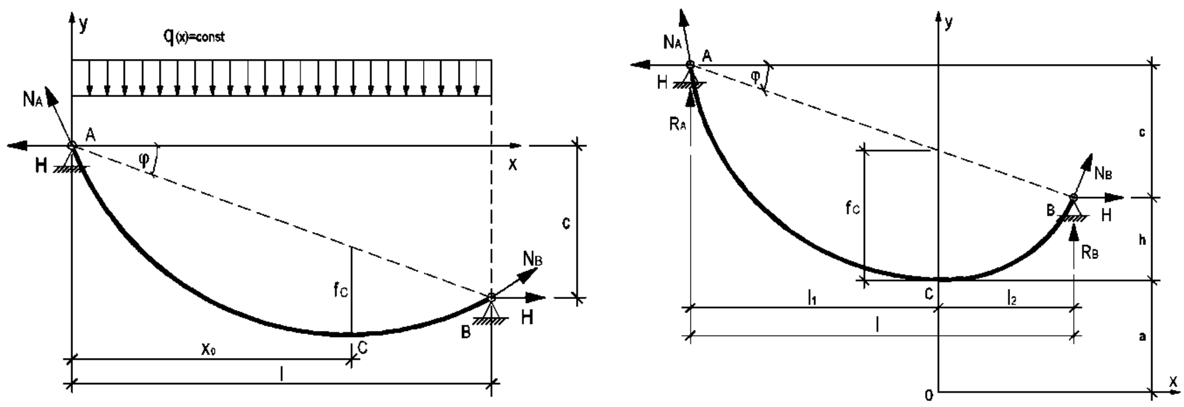
Abstract: The article presents a critical analysis of some formulas for calculation of the length of elastic cables. Also, a numerical analysis is performed to investigate the change of length in function of self-weight and different support levels.
Key words: cables, length, catenary, self-weight, different support levels

CABLE LENGTH IN CASE OF SUPPORTS ON DIFFERENT LEVELS. ASSUMPTIONS AND FORMULAS

The numerical analysis is made considering the following assumptions:

1. The cable has the same cross-sectional area and is of the same material for both static schemes.
2. The cable loading is one and the same for the different support levels. The different cases of loading (as a magnitude) are simulated by the loading parameter ql/H which is divided in steps of 0,25 (from 0,25 to 4). At the same time, the span length $l = 100m$ and the thrust $H = 500\ kN$ remain constant, and the change of the uniformly distributed load q is divided in steps of $1,25\ kN/m'$ - $from\ 1,25\ to\ 20\ kN/m'$.
3. The support levels are with a height difference of $5, 10, 15, 20, 40, 60, 80\ u\ 100m$.



a) static scheme „parabola” b) static scheme „catenary”

Figure 1. Static schemes for a cable with supports on different levels

The cable length is derived by the following formulas:

$$L = \frac{H}{q}\left(\sinh\frac{q}{H}l_1 + \sinh\frac{q}{H}l_2\right) + \frac{H.l}{2EA}\left(1 + \frac{H}{ql}\sinh\frac{ql}{H}\right) \tag{1}$$

which represents the exact catenary length equation,

$$L = \frac{l}{\cos\varphi} + \frac{D}{2H^2}\cos^3\varphi + \frac{H.l}{EA}, \tag{2}$$

suggested by Karnovski and Lebed in [1], and

$$L = l\left(1 + \frac{tg^2\varphi}{2}\right) + \frac{D}{2H^2} + \frac{H.l}{EA} \tag{3}$$

suggested by Kardjiev in [2].

CRITICAL ANALYSIS OF FORMULAS FOR LENGTH CALCULATION FOR CABLES WITH SUPPORTS ON DIFFERENT LEVELS. NUMERICAL RESULTS.

Certain parts of the following analysis are performed and presented in [3].
With span length $l = 100\,m.$ and support levels difference greater than $60\,m.$, the angle between the chord connecting the supports and the horizon becomes greater than 30^o.
This type of cables are usually called „steep" and are of limited interest for the conventional practice [2].
The analysis of **Figure.2** shows, that when the uniformly distributed load has small values (light cable), the three above mentioned formulas give similar results for the length. At that same time, with increase of the support levels difference results in greater difference in the results.

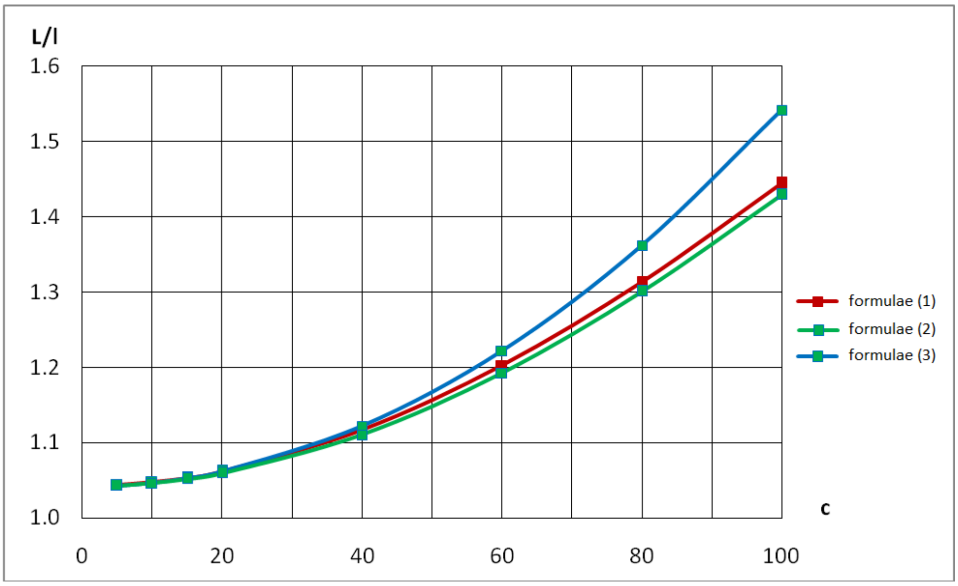


Figure 2. $\frac{L}{l}$ ratio in dependence of support levels difference c with $\frac{ql}{H} = 1$

Figure 3 shows that when q has moderately high value formulas (1) and (3) give close results for cables with relatively small difference in support levels. Formulae (2) always gives smaller cable length, and at the same time the difference between the similar value calculated by (1) and (3), and the result by (2) on the other hand, increases for steeper cables.

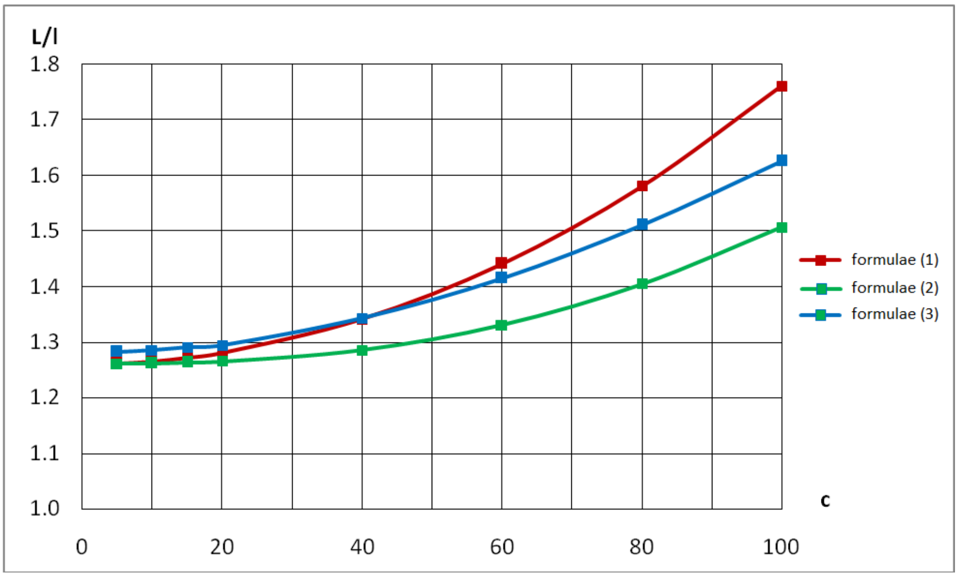


Figure 3. $\frac{L}{l}$ ratio in dependence of support levels difference c with $\frac{ql}{H} = 2,5$

We can see from **Figure.4** that for relatively high values of q (heavy cables) formulas (1) and (2) give relatively close results. At the same time formulae (3) **always** gives smaller cable length values. In steeper cables, that difference is considerable.

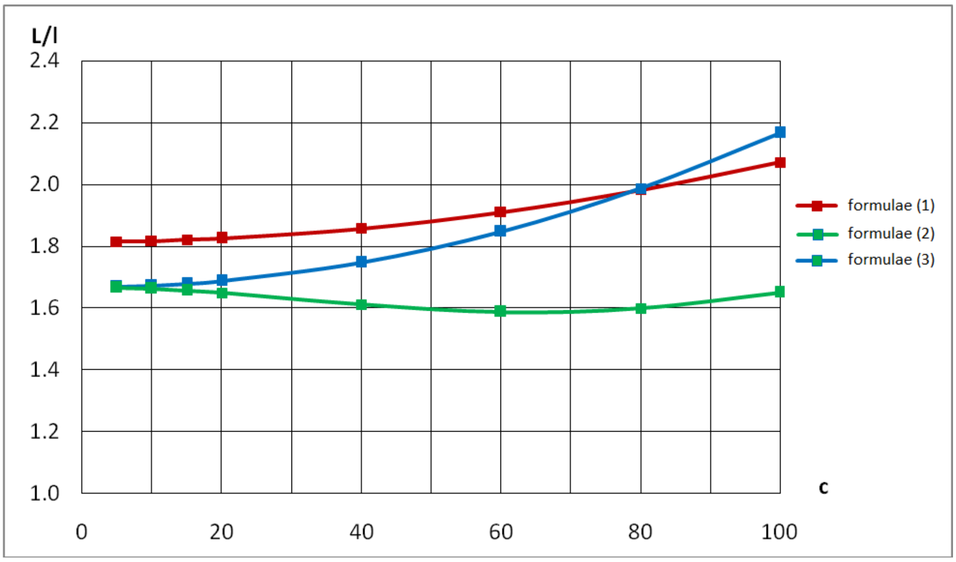


Figure 4. $\frac{L}{l}$ ratio in dependence of support levels difference c with $\frac{ql}{H} = 4$

Using formulae (3) for length calculation for heavy cables also leads to the following paradox: in relatively steep cables the calculated cable length is smaller than that for less steep cables!
Comparison of cable lengths according to (2) and (3) leads to:

$$L(V.2) - L(V.3) = \frac{D}{2H^2} \cdot a(\varphi) - l.b(\varphi), \qquad (4)$$

where the functions $a(\varphi)$ и $b(\varphi)$, are :

$a(\varphi) = (1 - \cos^3 \varphi)$; $b(\varphi) = \left(1 + \dfrac{tg^2\varphi}{2} - \dfrac{1}{\cos\varphi}\right)$ and are presented on Figure.5 below:

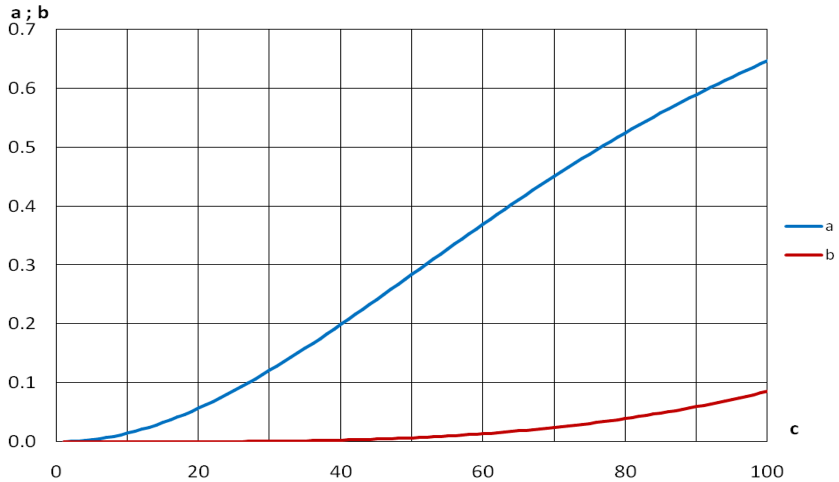


Figure 5. Functions $a(\varphi)$ and $b(\varphi)$

It is easily seen that equal cable length by the two formulas is obtained **only** in cables with supports on the same level. For cables with supports on different levels formulae (2) **always** gives greater value for the cable length.
Increasing the span length results in very rapid increase of the first additive in (4) in respect of the second additive. If the loading increases simultaneously, the additives difference becomes even more considerable.

ANALYSIS CONCLUSIONS

If we accept for base the results obtained from the (1), we can make the following conclusions:
For the most common cables used in conventional systems $\left(\textit{these are relatively light cables } {}^{ql}\!/_{H} \textit{ below } 1.5\right)$, the accuracy for practical needs is reasonable when using all three formulas (1), (2) and (3).
For moderately loaded cables with moderate support levels difference $\left({}^{ql}\!/_{H} \textit{ up to } 2.5 \textit{ and slope up to } 30^\circ\right)$, again all three formulas can be used. The difference in the results obtained by (1) compared to those when using (2) and (3) are of magnitude of 2-4%.
For moderately loaded cables with great support levels difference $\left({}^{ql}\!/_{H} \textit{ up to } 2.5 \textit{ and slope above } 30^\circ\right)$ and for heavy cables $\left({}^{ql}\!/_{H} \textit{ above } 2.5 \textit{ regardless the slope}\right)$ it is suggested only formulae (1) to be used.

SOME SPECIFICS OF THE APPROXIMATE SOLUTION FOR THE LENGTH OF CABLES WITH SUPPORTS ON THE SAME LEVEL. NUMERICAL RESULTS.

Cable length for cable with supports on the same level, loaded with uniformly distributed load, is calculated according to:

$$L = \int_0^l \sqrt{1 + \left(\frac{dy}{dx}\right)^2}\, dx\,, \tag{5}$$

The cable sag is $f = \dfrac{ql^2}{8H}$, so the cable length is :

$$L = \int_0^l \sqrt{1+\left(\frac{4f}{l}\right)^2\left(1-2\frac{x}{l}\right)^2}\,dx\,, \tag{6}$$

If (6) is represented by power series according to the rule $\sqrt{1+\varepsilon} \cong 1+\dfrac{\varepsilon}{2}-\dfrac{\varepsilon^2}{8}+\dfrac{\varepsilon^3}{16}-\dfrac{5\varepsilon^4}{128}+\dots$, the cable length becomes :

$$L = \int_0^l \left\{1+\frac{1}{2}\left[\frac{4f}{l}\left(2\frac{x}{l}-1\right)\right]^2-\frac{1}{8}\left[\frac{4f}{l}\left(2\frac{x}{l}-1\right)\right]^4+\dots\right\}dx\,, \tag{7}$$

Integration of (7) and considering of $f = \dfrac{ql^2}{8H}$, we obtain the following approximate expression for the cable length:

$$L = l\left[1+\frac{1}{24}\frac{q^2l^2}{H^2}-\frac{1}{640}\frac{q^4l^4}{H^4}+\frac{1}{7168}\frac{q^6l^6}{H^6}-\frac{5}{294912}\frac{q^8l^8}{H^8}+\dots\right], \tag{8}$$

In the numerical analysis the loading parameter ql/H is assumed to change in discrete steps of 0,25 ($from\;\; 0{,}25\;\; to\;\; 6$). The ratio $\dfrac{L}{l}$ in dependence of the number of members from (8) is then analysed. A, B, C, D and E on the figure below, represent the ratio between the length calculated from (1) and the same ratio calculated using the first 4 members of the power series in (8), respectively:

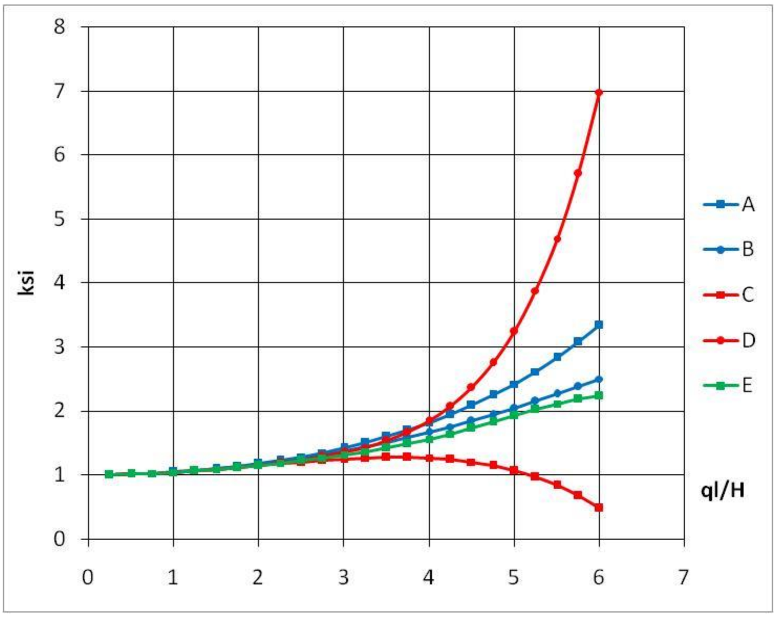


Figure 6. Ratio between cable lengths calculated from exact catenary formulae (1) and approximate solutions considering one or more members of (8)

From here a simple but very interesting conclusions can be made:

Opposite to intuition, taking into consideration more members from (8) results in **less accurate results**! Thus considering only the first two members gives better accuracy than considering more.
The authors suggest that either all members of (8) should be used with a more exact numerical solution, or just the first two - for calculations „by hand”.

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IMPROVED THERMAL ENERGY STORAGE WITH PCM – AN IMPORTANT PART OF EU PROJECT CONCEPT HOLISTIC ENERGY AND ARCHITECTURAL RETROFIT TOOLKIT (HEART)

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Abstract: European directive on the energy performance of buildings forced Europe toward more efficient use of energy in buildings. Different incentives among with subsidies made renovation of buildings in Europe possible. However majority of buildings retrofit are partially renovated by replacing particular component in the building system i.e. by applying envelope solutions only without regard to the rest of the building system. Within present paper the toolkit with holistic approach to energy retrofit of residential buildings is presented which is developed under EU funded project entitled HEART. Mentioned toolkit also optimizes energy performance of a building with synergetic operation between different subcomponents which operates according to an integrated logic. The toolkit platform effectively manages with different energy flows produced on-site by the PV plant or obtained from the grid deciding among direct use, thermal or electric energy storage or feeding in the grid as dictated by convenience and needs. Through this perspective the buildings' user evolves from being a consumer to a prosumer. The thermal energy storage in the buildings' system gives possibility to store electrical energy in form of thermal energy produced by heat pump which is powered by PV. This contributes to higher energy effectiveness of the whole system and step towards sustainability with high ratio of on-site use of self-produced energy. The improvement of sensible thermal energy storage with integrating phase change materials is presented with which higher energy density of storage unit is achievable.
Key words: retrofit, holistic approach, phase change materials, latent thermal energy storage

INTRODUCTION

Prudent and efficient utilization of renewable energy sources is needed in order to meet demands from European directive on the energy performance of buildings (EPBD) and to comply with Kyoto Protocol and newly agreed Paris agreement for global clean energy transition. Already known and widely referenced fact from EPBD 2010 [1] forced the focus on renewable energy sector which has been encouraged to improve effectiveness of utilization of renewable energy sources. The 2015 Paris Agreement on climate change boosts the EU efforts to decarbonize its building sector what also led to amending EPBD 2010. Taking into account that almost 50 % of EU's final energy use is used for heating and cooling of which 80 % is used in buildings where 75 % of it represent a residential building stock. The EU strives to achieve energy and climate goals with endeavour to renovate its building sector by giving priority to energy efficiency as well as considering deployment of renewable energies [2],[3]. To reduce final energy use in newly constructed buildings is one thing but in existing ones it represents a major challenge. Despite achievements in increasing buildings energy efficiency retrofits are mostly carried out according to fragmented approach of particular components in the building system. This results in the improved envelope or HVAC solutions instead of systemic and effective integration of particular components and its synergetic operation where if not approached in that matter results in significant inefficiencies and mismatch losses. Such inefficiencies and mutual interferences can seriously restrain the actual achievable energy saving potential [4–6]. Nevertheless that progress in energy retrofit of building sector in Europe has been made in recent years it has to evolve further to achieve the goal which EU has set. With applying systemic solutions capable of providing synergistic response to the outline needs improvements in this direction can occur what is the subject of consideration in EU funded HEART project.

OBJECTIVES

HEART project focuses on improving energy efficiency in the residential building sector and aims to develop, test and validate a holistic and multi-technological integrated and interconnected system for the deep retrofit of residential buildings. HEART stands for *Holistic Energy and Architectural Retrofit Toolkit* where its general objectives can be summarized as follows:

- enabling a nZEB renovation,
- promoting an overall vision of building energy performance considering heating, cooling and DHW without neglecting power needs,
- increasing cooling demand and summer thermal comfort requirements,
- consolidation of the role of renewable energy sources in buildings energy efficiency with special emphasis on PV and increase in on-site use of self-produced energy,
- rationalization of building retrofit interventions in order to create synergies between envelope technologies and technical systems and also increasing the role of BEMS (Building Energy Management Systems) and ICT (Information and Communication Technology),
- strengthening in accessibility and interoperability with smart grids,
- improvement of design-funding-construction processes in building energy retrofit,
- reinforcement of public and private support for the economy of energy retrofit.

HEART provides an effective response to both summer and winter needs acting on the building's overall energy balance. Application target of project is multi-storey residential buildings of the second half of the 20th century located in the moderate climate of Europe (part of South and Central Europe). Within the project the technical, economic and social aspect of energy retrofit will be tackled. The main objective of the project is development of holistic and multifunctional solutions in a toolkit for joint response to different needs by energy retrofit of residential buildings. This multifunctional energy toolkit based on the synergistic interaction between building technologies and technical system is structured to perform technical, decision-making, management and information features with actively involvement of different stakeholders (investor, developer, designer, end-user, ect.) in the retrofit process. For maximal effectiveness of the retrofit process the toolkit is supported by a cloud-based platform with computational, management and operating logic with special aim to BEMS which optimizes the overall energy performance of a building and actively involves end-users in the building management. With simulation and adaptive-predictive features computer models controls and regulates operations and intervenes at an early stage of the decision-making and design phases to select optimum system configuration. The goal of the project is to establish synergetic operation between particular components integrated in the system to improve its effectiveness considering also affordability of the buildings' retrofit and reducing energy use by up to 90 % and cut payback periods to less than 15 years. With regard to boundary conditions to match particular components in the system its configuration is set to be flexible. Main benefits of HEART project and developed toolkit are optimization of the decision-making and operating phase, reduction of energy use, optimization of selected life-cycle environmental indicators (e.g. total primary energy consumption, operational and embodied greenhouse gas emissions, etc.), reduction in retrofit and operating cost, increased levels of winter indoor thermal comfort levels, increase in on-site renewable energy use, rationalization of energy flows within the building and to or from the electrical grid [7].

Concept of HEART toolkit

The concept of HEART represents a multifunctional toolkit for building energy retrofit within which following subcomponents ICT (Information and Communication Technology), BEMS (Building Energy, Management Systems), HVAC (Heating Ventilation & Air Conditioning), BIPV (Building Integrated Photovoltaics) and envelope technologies interact between each other to achieve higher levels of energy effectiveness of the whole system including with effective interaction with the Smart Grid. The toolkit runs on cloud-based platform with computing power, concentrating managing and operational logic that supports decision-making in the planning phase of building energy retrofit and optimizes energy performance in the operational one. The interaction between the cloud platform and commercial BIM (Building Information Modelling) standards for building and components design is provided. The concept of the HEART toolkit with included subcomponents and their connectivity in the system is presented in the

Figure 1. Those subcomponents are under development within the project HEART project and are listed below:

- Cloud-based DSS (Decision Support System) and BEMS (Building Energy, Management Systems);
- Multifunctional prefabricated external thermal insulation in which wiring, pipes, vents and sensing options can be integrated;
- Universal PV tiles for pitched roofs, customized with respect to common roofing (for flat rooftops regular open racks systems would do);
- Multi-Input/Multi-Output power controller for interconnection optimization among production, storage and consumption devices;
- Hydronic air-to-water DC modular heat pump;
- Advanced hot/cold storage tanks for thermal storage of heat pump that runs on PV;
- Battery pack for PV electricity storage and power management (the only subcomponent not specifically developed in the project);
- DC smart fan-coils for heating/cooling of rooms (replacing existing radiators).

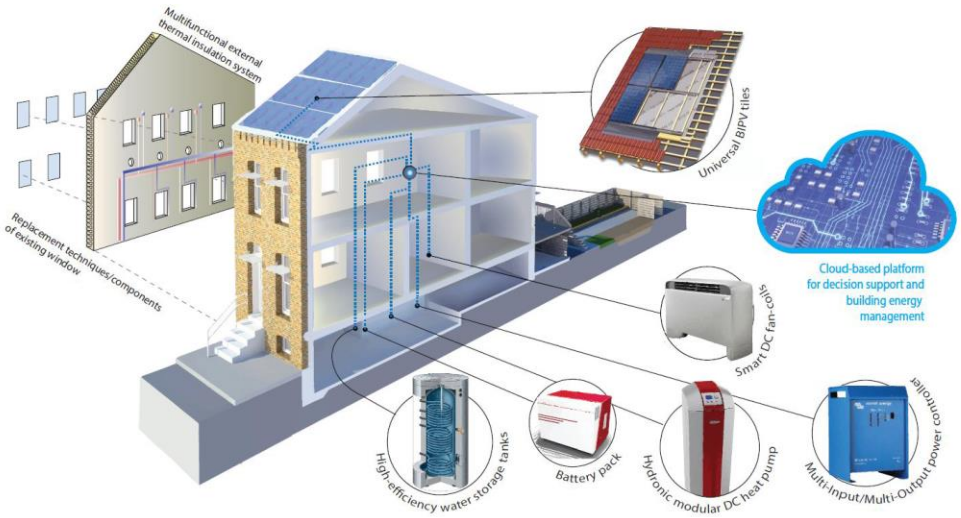

Figure 1. Concept of HEART toolkit [7].

The user (designer at the beginning) will be able to create an account on the web page where it will be able to access a purpose area reserved to the specific building of interest. The user friendly-interface allow to fulfil building profile with its boundary conditions (geometric and constructive data, microclimate, energy costs, building users' profiles, ect.), restrictions (sustainable costs, building codes, ect.) and goals (smaller energy use, return on investment, ect.). Mentioned data can be inserted either by recalling specific documentation or by accessing purposed databases on the platform. Creation of a virtual model of the building is set to be done in the first step where iterative process that simulates size and different possible combinations of buildings' technologies such as thickness of thermal envelope, power of a heat pump and size of a PV plant is performed. Whit iterative evaluation procedure design time is significantly reduced and also rough identification of possible architectural and installation related interventions can be made in this step. In the next step preliminary automatic check on the applicability is performed and then DSS selects specific technologies that best suit the retrofit of buildings' envelope and HVAC system within predefined shortlist of subcomponents what also rationalize the design making phase. Considered technologies in the toolkit are specifically developed or adapted from HEART Consortium's partners in order to obtain an optimal integration level. Technical data of considered technologies will already be present in the platform but if needed it could be integrated or updated. The procedure leads than from a utility function to identification of the optimal retrofit solution from energetic, environmental, economic and management point of view followed by priorities filled out by the user which is at this point mainly the owner, building manager or investor. At the end the obtained optimal solution serves as a reference for the retrofit plan and renovation intervention. Because a lot of unpredictable things can come to the surface in the

construction phase of the retrofit, the model can be progressively updated with modifications during that phase what allows to verify its effectiveness and give useful feedback to the user which at this point is mainly the designer or the contractor. The interactivity among different stakeholders and HEARTs' platform is shown on Figure 2.
The cloud-based platform utilize virtual model of the building by applying predictive-adaptive logic and by exploiting external (weather forecast, variation in energy tariffs) or internal (inputs and feedbacks from buildings' users) information to manage energy flows and electrical grid interaction. This kind of energy management and smart grid interactivity improves building-systems effectiveness. Moreover because measurement and simulations are being continuously performed and regarding boundary conditions of the system this type of logic contributes to enhance the passive features of the building such as exploitation of solar gains for heating purposes or the envelopes' thermal inertia to reduce both summer and winter loads. Small measurement sensors integrated in the buildings' envelope for the collection and storage of data provide that sort of information. This approach enables a sort of IoT (Internet of Things) of buildings' components which increases the interactivity between envelope conditions and HVAC system. It also increases the data management in general economy of the project in order to monitor and enhance performance of the whole building system.

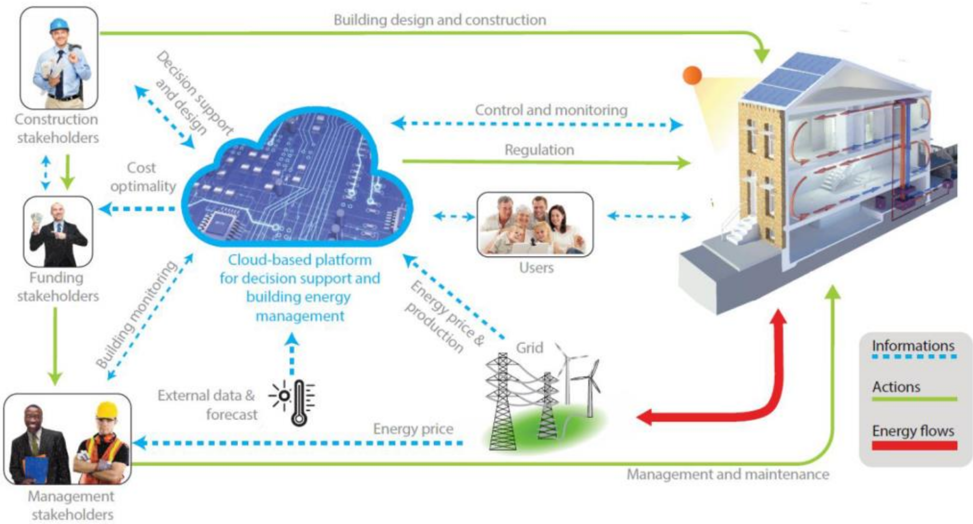

Figure 2. Concept of HEART [7].

The operation protocol of the model has integrated self-learning function which improves its precision in time comparing simulation and forecast results with feedbacks from continuous building monitoring and from users (at this point inhabitants) on order to validate computational parameters. Continuous monitoring of buildings' effectiveness is provided by strategic placement of different measurement sensors such as temperature, relative humidity, CO_2, occupation etc. The model within toolkits' control logic enables minimizing the number of measurement points which function is validation of a mostly virtual but highly reliable monitoring. Obtained information from the model helps to create and provide directions relative to operating conditions, mode of use, energy use, maintenance needs, malfunction etc. The BEMS also enables direct interactivity with buildings' where they can be informed about buildings' energy performance and can also control it by using associated applications through mobile devices like smart-phones. Inter-device communication and in-building data transmission uses wireless technologies with specific reference to the Narrowband Iot protocol. Energy performance monitoring and control of the building through platform of toolkit provide also useful information to other HEARTs' users such as building managers, investors and grid operators. Figure 2 clearly demonstrates energy flows and flow of information between platform of the toolkit and all the parts where it obtains information which when processed acts as a feedback whit actions.

Thermal energy storage

The term thermal energy storage (TES) represents either heat or cold storage where heat or cold can be stored in a tank (unit) and used later when needed. Thermal energy can be stored through physical processes in sensible (liquid, solid materials) or latent (phase change materials) TES units. Thermal energy stored in sensible heat increases approximately linearly with temperature (dashed line in Figure 3). Thermal energy stored in latent heat is when materials change their state of aggregation within a defined phase change temperature which is nearly constant (solid line in Figure 3) [8].

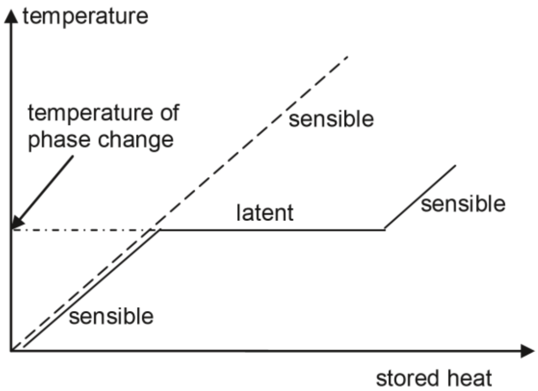

Figure 3. Thermal energy storage with and without phase change assuming ideal behavior of PCM [8].

Typical TES units are sensible types which uses water (in liquid aggregate state) as storage medium. Phase change materials (PCMs) have advantage over other storage materials in that they have higher energy density and can store higher quantities of thermal energy per volume and mass at smaller temperatures of heat transfer medium [9]. Potential applications of PCM can be found from difference between sensible and latent TES shown in Figure 3 where latent TES can be used in applications where constant temperature is needed. During this project improvement of sensible TES unit is proposed as is shown on
Figure 4.

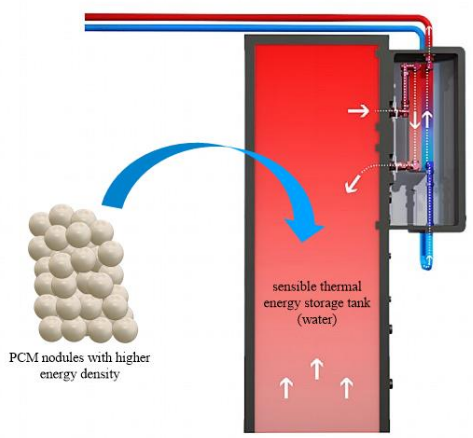

Figure 4. Improved sensible TES with PCM [10],[11]

Spherical nodules filled with PCM are inserted in sensible TES unit with water as heat transfer medium which circulates in the unit and ensures heat exchange between PCM in nodules and water. By adding PCM nodules to the water tank we obtain hybrid TES where PCM presents 40% of the volume according to the whole volume of the TES unit and the rest is filled by water which also acts as a thermal storage medium. Advantage of the proposed system is in higher energy density for thermal energy storage in comparison with water at the same temperature level. At 40% of phase change material filling at temperature difference of 5 K latent TES unit can store up to 5 times more thermal energy than sensible one because of its higher energy density that can be stored during phase

change. Time of supplying thermal energy demand is in case of latent TES unit 3.5 times longer than in case of sensible one. TES has high potential in applications where small temperature differences in storing of thermal energy take place especially if temperature level of supplying thermal energy in the system needs to be low which is the case in presented HEART project.
Because the aim of HEART project is to make big step towards sustainability therefore the use of renewable energy sources have to be utilized in biggest possible proportion. To ensure this utilization the TES unit is considered to level solar energy gain and shift energy load to time when demand take place in order to reduce compressor power of heat pump and that it can operate under steady conditions. Because the constant inlet temperature in heating/cooling system is needed latent TES is having advantage over sensible one where latent TES have higher energy density stored at constant temperature of PCM. The central latent TES is used for heating purposes in winter and cooling purposes in summer what have not been done yet in practice. This is possible to achieve in case of HEART project because inlet temperature in heating/cooling system is approximately the same throughout the whole year and is set to be around 25°C.

CONCLUSION

The HEARTs' developing toolkit is a multi-stakeholder tool which can be used by almost all stakeholders involved in the renovation process (investors, real estate developers, designers, contractors, installers building managers, financers, decision makers inhabitants etc.) in different phases of the buildings' life. Contribution of HEARTs' toolkit to the development of buildings retrofit can be summarized through following main features:

- Optimization of retrofit planning and implementation;
- Energy use reduction for heating, cooling and DHW;
- Increase in on-site use of self-produced energy from renewables;
- Rationalization of all energy flows inside of building (including renewables) and between building and smart grids;
- Users' interactivity in energy-efficient management of the building;
- Support to activities for energy financing.

One of the components in the system that plays a big role in sustainable energy use is TES where latent TES has high potential in applications where small temperature differences in storing of thermal energy take place especially if temperature level of supplying thermal energy in the system needs to be low which is the case in presented HEART project.

ACKNOWLEDGMENT

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EXPERIMENTAL TESTING OF A THERMAL AND ELECTRICAL PERFORMANCE OF A HYBRID PHOTOVOLTAIC-THERMAL SOLAR COLLECTOR

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Abstract: Hybrid photovoltaic thermal solar (PVT) collectors represent a relatively new technology on the market which combines the electricity and heat generation from the same receiving surface in one device. The hybrid PVT collectors provide both heat and electricity, while the heat generation is several times higher than the electricity. The PVT collectors improve the performance of PV modules keeping the cells cooled, increasing the overall efficiency of the panel. In this paper, a theoretical and experimental study of a photovoltaic thermal hybrid solar collector is presented. Also, we analyzed the influence of various weather conditions against the technical performance of PVT collector.
Key words: PVT collector, thermal performance, electrical performance, solar energy

INTRODUCTION

The energy sector is in transition worldwide because of increasing demand for energy, significantly fluctuating oil prices, stronger desire for energy supply security and independence and in response to sustainability, conservation and environmental considerations. Solar energy has the potential to provide a significant portion of the renewable energy required to meet these and other national and international targets and obligations. Solar energy technology is expected to play an important role in attaining the 10 % renewable energy target by 2020. One of the simplest and most direct applications of the use of solar energy is the conversion of solar radiation into heat and electricity from the thermal collector and PV panel that can be used in heating water or air and lighting. The idea is to integrate in a simple device a PV panel and a thermal solar collector, to create the hybrid PVT solar collector. Hybrid PVT collectors are multi-energy and multi-functional components converting solar energy into electricity and heat. The synergistic combination of the improved electrical output and the associated heat-provision potential have motivated the development of hybrid PVT concepts, which have emerged as holistic solar energy solutions that combine a PV module for electricity generation, coupled with a heat exchanger arrangement and a coolant circuit containing a heat transfer fluid for heat provision from the same collector area.
Photovoltaic system converts solar energy into direct current and its performance is affected by various factors. Temperature is one of the important factors to investigate where in summer the panel's temperature can reach up to (50-60) ºC resulting in 3% to 4% reduction in the output power. PV panel surface temperature increases due to low solar energy to electricity conversion efficiencies as not all of the solar energy absorbed by PV cells can be converted to electrical energy. To satisfy the law of conservation of energy, the remaining solar energy must be converted to heat and this contributes to a drop in the panel electrical efficiency. To address this undesirable effect, heat extraction by fluid circulation can be done to reduce PV panel temperature and produce hot water using PVT system, thus achieving a higher energy conversion rate of the absorbed solar radiation [1].
Another advantage of combining the photovoltaic and thermal system is that total area requirement of a PVT collector is around 40% less [2] compared to photovoltaic and thermal collectors with the same total capacity. In cases where available area is limited and maximum utilization of the available space is desired, PVT collectors shine as the better alternative. It is also suggested that PVT collectors are aesthetically more appealing compared to a combination of thermal and photovoltaic collectors [2].
The different types of PVT collectors were classified in categories, as presented in the Figure 1. The first category corresponds to concentrated PVT collector, with either high concentration factor or lower concentration factor. The second category corresponds to all flat plate PVT collectors.

According to the system where they are integrated, those flat plate PVT collectors can be either glazed or unglazed. In both case, the cooling fluid can be liquid (water or glycol) or air [3].

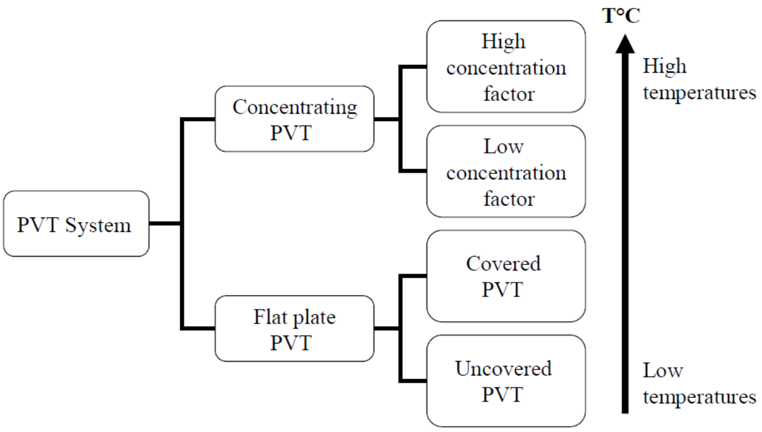

Figure 1. Classification of PVT systems

A number of investigators have undertaken research in this field, in which different approaches were used to estimate the technical performance and economics of PVT systems [4-5]. In our laboratory we experimentally testing PVT hybrid systems with commercial silicon PV modules of typical size and thermal units using water as working fluid. The outdoor testing was running in period of August 2018. The result of this paper will provide useful information about the usage of this type of solar collectors for production of electricity and heat power for weather conditions in Serbia.

THE THEORETICAL ASPECT OF THE HYBRID PVT COLLECTOR

The present paper is based on hybrid PVT systems because the associated research is concerned with the distributed supply of both electricity and hot water in the domestic and industrial sector, where this technology is expected to have its greatest potential due to the combination of both PV and solar-thermal collectors in a single system. During an operation of the PV system, the solar cells are warming up by a part of the solar irradiation absorbed in the cells, and as a result they are having less electrical efficiency. A solution to this problem is cooling a panel with liquid or air and lowering its temperature and thus increasing electrical efficiency. The total energy, both heat and electricity that can be obtained from a liquid type hybrid PVT system depends on the following factors: the design of a PVT system, the solar irradiance, ambient temperature and wind speed and a consumption of a heated water [6].

The performance of PVT collectors consists of thermal efficiency η_{th} and electrical efficiency η_{el}. These efficiencies usually include the ratio of the useful thermal gain and electrical gain of the system to the incident solar irradiation on the collector's area within a specific time or period. The sum of the efficiencies, which is known as total efficiency η_o is used to evaluate the overall performance of the PVT system [3]:

$$\eta_o = \eta_{th} + \eta_{el} \tag{1}$$

The thermal efficiency η_{th} of the steady state conventional flat plate solar collector is defined as the ratio of useful heat collected to the total energy:

$$\eta_{th} = \frac{Q_u}{G} \tag{2}$$

where Q_u is useful heat gain of a flat-plate thermal collector, and G is a total solar radiation on a collector's surface. Useful heat gain is available as [7]:

$$Q_u = \frac{\dot{m}C_p\left(T_o - T_i\right)}{A} \tag{3}$$

where $\dot{m}$ is the mass flow rate of heat transfer fluid per unit collector area, C_p is the specific heat of the transfer fluid, A is the aperture area of the tested system, and T_o and T_i are the outlet and inlet cooling fluid temperatures, respectively.
The electrical efficiency η_{el} can be defined as:

$$\eta_{el} = \frac{I_m V_m}{AG} \tag{4}$$

where I_m is the value of current, and V_m voltage at the maximum power point of PV module operation.

SYSTEM DESIGN OF EXPERIMENTAL TESTING

For testing of electrical and thermal characteristics of PVT and PV equipment shown on figure 1 was used. This testing system was constructed at the Faculty of Technical Science in Čačak. Two identical polycrystal PV modules (Figure 1) with the nominal power of 250 W are used for testing for weather conditions in Čačak [8]. In hybrid PVT solar collector copper pipes for heating water is installed, which electrical and thermal characteristics are testing. Rated mechanical and electrical parameters of PV and PVT are:

- The dimension of the module: 1642×999 mm
- Electrical max power: 250 W
- Open circuit voltage: 37,75 V
- Short circuit current: 9,89 A
- Length of the active part of the pipe: 14.4 m.

The modules were positioned towards the southeast, with an azimuth of 21° and slope of 45°. For testing of PV and PVT modules 7.5 Ω resistor was used. Current and voltages measurement were realized with NI 9227 and NI 9225 acquisition card. Water flow was measured using the flow sensor with the range of 0-20 l/min and output signal 4-20 mA. Inlet and outlet temperatures from PVT module were measured using the thermocouple. Signals from the flow sensor and two thermocouples was measuring with NI 9203 acquisition card. All acquisition cards are the connection with the computer using CompactDAQ Ethernet chassis cDAQ-9184. During the testing process of the PVT module, an open system is applied where cold water is taken directly from the pipelines. Block diagram of the testing system are shown in Figure 3.

Figure 1. Testing PVT and PV modules and data acquisition system
1 – hybrid PVT solar collector, 2 – PV solar collector, 3 – resistor, 4 - acquisition cards, 5 - computer

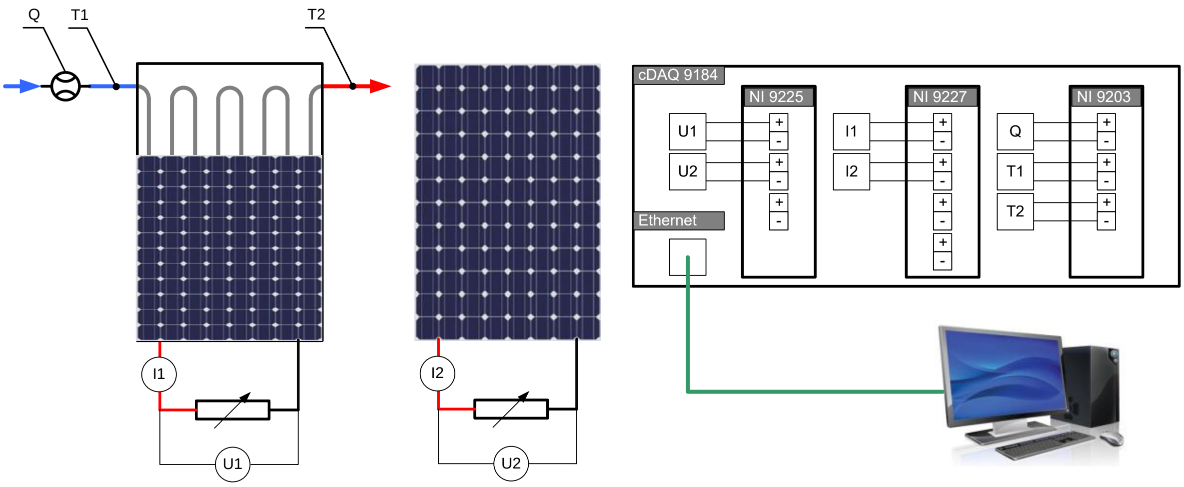

Figure 3. Block diagram of the testing system

EXPERIMENTAL RESULTS AND DISCUSSION

The results of power measurements of compared PVT and PV collectors presented are for the 18 August 2018. The electrical, thermal and total power of hybrid PVT are shown in Figure 4. Also, figure 4 shows values of irradiation obtained from the automatic weather station in Čačak. The testing results of hybrid PVT collector show that the total heat output power is significantly higher than that the electrical power. Of course, the maximum electrical power of the module is determined by the operating point, that is, the load resistance (in this case 7.5 Ω).

The average flow rate during testing was 150 l/h, with a deviation of up to ±10%. The inlet water temperature of the PVT collector was 21°C, while the outlet water temperature is significantly increased, with a maximum value of 29 °C (13:30^h). This maximum value of water temperature corresponds to the maximum thermal power of 1396 W (Figure 4), while the average thermal power for the observed measurement period was 705 W. The electrical power from PVT collector was significantly lower than the thermal power, with the maximum value of 151 W (13:30^h). If we were to observe the sum of both power, the maximum value was 1460 W.

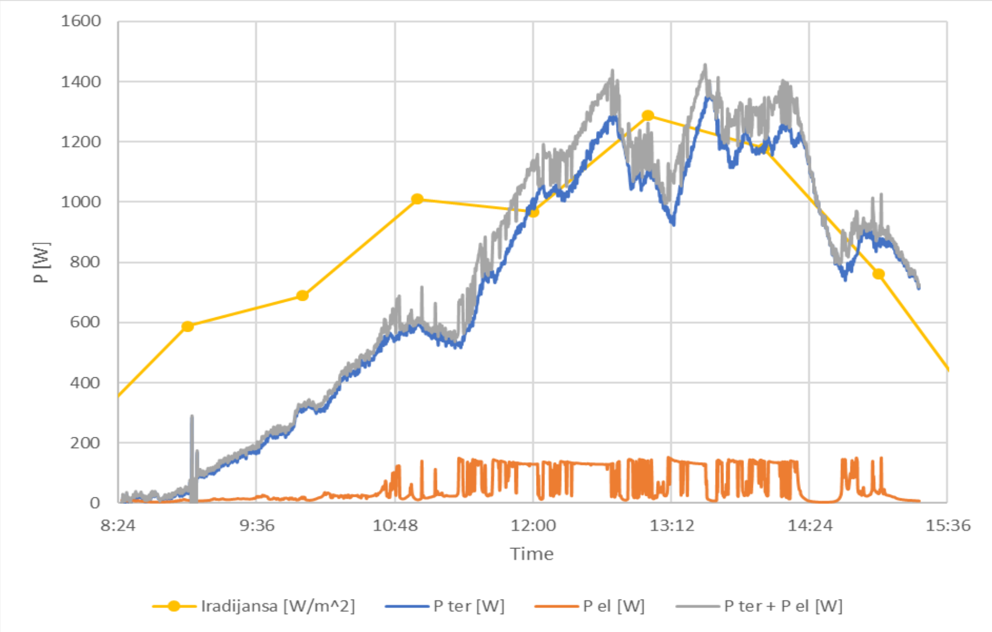

Figure 4. Test results of electrical, thermal and eqivalent PVT collector power

Results of measurement of electric power for compared hybrid PVT and PV collectors are shown in Figure 5. Results show the significant oscillations of obtained electrical power. The reason for the expressed power oscillation is the occasional cloudiness during the measurement process. The response of electric power to the decrease of irradiance is considerably faster than the thermal power. If we compare the obtained values of electric and thermal power of hybrid PVT collector (Figure 4), it is noticeable that the thermal power slowly increases and decreases with respect to the electrical one, because hybrid PVT collector takes some time for warming up and cooling down. The difference in between electrical power for compared PV and PVT is shown in Figure 5. Results show that the hybrid PVT collector has greater power in periods of slower power changes. This is a direct consequence of the heat transfer from the PVT collector, which results in lower temperatures of PV cells and higher voltage of the module, which directly affects the PVT collector efficiency.

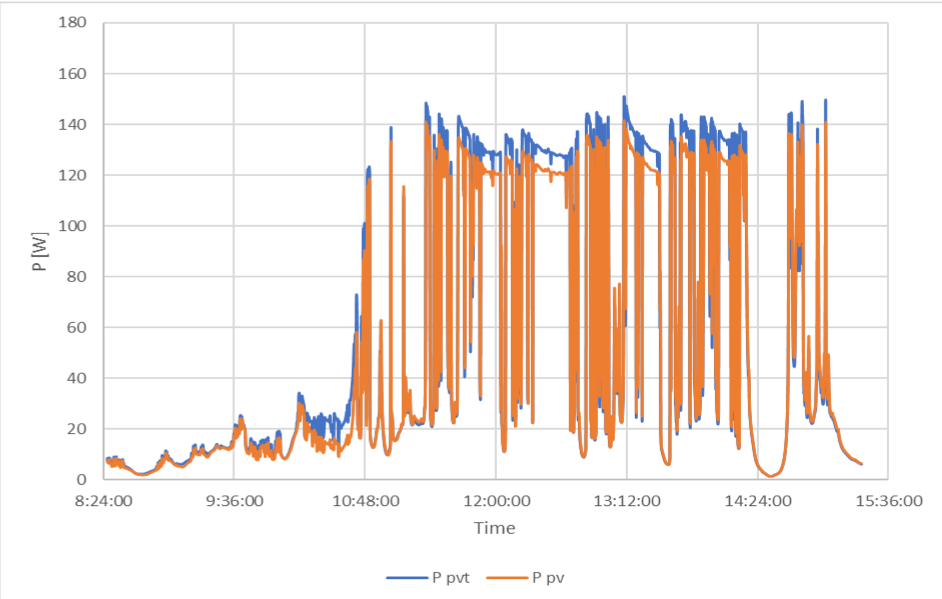

Figure 5. Test results of electrical power of compared PVT and PV collectors

The average values of the electric power measured during the observed period were 50,5 W for PV and 53 W for the PVT module. Therefore, the obtained electrical power from hybrid PVT collector is up to 4,7 % higher than the obtained electrical power from PV collector. During the testing period, the maximum PVT power was 150 W, while the maximum PV power was 141,6 W. Results show that using hybrid PVT collectors we can get up to 5,6 % more electrical power than from PV collector.

CONCLUSION

The usage of the solar energy, in general, can be divided into two divisions: the PV technology that converts the solar energy into electricity and thermal solar technology that convert the solar energy into heat. Hybrid PVT collectors are very useful devices which enable to produce electricity and heat simultaneously. The paper presents the basic characteristics of hybrid PVT collector as well as the advantages of its use. The analyzed testing system is presented for the comparative measurement of the thermal and electrical power of hybrid PVT and PV collector. These results show that hybrid PVT collector gets a low increase in obtained electrical power than PV collector, with simultaneous production of significant heat output. It should be emphasized that no optimal water flow analysis was performed. Future research should, therefore, focus on the study of PVT systems based on the shape and geometry of the heat exchanger.

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MODERN TECHNOLOGIES FOR MOTOR VEHICLES ON ELECTRIC POWER AND SECURITY OF PARTICIPANTS IN TRAFFIC

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Abstract: The automotive industry is the driver of the development of the economy that integrates achievements in the field of technology, technology and almost all other scientific disciplines. The experiences and knowledge gained in research related to development, production and exploitation of passenger cars are increasingly being applied in other industries. Since limited amounts of fossil fuels are limited, an alternative mode of transport, such as electric vehicles, has been sought for years. The drive of electric cars is aimed at improving energy efficiency and reducing air pollution in countries and cities. Also, by lifting and lowering the "lying down police officer", the flow of automobile can be absorbed as well as the reduction of fuel consumption.
Keywords: car, electric drive, "lying down police officer", automation

INTRODUCTORY REVIEWS

Nowadays, when new technologies are being developed, special attention is paid to protecting the environment due to pollution due to the high number of cars and the safety of road users.
As fossil fuels are getting smaller, and in their combustion, a large amount of carbon dioxide is released, there is a huge pollution of the environment. In order to reduce pollution, the gangs are working on alternative fossil fuel replacement solutions. More recently, it is being replaced by the replacement of conventional cars with hybrid or fully electric drives. Hybrid drive uses more power sources. The most common is a combination of a gasoline or diesel engine with an electric motor.
Regardless of the type of drive in cars, their number is constantly increasing, which affects the safety of other road users (most often pedestrians). That is why it seeks to increase the safety of participants, especially by reducing the risk. This is done in many ways. One of the ways is to reduce the speed of cars in areas where there is an increased risk of pedestrian injury (in front of schools, hospitals, pedestrian crossings etc.). Speed reduction is most often done by mechanical obstacles - "lying policemen". Usually these obstacles are fixed, but they can also be mobile.

MATERIAL AND METHODS

Global modern car production and road safety trends are characterized by a reduction in energy consumption for their propulsion and an increasing safety of both cars and road infrastructure. The desire for progress through the development of innovative technologies in the automotive industry gives an increasing number of manufactured electric cars. In order for them to function, it is necessary to provide the appropriate logistics that will enable them to continuously charge them with the flow for their movement. Securing all non-filling processes for charging an electric motor is quite demanding, and sometimes costly [17]. At the moment, in Serbia, the provision of infrastructure responsiveness is the installation of equipment that will allow the pre-charge charging of electric cars [16].
Also, in order to provide road infrastructure, especially in urban areas, "lying policemen" sometimes need to ensure their descent due to the acceleration of traffic flows, as well as the reduction in fuel consumption [24]. These mobile mechanisms in Serbia have not yet come to life, but soon it will be necessary.

System for the free control of the car on the electric power

Today, when the need for fossil fuels is increasing, and fossil fuels are getting smaller, scientists turn to designing an electric car that will replace fossil fuel cars. The problem that occurs with both classical and electric cars is the need for occasional filling with both fossil fuel and electricity. For fossil fuels, there is already built a complete infrastructure for production, transport, storage and distribution.

For electric cars there is not a large number of distribution points, that is, charging points. Usually the owners of such cars are forced to complement their cars overnight in their garages (Fig.1). Also, if charging is done on specially designed parking spaces (Fig. 2 and 3), this requires a lot of time and physical connection with the cable between the car and the charger. If charging is done outdoors, weather problems can make charging difficult [1].

a) b)

Figure 1. Examples of home chargers cars a) [2,20], b) [3]

Figure 2. Example of a charger in front of a shopping center [4]

a) b)

Figure 3. Electricity filling stations a) [5], b) [6,16]

In order to reduce the charging time, it also facilitates charging (while the car is charging it is unusable for the owner), it is designed to improve the wireless car charging system. The principle of Wireless charging is shown in Figure 4.

The principle of wireless charging is based on electromagnetic induction between the two coils. The first coil is in or on the base, while the other coil is on the car itself. The alternating current from the socket in the wall converts to a pulse-one-way power supply (Fig. 5). Electromagnetic induction is induced in another coil (which is in the car), an electric motor that turns into a one-way and recharges the battery- battery in the car [22].

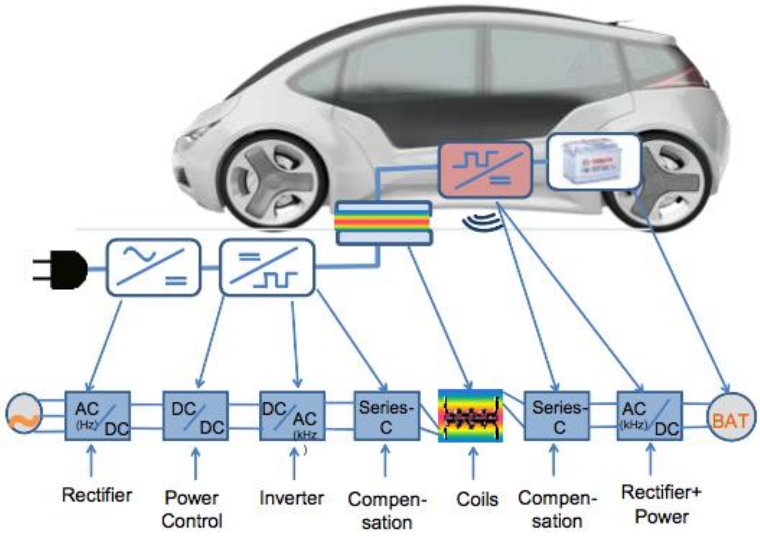
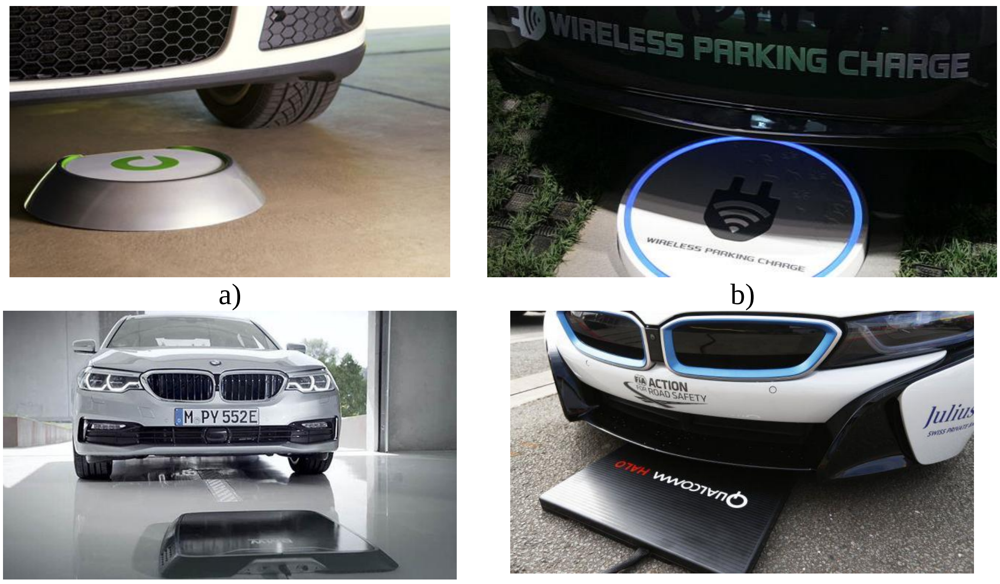


Figure 4. Wireless charging principle [7,17]

a) b)

Figure 5. Example of a transfer coil: a), b) [8]



c) d)

Figure 6. Examples of wireless chargers a) [9], b) [10], c) [11], d) [12]

With this system, the transmission spool is fixed and the charging is done, the car must be parked above the transfer roll. The transmission spool can be placed in the garage, in the parking lot or, for example, in the street in front of the traffic light, so that while the vehicle is standing on the traffic light, the car is filled [19].
Regardless of the fact that the wireless charging system makes it easy to charge only because it is not necessary to get out of the car to connect the cable with the charger, it is still necessary for the car to stand idle until the batteries are full, which again requires a while. That's why scientists work on a continuous loading system, i.e. Filling the car on the go. In order to do this, a transmission spool must be placed in the carriageway itself, and the car is charging while traveling on the road. It can be in a separated highway bar or in another highway bar [13].

Figure 7. Setting the coil in the path [13]

Figure 8. Special highway filling line for automobiles [13]

System for automatic lifting and removal of the "lying down police officer"

Often in traffic we encounter obstacles on the way in the form of a "lying policeman". The purpose of a "lying policeman" is to slow down the vehicle in order to drive safely, as it is possible to slow down the vehicle faster and easier stop if it is for some reason necessary. The most common is when pedestrians want to cross the carriageway.
" Lying down police officer " is most often placed in front of: schools, hospitals, public institutions and is in operation 24 hours a day With this system, the transmission spool is fixed and the charging is done, the car must be parked above the transfer roll . The transmission spool can be placed in the garage, in the parking lot or, for example, in the street in front of the traffic light, so that while the vehicle is standing on the traffic light, the car is filled. As its function is to slow down the vehicle, and this takes place indefinitely, regardless of weather or environmental conditions, it is sometimes not necessary to slow down the traffic. For example: during the break when children do not go to school, or when there is no schooling in the school (in the evening and overnight), also when public institutions are closed [21].
When we do not have the need to slow down the traffic, then it is necessary to "lower" the obstacle. This can be done by activating the mechanism in the "lying cop". The power supply of the mechanism as well as the symbol itself, which has an LED display panel, is made either from a street lamp located near or as a fully autonomous solar powered device [23].
The principle of operation of the automatic system is as follows:
When we want to lower the obstacle, this is done by the time program in the forward program. For example: When children are not in school (from 19h to 7h on the next day, on the electricity itself, where the information about the obstacle on the road to the "STOP" is first changed, and after a few seconds the activation of the mechanism of the "lying policeman" .
By lowering the mechanism, the "STOP" symbol changes to the speed limit symbol.
The system consists of the following:

1. An electric power supply comprising a power supply unit, a contactor and a control panel (Figure 9),
2. Led signs - a panel showing road information, limited speed, or "STOP" (Figure 10),
3. Boxes with the key that when the pedestrian wishes to cross the street (Figure 10), simply pressing the button will make a change from the speed limit sign to the "STOP" symbol (Figure 11),

4. "lying policeman" with a movable mechanism for lowering / lifting the obstacle itself (Figure 12),
5. The bearing pole on which the solar panel is mounted (Figure 13).

Depending on the need, the basic system can be expanded in several ways:

1. Instead of an authorized person (eg a school policeman) turning the key directly to the electroorman, it can be lifted / lowered, this can be done remotely from a command center (Figure 14).
2. By adding a video surveillance camera, it is possible to monitor the traffic and, if necessary, remotely activate the system from the command center (Figure 15).
3. Instead of an ice sign, an ice panel can be set that could print the speed of the incoming vehicle (Figure 16) [19].

Figure 9. Electrical cabinet

Figure 10. Ice sign

Figure 11. Box with buttons

Figure 12. “Lying down police officer”

Figure 13. A bearing pillar for a solar panel

Figure 14. Command room

Figure 15. Video surveillance

a) b)

Figure 16. Road warning signs a), b)

RESULTS AND DISCUSSION

In the world as well as in Europe, electric cars are increasingly used in transport, agriculture, forestry and construction, and due to the characteristics of less emissions of harmful gases compared to conventional fuel, and cheaper fuel [18].
The barrier to the wider introduction of an electric vehicle makes it unusable due to the lack of adequate charging systems.
As for safety in the production of new cars, very high attention is paid. Also, special attention is paid to the road infrastructure that should provide greater safety for all participants in the traffic [21]. Special attention is paid to installing and upgrading the operation of "lying policemen", which enable faster traffic flow to greater security at times-adjusted intervals.

CONCLUSION

As technology evolved, it found its most common application in cars - they were a kind of polygon for its further development. Today, when technology advances at light speed, drives on electric drives are increasingly represented, and also passenger safety is at a high level.
Finally, developed systems from the discussed themes that are used today, seem to have come from a distant future.

ACKNOWLEDGEMENTS

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RESEARCH AND DEVELOPMENT OF THE VEHICLES IN THE SERBIA FROM THE RECYCLING ASPECT

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Abstract: The paper discusses components of sustainable development, ecology, dismantling and recycling of motor vehicles. The components are related to: materials, engine fuels, working fluids, installation of hazardous materials, energy efficiency, waste in the process of production, use of sustainable technologies and design suitable for recycling. Also, elements of sustainability in the construction of motor vehicles, as well as certain legal environmental protection measures are being considered. In the Republic of Serbia, certain measures are taken in the direction of research and development to reduce the negative environmental impact of vehicles and the automobile industry. However, achieved results are still far from the desired level. There is space for improvement in the sphere of used materials, energy efficiency production of technologies and the application of sustainable technologies. These segments should have special attention because recycling of motor vehicles could have a significant impetus to the improvement of the sustainable development in the Serbia.
Key words: motor vehicles, research and development, recycling, environment, Serbia

INTRODUCTION

Motor vehicles, as modern technical and technological achievements, enable the intensive transport of people and goods, and due to this mobility, the rapid development of human civilization took place. However, as a cogently civilizational achievement, motor vehicles are one of the largest polluters of the planet, starting from the production process, to the end of their life cycle. Due to all this, the importance is increasingly given to the ecological aspects of production, exploitation and recycling of motor vehicles. In this paper, the accent is on the recycling of motor vehicles at the end of their life (ELV).

According to [1], deciding of recyclability level of a product depends on: 1. Objective criteria; 2. Strategic output and 3. External controls.

In developing of concept of a product suitable for recycling, the following questions should be answered, [2]:

- How to reduce the time and costs of dismantling?
- Which is the optimum percentage of disassembly?
- How to solve logistical problems?
- How to improve the separation of different fractions from plastic?
- Is it possible to find buyers for plastic fractions?
- How to improve the metal recycling process in order to obtain "cleaner" fractions?
- What is the optimal scenario for ELV from the aspect of the environment and economy?
- Is it possible to use "intelligent" materials to improve the dismantling process?

In paper [3] are defined criterias for recycling materials, which were divided into three groups:

1. Technical (quality of the recyclable material, the possibility of additional processing, capacity (possibility) for further application, material damage, separation capability and identificationpossibility).
2. Economic (continuity of treatment quantities, price of new material, sorting purity, degree of soiling, and demand on the market).
3. Ecological (unwanted consequences, linking unwanted consequences, resources spend, energy consumption, taking up space, etc.).

In paper [4] are defined circular flow of matter and energy when making any king of a product, including an automobiles (Figure 1). Recycling reduces the share of disposal and demand of raw materials while reduce energy consumption and emissions into the environment.

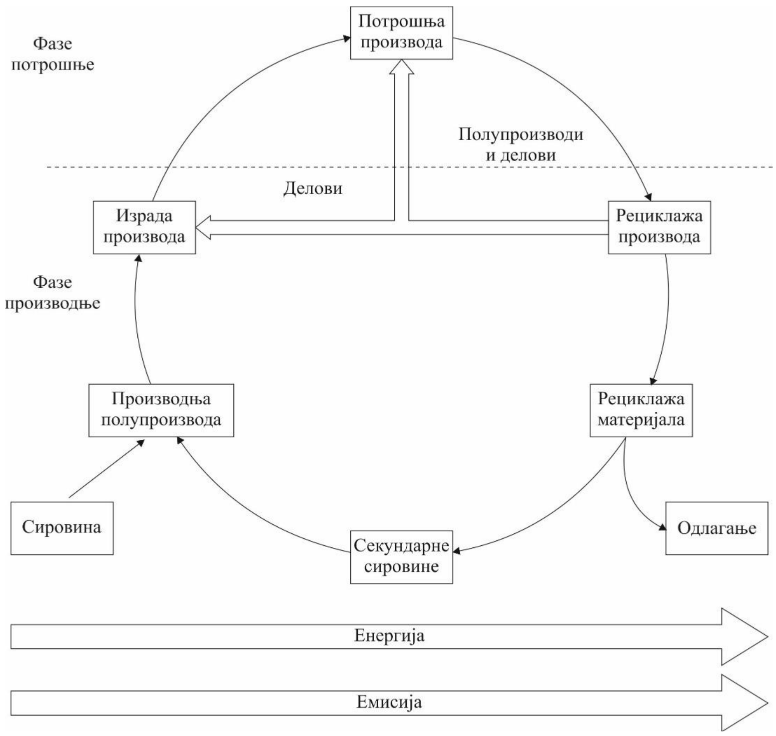

Figure 1. Circular flow of matter and energy, [8]

In Japan, in 2006, five million motor vehicles were newly registered фрома total of around 76 million, [5]. De-registered approximately 5 million, 1.5 million exported, and about 3.5 million motor vehicles were transferred to recycling. Of this, about 3.167.000 vehicles were dismantled, and 4.823.000 vehicles were treated with shredders. Thereto the recyclability of the complete vehicles was about 12%, and the ASR residue was about 70%. By promoting the national recycling strategy 3R (Recycling, Re-use, Reduce) in Japan, a total recyclability ratio of ELVs 95% and ASR of 70% was established, which was a challenge for other countries. The biggest problem was the ignorance about the status of deregistered vehicles. In most cases (about 64%) they are sold to others, and less exported (18%), and further their status is unknown about 14% of cases.

In USA, according to [6], in the last decade of the 20th century, there were on average 123 million vehicles, and about 11 million were deregistered, which is about 11%. The vehicle deregistration rate depended on the general economic conditions, the accident rate, the age of the vehicle. In the same period, the recycling rate (coefficient) was around 95%. In the same period there was an increase in the life span of cars from about 11 years to 14 years, and the share of metal in the vehicle decreased from 70% to 68%, other metals increased from 8% to 9%, and non-metals increased from about 22% to 23 %.

Table 1 shows main automobile parts, their primary sort of materials and primary processes.

Table 1. Automobile parts, their primary sort of materials and primary processes, [7]

Automobile part	Primary material	Primary process
Chassis / Suspension		
Gear rack / Steering shaft	Steel, Magnesium, Aluminum	Casting, Preassure, Forging in a mold, Machining
Differential set	Steel, Plastics	Preassure, Shaping
Front suspension	Steel, Aluminum	Preassure, Forging in a mold
Racket (bandage)	Steel, Aluminum	Preassure, Forging in a mold
Brakes	Steel, Friction material	Preassure, Forging in a mold
Seats		
Seats	Steel, Cloth, Foam	Shaping, Preassure
Instrument table	Steel, Cloth, Foam	Shaping, Preassure
Wrappers / Floor	Synthetic cloth	Shaping

Outdoor equipment (doorlock, mirrors, etc.)	Plastics, Aluminum, Cast zinc	Shaping, Casting, Preassure
Heating and cooling system		
	Aluminum, Steel, Plastics	Casting, Shaping, Preassure
	Copper, Aluminum, Plastics	Extrusion, Shaping
	Plastics, Steel	Preassure, Shaping

DEVELOPMENT OF MOTOR VEHICLES CONDUCIVE TO FOR THE ENVIRONMENT

From research and development depend all other phases in the life cycle of a motor vehicle. In order to determine the current situation in the development of motor vehicles of domestic producers, it is necessary to analyze the appropriate components of the construction of existing and new models. This components sould be definied in a way to support sustainability, ecology, dismantling and recycling of motor vehicles. Components are related to: materials, propellants fules, working fuels, installation of hazardous materials, energy efficiency, waste in a production process, using of sustainability technologies and design useful for recycling. Hereinafter are analysing listed components, [8].

a) Materials - Generally, eco materials refer to constructive materials, fuels and electro materials and that materials sould be environmental friendly. As far as the built-in materials are concerned, the motor vehicles of domestic producers are at the level of the built-in materials from the 1970s and 1980s, which means that there are no recyclable materials. Namely, due to the very low production of domestic cars and the absence of any serious development, activities on the development of new building materials are absent. In this part sould ask for help from foreign partners at the moment when they start implementing the signed contracts.

b) Propellants fules - Many countries, and above all, EU member states, adopt positive regulations on air quality protection (EURO 1-6). These regulations enforce fuel producers and the automotive industry to find solutions which will less pollute the environment. Today's trend is a hybrid vehicle and new plants (for alcohol, bio-diesel, natural gas, and electrical energy - batteries). It is largely working on the fuel cells and the using of hydrogen as a fuel for the future. The more massive practical application of fuel cells is expected after 2020.

c) Working fluids - It is largely working to replace the current fluids in the air conditioning systems of a motor vehicle, but also on new liquids for washing windshields, as well as for the vehicle hygiene.

d) Installation of hazardous materials / materials - The EU has adopted appropriate directives limiting the installation of mercury, cadmium, hexavalent chromium, lead, sulfuric acid, etc., and the resulting waste containing these substances is subject to special treatment.

e) Energy efficiency of motor vehicle production technologies (including component production) - This activity is of multiple importance for the recycling of motor vehicles, but also for preserving natural resources in general (ore, water, energy). Serbian automotive industry spending 3-4 times more energy by unit of product of motor vehicle than other automotive industries in the world. That is not only economical loss, and it is create a much higher amount of wasted materials and materials which accrue from the production of raw materials, components and motor vehicles as a whole. Further trends in the world are moving to bigger rationalization of energy and materials in the production of motor vehicles, with the introduction of advanced technologies and the development of modern construction of motor vehicles. On the other hand, it is moving towards the development of renewable energy sources and increasing the share of recycled materials and parts in the new vehicle.

f) Waste which accrue during the vehicle prodiction (including production of material, energy and components) – Main trend is waste minimizing during the whole life cycle of motor vehicle. Thereto, the waste that is generated by the production of all forms of energy necessary for the automotive industry is forgoten, as well as waste resulting from the excavation and processing of ore for obtaining the necessary raw materials and materials. Then comes the waste generated by the production of components of a motor vehicle, which is considerably smaller than the previous one, although it is by its structure and quantity highly significant and problematic.

On the other hand, great efforts are being made to achieve the motor vehicle production with zero waste (example of Japan) when we talk about materials and components, but the issue of emissions of harmful substances (air, water, land) remains. This means:

- projected energy efficiency of the motor vehicle during the exploitation period,

- the projected structure and quantity of waste generated by the motor vehicle during the exploitation period,
- the simplification degree of assembly of parts and frames,
- physical marking of the type of material (parts),
- projected life span of motor vehicle,
- projected recycling level of material (structure, weights and amount of material recycling).

g) Sustainability technologies - Sustainability technologies in vehicle production referring to next areas: using of natural resources (ore, energy, biomass), production, maintenance in exploitation, dismantling, recycling of materials, energy recovery and storage of permanent waste. And in this case Due to the situation in the automotive industry of Serbia, there are no activities that would create the basis for sustainable development and production of motor vehicles. But from future foreign partners, when they start implementing agreements and projects, these activities need to be requested.
h) Recycling design - Recycling design referring to the ease dismantling of parts and composition, ecological materials and their complete recyclability, high energy efficiency in the entire production and life cycle of the motor vehicle.

PRODUCTION (MATERIALS, COMPONENTS, MONTAGE) MOTOR VEHICLES

Motor vehicle production is a very complex process that generates large amounts of waste and toxic substances that enter the air, water, on the land and in the land. The beginning of production is adaptation of ore and other materials (oil, crude rubber, organic matters), energy production (electric, heat), production of drinking and industrial water, production of propellant fuels (oil, petrol, gass, hydrogen), working fluids production, prodiction of components, propulsion aggregates and at the end, motor vehicle construction.
In order to examine the state of waste and toxic substances at this stage of the life cycle, it is necessary to provide a whole range of information from the relevant production processes, [8]:

- annual volume of production of motor vehicles in domestic automotive industry,
- the structure and quantity of used materials,
- quantity of used energy and energy efficiency of all processes,
- technological characteristics of process (emission and imissions of toxic substances),
- the structure and quantity of used motor fuel,
- structure and quantity of waste which is generate during the year (especially toxic waste),
- waste recycling level by structure during the year,
- taken steps on recovery and removal of toxic substances accrued in production processes,
- consumed amount of water during the year in m^3,
- amount of waste waters during the year in m^3,
- transport of ore, materials, fuel and components in tonnes for the year.

Sustainability elements in the motor vehicle production

Technology developement of production of motor vehicles should provide sustainability acquirable through the elements, which are: (1) low costs, (2) efficient consumption, (3) safety, (4) reliability, (5) technology, (6) comfort, (7)) transparency, (8) attractiveness, (9) motor vehicles, (10) low emissions, (11) good performance and (12) high recyclability, [8].

LEGISLATION OF ENVIRONMENTAL PROTECTION

Political measures (standards, directives, laws) aim primarily at protecting the environment and preserving the natural dynamics of our planet - Earth. Explanation is given in a brief description of some of these measures, [8].
a) Labeling – Labeling should show in the ranging system which will provide practical information for customers that could help them to choose the most environmentally friendly vehicle for their transportation needs.
b) Mobile Air Conditioning - Society of Automotive Engineers (SAE), Mobile Air Conditioning Society and U.S. Environmental Protection Agency have established global co-operation in plan for

reducing the impact of air conditioning on the Earth's climate. The realized partnership has the following goals:

- Promoting of new generation system of air conditioning which is better for environment,
- development of cost-effective design and improvement of service procedures in order to minimize the emission of refrigerants,
- communication of technical progress with political decisions and the public,
- documenting the current state and short-dated solutions for improving the design of the air conditioning system and the environmental performance, handling and maintenance performance.

c) REACH - is a new regulation of the European Chemicals Commission and their safe use (EC 1907/2006). It requires the registration, evaluation, authorization and restriction of chemical substances. The Regulation applies from 1 June, 2007.
d) Euro NCAP - aims to provide realistic and independent access to security for automotive consumers and the automotive industry to some of the most popular type of cars in Europe. By law, each new car model has to carry out the safety test (crash test and other) before its sale begins.
e) E-Safety – The first support of the Intelligent Car Initiative, is a working initiative of the European Commission, industry and other stakeholders. The system uses information and communication technologies to increase road safety and reduce the number of accidents on European roads.
f) Euro V - All data given in Table 2 relates to new regulations. EC directives also specify other data - one year later, applicable at the first registration or before the first use of the vehicle (table 2).

Table 2. EU standard emissions for passenger vehicles (categories M1*), g/km

Class	Date	CO	HC	HC+NOx	NOx	PM
Diesel						
Euro 1†	1992.07	2.72 (3.16)	-	0.97(1.13)	-	0.14(0.18)
Euro 2, IDI	1996.01	1.0	-	0.7	-	0.08
Euro 2, DI	1996.01a	1.0	-	0.9	-	0.10
Euro 3	2000.01	0.64	-	0.56	0.50	0.05
Euro 4	2005.01	0.50	-	0.30	0.25	0.025
Euro 5	2009.09b	0.50	-	0.23	0.18	0.005e
Euro 6	2014.09	0.50	-	0.17	0.08	0.005e
Petrol						
Euro 1†	1992.07	2.72 (3.16)	-	0.97(1.13)	-	-
Euro 2	1996.01	2.2	-	0.5	-	-
Euro 3	2000.01	2.30	0.20	-	0.15	-
Euro 4	2005.01	1.0	0.10	-	0.08	-
Euro 5	2009.09b	1.0	0.10C	-	0.06	0.005d,e
Euro 6	2014.09	1.0	0.10C	_-	0.06	0.005d,e
At the Euro 1..4 stages, passenger vehicles>2.500 kg were type approved as Category vehicles N1 † - Values are the limit for product comfort (COP) a - to 1999.09.30 (after this date DI engines must realize the IDI limit) b - 2011.01 for all models c – and NMHC = 0.068 g/km						

CONCLUSION

Motor vehicles significantly pollute the environment. It is very important to continuously invest in research and development to reduce the negative environmental impact of cars and the automotive industry. It is therefore necessary to use ecological materials and ecologically clean technologies in the production of motor vehicles, and vehicles that have completed their lifetime cycle must be recycled appropriately. In Serbia, some measures are taken in this regard, however, the impression is that the achieved results are still far from the desired level. In particular, there is space for improvement in the sphere of materials used, energy efficiency production technologies and the application of sustainable technologies. To these segments should pay special attention to the fact that recycling of ELV can be a significant impetus to the improvement of the sustainable development of the Republic of Serbia.

Acknowledgment
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OPTIMIZATION OF DRYING AND TRANSPORTING PROCESS OF SYNTHETIC RUBBER ON THE STRIP DRYER AND PNEUMATIC CONVEYORS

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Abstract: This paper presents control thermal calculation of the strip dryer for drying synthetic rubber and also the whole description of working process and additional equipment for strip dryer. The drying process has several stages. Heated warm unsaturated moist air is purged through a pad of moist rubber and that is how the drying process is performed. Before the next stage of drying process begins, it is necessary to permanently re-heated and prepare that moist air for the next stage of drying. This kind of technological process had required the introduction of inter-phases parameters of the drying process which are obtained by calculation. The appearance of the drying process on diagram indicates on multi-phases drying process of heat-sensitive materials with inter-heating. Besides of previously mentioned calculation, we also made the calculation and analysis of operating parameters of pneumatic conveyors which are used to transport the granulated rubber
Key words: synthetic rubber; processing equipment; strip dryers; pneumatic conveyors, thermal calculation.

INTRODUCTION

Natural rubber is obtained from the juice named latex by incising the tree of rubber. Milky juice becomes elastic-resin mass in contact with air and with separation of water from it. The first usage of rubber was for erasing graphite, but invention of solution brought us another usage for rubber like making waterproof products. At that time bad characteristics of natural rubber were these: if the weather was hot natural rubber becomes soft and sticky and if it was cold weather it becomes rigid and inflexible. Because of these characteristics, these products were not the most suitable for use. In 1827 Thomas Hancock has patented the mechanical process of translating rubber from the sinewy stage to the plastic stage. The entire process was based on the processing on the roll mills. The entire process was based on the processing on the machine which has two horizontal and parallel rollers. This procedure is called mastication (pressing). This process allows the easier processing of rubber, and it is still used in the rubber industry. Charles Goodyear was able to make a whole new material from the rubber, which have not change the characteristics on temperature like rubber. This material is obtained by softening the rubber with the salts of sulfur and lead on elevated temperatures. Goodyear called this process metallization and after he had patented it in 1994 he called it vulcanization. In the world, industrial needs for the rubber were being bigger from day to day. Because of that, the find could not be able to adequately respond to the industrial needs, so they decide to find and produce new forms. Synthetic rubber has made the revolutionary change. It is proved that synthetic rubber is much better than natural rubber, because at the elevated temperatures it softens while the natural rubber at the elevated temperatures hardens. A particular advantage is that in contact with the derivatives of petroleum and the organic solvents do not swell, and which has its usage in the making of tanks for the airplanes, and also in the making of elastic pipes for the passage of oil and petroleum products in the oil industry, etc. [6].

MATERIAL AND METHODS

Preparation of the granulates of rubber for the pneumatic transport on the hammer mill

Needments of the dryer for the uniformly dosing of the rubber have been satisfied by the pneumatic transport, which requires a certain size of the granules of synthetic rubber [2], [3]. The granulation of certain dimensions is obtained by using the hammer mill. The material is crushed by using the steel hammer, and also with hitting and cutting in contact with sharp ridge. The speed of rotation of the rotor is from 200 to 1800 min-1, depending on the size of the machine [4]. . Hammer mills can also be more complex for example, with the two rotors with hammers which are rotating in the opposite direction, with very large capacities of up to several hundred thousand kilograms per hour. Material is inserted through a funnel. In the first step, the hammers roughly crashed the material then the hammers that are coming next continuing with crashing the material which falls through the grating which is on the bottom of the hammer mill. The degree of fragmentation is controlled with the grating. In the following text are the characteristics of the hammer mill CONDUX Type 80/60 / nl, which is used for crushing the rubber.

Specifications for mill CONDUX type 80/60/nl

Diameter of mechanism with hammers................800 mm
Working width...600 mm
Operative engine P=75 kw, n=1485 min^{-1}
Engine KRS ø355; 8 grooves; profile SPC
Mills KRS ø500; 8 grooves; profile SPC
8 V-belts, profile SPC LW=3550 mm
RPM (revolutions per minute) for mill cca 250 min^{-1}
Weight of mill, basic frame and engine cca 2565 kg.

Analysis and calculation of operating parameters of the mill and proving of the working characteristics

- Q = 5 (t/h)
- D = 800 mm - diameter of mechanism with hammers
- L =D·π = 800·3,14 = 2512 mm - circumference of mechanism,

Capacity of crusher:

$$Q = \frac{\mathrm{k} \cdot D^2 \cdot L \cdot n^2}{3600 \cdot (i-1)} \text{ (t/h)} \tag{1}$$

Based on the previously mentioned parameters, we have:

$$n = \sqrt{\frac{Q \cdot 3600 \cdot (i-1)}{k \cdot D^2 \cdot L}} \qquad n = 254,83\ \mathrm{min}^{-1}$$

we adopt these two parameters : k = 4 ÷ 6, k = 5 – empirical coefficient
i = 30 – the degree of reduction for the fine crushing

According to the manufacturer of equipment for CONDUX type 80/60/nl recommended RPM for mill is cca 250 min^{-1}. Based on the whole previous calculation, we can see that we almost got identical values, so we see that the empirical assumptions are correct.

Calculation of the pneumatic transport of rubber granules from the hammer mill to the dryers for drying rubber

After the process is finished in hammer mill, with pneumatic conveyors rubber granulates are delivered to the bunker of the strip dryer. Below you will see the whole calculation for the pneumatic transport to the dryer, based on the known parameters [8], [1].
G_s = 5000 kg/h - transport capacity,
d= 400 mm - pipeline diameter,
ρ_ε = 850 kg/m^3 - volume density of granulate,
V_f =15 m/s - adopted transport speed
L_e =20 m - equivalent pipeline length,

$\sum \xi = 0{,}70$ - sum of the coefficients of local resistance loss,
$\rho_f = 1{,}22\ kg/m^3$ - density of fluid- air
$\lambda = 0{,}02$ - the coefficient of friction in the pipeline
$K = 0{,}5$ - coefficient which increases the pressure drop in the movement of the mixture in relation to the circulation of clean air,
$K_r = 1{,}6$ - coefficient of resistance for the wastage of materials
$H = 5\ m$ - geodetic height of raising the granulate.

Table 1. The steps for calculating the pneumatic transport

Unknown parameters	Equations for calculating	The obtained values
Amount of air	$Q_f = \frac{d^2 \cdot \pi}{4} \cdot V_f$	$Q_f = 0{,}125 \left[\frac{m^3}{s}\right]$
Coefficient of concentration	$c_k = \frac{G_s}{\rho_f \cdot Q_f}$	$c_k = 9{,}067$ $c_k = 9$
Losses due to friction of material on the walls of the pipeline	$\Delta p_{tr} = \left(\lambda \cdot \frac{L_e}{d} + \sum \xi\right) \cdot \rho_f \cdot \frac{V_f^2}{2} \cdot (1 + K \cdot c_k)$	$\Delta p_{tr} = 3593.205 Pa$
Losses due to the geodetic height	$\Delta p_h = \rho_f \cdot c_k \cdot H \cdot 10$	$\Delta p_h = 549 Pa$
Losses due to wastage of materials	$\Delta p_r = K_r \cdot c_k \cdot \rho_f \cdot \frac{V_f^2}{2}$	$\Delta p_r = 1974{,}4 Pa$
Total pressure drop	$\Delta p_{uk} = \Delta p_{tr} + \Delta p_h + \Delta p_r$	$\Delta p_{uk} = 6116{,}605 Pa$

Based on the values from the previous calculation, we can choose high-pressure centrifugal fan with following characteristics:

$Q_v = 1220\ m^3/h$ $\Delta p_{uk} = 0.115\ bar$ $N = 18{,}5\ kW$

The control thermal calculation of the one-stripe dryer

In this section will be carried out the electric – thermical calculation of all relevant thermic dimensions that characterize the process of drying the rubber on the strip dryer [4],. The axonometric view of the first zone of the strip dryer with all devices, is given on the figure 1.
Values for physical quantities which are used for electric- thermal calculation of drying process of rubber:
$\rho_{SV} = 1.15 (kg/m^3)$ - partial density dryness of dry air in humid air
$\rho_{SM} = 350 (kg/m^3)$ - partial density of the dry rubber in the humid rubber
$L = 5 (m)$ - length of the tape
$l = 4 (m)$ - width of the tape
$h = 0.06 (m)$ - the height of the layer of the humid rubber on the conveyor belt
$\omega_V = 0.4 (m/s)$ - flow speed of the humid air
$\omega_T = \omega_M = 0.02 (m/s)$ - speed of the conveyor belt (humid rubber)

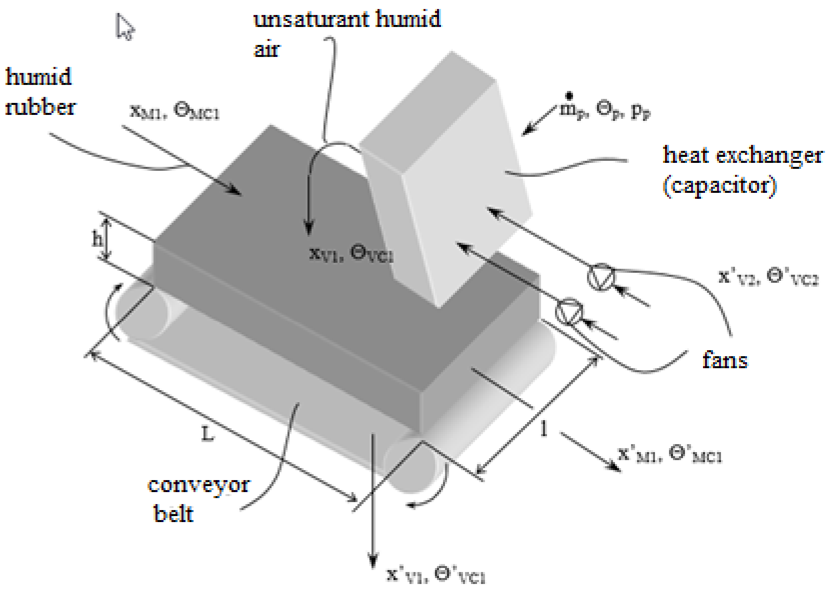

Figure 1. Axonometric view of the first zone of the strip dryer

$p_p = 12(bar)$ - pressure of the dry saturated water vapor in the heat exchanger (capacitor)

$c_{PSV} = 1000(J/kgK)$ - STK of dry air while $p = const$

$c_{PVP} = 1860(J/kgK)$ - STK of water vapor while $p = const$

$r_o = 2500(kJ/kg)$ - latent heat of evaporation of the water on the temperature $\Theta = 0.01(^oC)$

$c_{SM} = 2050(J/kgK)$ - STK of dry rubber

$c_{\omega l} = 4015(J/kgK)$ - STK of humidity

$x_{V2}{}' = 0.089(kg_{VP}/kg_{SV})$ - absolute air humidity at the input to the heat exchanger

$x_{V1} = x_{V2}{}' = 0.089(kg_{VP}/kg_{SV})$ - absolute humidity before the beginning of drying process

$x_{V1}{}' = 0.104(kg_{VP}/kg_{SV})$ - absolute humidity after the end of drying process

$\Theta_{VC2}{}' = 55(^oC)$ - temperature of humid air at the input to the heat exchanger

$\Theta_{VC1} = 90(^oC)$ - temperature of humid air before the beginning of drying process

$\Theta_{VC1}{}' = 56(^oC)$ - temperature of humid air after the end of drying process

$x_{M1} = 0.1495\left(\frac{kg\omega l}{kgsm}\right)$ - the absolute humidity of the rubber before the beginning of drying process

$g_{\omega l1} = \frac{x_{M1}}{1+x_{M1}} = \frac{0.1495}{1+0.1495} = 0.13\left(\frac{kg\omega l}{kg_M}\right) = 13(\%)$ - relative humidity of the rubber before the beginning of drying process

$\Theta_{MC1} = 50(^oC)$ - temperature of humid rubber before the beginning of drying process

Table 2. Electric- thermal calculation of the drying process of rubber

Unknown parameters	Formula for calculation	Obtained values
The surface of the conveyor belt through which the air flows, is:	$\boldsymbol{A_v = L \cdot l}$	$\boldsymbol{A_v = 20\ m^2}$
Surface cross section of humid rubber on the conveyor, is:	$\boldsymbol{A_M = l \cdot h}$	$\boldsymbol{A_M = 0{,}24\ m^2}$
The mass flow of dry air. is:	$\dot{m}_{SV} = \rho_{SV}\ \omega_V\ A_V$	$\dot{m}_{sv}$ **= 33120 kg/h**
The mass flow of dry material, is:	$\dot{m}_{SM} = \rho_{SV}\ \omega_M\ A_M$	$\dot{m}_{svm}$ **= 6048 kg/h**

Equation of the heat balance of the process of heating the humid air in the heat exchanger - the condenser:

$$\dot{m}_{SV}\left(c_{PSV} + x_{V2}' c_{PVP}\right)\Theta_{VC2}' + \dot{m}_P r(\Theta_P) = (c_{PSV} + x_{V1} c_{PVP})\Theta_{VC1}$$

za $p_p = 12(bar) = 0 \quad \Theta_P = 187.95(^oC) = 0 \quad r(\Theta_P) = 1987000(J/kg)$

The mass flow of the dry saturated water vapor in the heat exchanger, is:

$$\dot{m}_P = 0.18888(kg/s) = 680(kg/h)$$

Equation of the material balance of the drying process

$$\dot{m}_{SV}(x_{V1}' - x_{V1}) = \dot{m}_{SM}(x_{M1}' - x_{M1})$$

The absolute humidity of the rubber on the output from the first drying zone, is:

$$x_{M1}' = 0.0674(kg_{\omega l}/kg_{SM})$$

The relative humidity of the rubber on the output from the first drying zone, is:

$$g_{\omega l1}' = \frac{x_{M1}'}{1 + x_{M1}'}$$

$\boldsymbol{g_{\omega 1} = 0{,}063\ kg_{\omega}/kg_M = 6{,}3\%}$

The equations of thermal balance of the drying process

$$\dot{m}_{SV}[(c_{PSV} + x_{V1}' c_{PVP}) \cdot \Theta_{VC1} + x_{V1} r_o] - \dot{Q}_g$$

The heat losses in the unit of time during the drying process are:

$$\dot{Q}_g = 5206.9(W)$$

This amount of heat are consumed by the humid rubber for its heating, so it follows:

$$\dot{m}_{SM}(c_{SM} + x_{M1}' c_{\omega l}) \cdot \Theta_{MC1} + Q_g' = \dot{m}_{SM}(c_{SM} + x_{M1}' c_{\omega l}) \cdot \Theta_{MC1}'$$

Temperature of the humid rubber on the output from the first drying zone:

$$\Theta_{MC1}' = 51.34(^oC)$$

The representation of the drying process on the $i_V - x_V$ diagram for humid air (Figure 2)

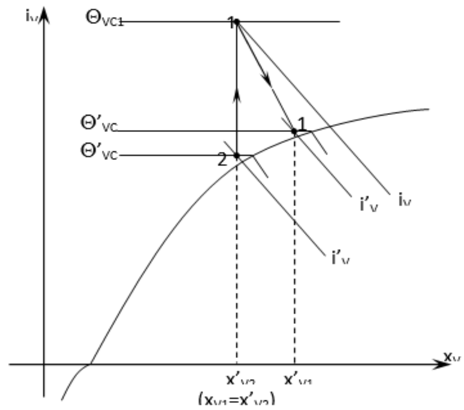

Figure 2. The representation of the drying process on the $i_V - x_V$ diagram for humid air

Calculation of the pneumatic transport of rubber granules from the strip dryers to the cyclones

The granules are having the surface cooling with the fresh air in the last ventricle of the dryer. Than the granules that are connected were mechanically broken and then take it to the machine for crushing which produces the uniform size of granules which are necessary for dosing in baling presses. Through the shake machine, desiccated granules of rubber will reaching the pneumatic conveyor [6], [5].

Parameters of pneumatic transport

G_s = 7000 kg/h - transport capacity
$\sum \xi$ =0,80 - sum of the coefficients of local resistance losses
ρ_v =1,2 kg/m^3 - density of fluid-air
λ =0,02 - coefficient of friction in the pipeline
K_r =1,4 - coefficient of resistance to wastage of material
N = 75kW - known information about the power of the installed fan

The steps in calculation of the pneumatic transport

The calculation is based on the known values (from the technological guidebook):
- quantity of air Q_v = 8000 m^3/h = 2.22 m^3/s
- bulk density 200-300 kg/m^3
- max. granulation 100 x 100 mm

- v=18,2 m/s - adopted transport speed based on bulk density 240 (kg / m3)
- L= L_h + L_v + L_{ek} - length of the pipeline,
  - L_{ek}= 0,8 - equivalent length of the pipeline
  - L_v =16,85 m - geodetic height of the granulate
  - L_h =14,6 m - horizontal section of the pipeline.

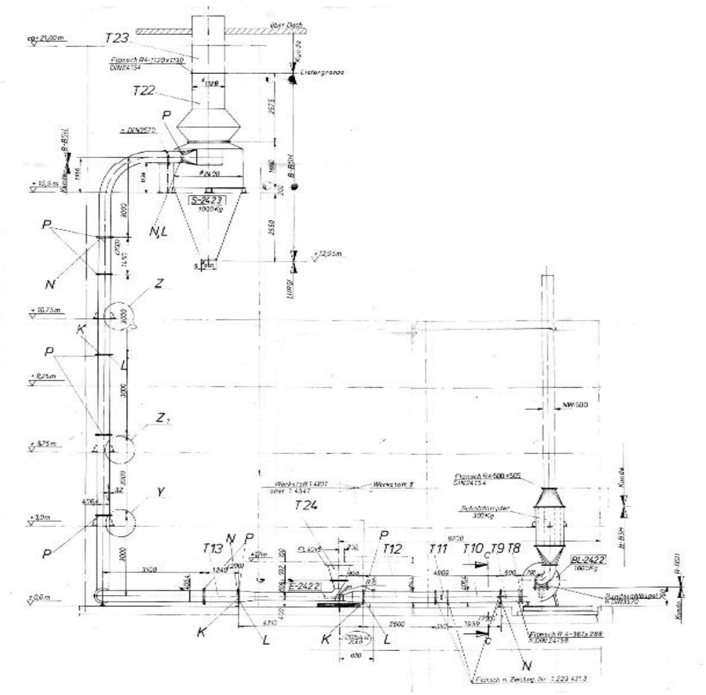

Figure 3. The scheme for pneumatic transport from the dryer to the cyclone

- for granular material v=18,2 m/s , C_k = (3÷8), C_k= 5 – coefficient of concentration
k = (0,5 ÷ 0,7) , k = 0,55 - resistance coefficient
- From the equation for the amount of air, we can determine the diameter of the pipeline:

$$Qv = \frac{d^2 \cdot \pi}{4} \cdot V_v$$ - The equation for the quantity of air (2)

Table 3. The steps for calculating the pneumatic transport

Unknown parameters	Formula for calculating	Obtained values
Pipeline diameter	$d = \sqrt{\frac{4 \cdot Q_v}{V_v \cdot \pi}}$	d = 0,394 mm
Pipeline length	L= L_h + L_v + L_{ek}	L=39,45 m
Losses due to friction of material on the walls of the pipeline	$\Delta p_{tr} = \left(\lambda \cdot \frac{L_e}{d} + \sum \xi\right) \cdot \rho_v \cdot \frac{V_v^2}{2} \cdot (1 + K \cdot c_k)$	$\Delta p_{tr} = 20887 Pa$
Losses due the geodetic height	$\Delta p_h = \rho_v \cdot c_k \cdot H \cdot 10$	$\Delta p_h = 876 Pa$
Losses due to wastage of materials	$\Delta p_r = K_r \cdot c_k \cdot \rho_v \cdot \frac{V_v^2}{2}$	$\Delta p_r = 1391{,}2 Pa$
Total pressure drop	$\Delta p_{uk} = \Delta p_{tr} + \Delta p_h + \Delta p_r$	$\Delta p_{uk} = 23154{,}2 Pa$
Power of installed fan	$N = \frac{k_1 \cdot Q_v \cdot k_2 \cdot \Delta p}{1000 \cdot \mu}$	N = 74,212 kW

According to the manufacturer of equipment, the power of installed fan is N = 75 kW. Based on the whole previous calculation, we can see that we almost got identical values for the power of installed fan, so we proved the assumptions at the beginning and empirical assumptions. All the assumptions that we mentioned at the beginning are correct.

CONCLUSION

In this paper was performed the calculation of the optimum operating parameters of the pneumatic conveyors and strip dryer, which is using for process of transporting and drying of the synthetic rubber. Dryers for drying the rubber in the finalization process, directly affects the quality of the final product. The drying process of synthetic rubber with the unsaturated humid air in the strip dryer, which is located in the finalization section, can be presented graphically with the „sharply" look in the „i_v-x_v" diagram for humid air. In every stage of drying process the unsaturated humid air is gradually cooled and saturated with moisture from the humid rubber. Each step in drying process, which corresponds to each drying zone, can be modeled (described) by one dots in the diagram. The sum of these dots shows us summary chart for the entire drying process. Changes in thermodynamic values can also be tracked from the individual parts or from the entire diagram. This justifies the selection of this control thermal calculation for the one strip dryer for the control of the drying process of synthetic rubber. Based on the known and obtained values, it is determined that values are in the same limit zone like the manufacturer recommended.

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AVAILABLE ENERGY POTENTIALS FROM WOOD AND HERBAL BIOMASS FROM THE TERRITORY OF THE MUNICIPALITY OF LUČANI

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Abstract: The basis of sustainability in terms of social stability is to secure new jobs and independence from energy imports. There is growing awareness of the need to replace fossil fuels and preserving the environment, which contributes to sustainability, and thus to the creation of a positive social climate towards renewable sources. Wood biomass has the widest use among different types of biomass. Well-designed forest complexes are a sustainable source of energy because they can be renewed, CO_2 emissions are neutralized and are a good substitute for existing fossil fuels. Creating a positive environment for the use of wood biomass brings with it a sustainable solution for future energy needs.
In this paper, the available energy potentials from wood and plant biomass arising in the territory of the municipality of Lučani.
Key words: wood and plant biomass, energy potential, Lučani municipality

INTRODUCTION

The use of available waste wood and plant biomass for energy or other purposes is significant due to poor energy potentials in general, as well as due to the reduction of import dependence, the provision of energy supplies, the reduction of environmental pollution, and the fulfillment of international commitments to reduce CO_2 emissions. Also, rational use of available waste wood and plant biomass for energy and other purposes would significantly influence the raising of the technological level of energy, mechanical engineering, food industry, etc., faster development of poorly developed regions rich in waste from agricultural wood and plant biomass realized through: realization of investments, engagement of local workforce, opening of new jobs, improvement of local infrastructure, and realization of income through various types of production. Some of the aspects of environmental protection are aggregate environmental impacts of wood and vegetable biomass residues in: air, watercourses and land and on the change or degradation of the habitat (humans, flora and fauna). To date, in our country, the knowledge about such influences is mainly based on observation and oral statements.
In addition, using waste wood and plant biomass generally can have three interrelated aspects: (1) economic (or perhaps techno-economic) sustainability, (2) ecological sustainability, and (3) social sustainability. So sustainable development systems depend on the practical application of appropriate technologies that provide the best "conjunction" between techno-economic feasibility, social acceptability and environmentally sustainable use of available resources.
Due to lower supply of fossil energy sources in the present time, growing interest in other energy sources is expressed. Such energy sources are alternative energy sources, or renewable energy sources. This group consists of energy sources: wind energy, solar energy, waterpower, geothermal energy, wave energy and energy obtained from biomass.
The most important energy of the 20th century was oil. In the world's primary energy consumption oil participated with about 35%, coal with about 24%, gas with about 18%, renewable energy with about 17% and nuclear energy with about 6%, [6,8].
One of the most important renewable energy sources, if not the most important, is biomass as for the amount of energy periodically renewed and relatively small cost of production and collection. The great advantage of biomass is reflected in the acquisition of eco-friendly alternative fuels, as one of the possible solutions is more imposing is biodiesel, fuel that originates from plant processing and waste oils, [1-3].

For sustainable economic development depends on sufficient amount of energy, and increased use of energy sources is unavoidable.

AVAILABLE ENERGY POTENTIALS FROM WOOD AND HERBAL BIOMASS FROM THE TERRITORY OF THE MUNICIPALITY OF LUCHANI

From the territory of the Municipality of Lučani (Figure 1.), energy use can be used from biomass from forest ecosystems, grass biomass (meadows, pastures), orchard biomass, raspberry, biomass of agricultural crops, etc.)

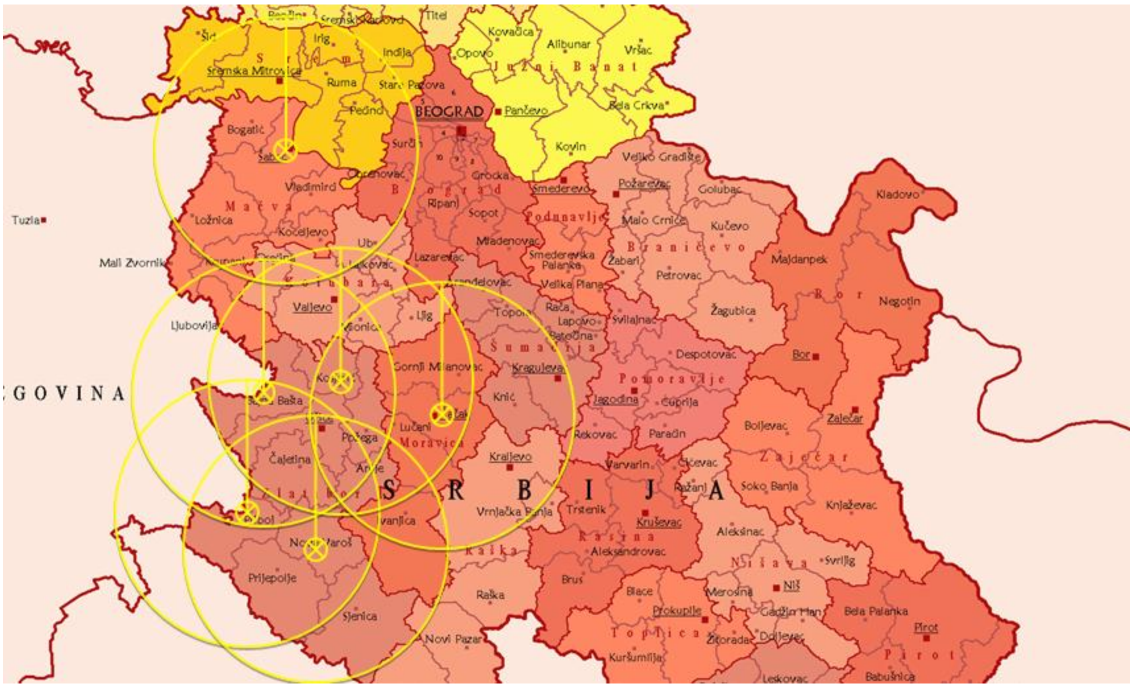

Figure 1. Municipality of Lučani with neighboring municipalities and Regions

Healthy wood from regular farming of forests

State forests under the forests in the municipality of Lučani extend to 3709.34 ha, while the area of forests in private ownership is 11914 ha, according to [7]. Based on forest management in state ownership, the annual average harvesting volume is 2800 m^3 per year. The intake of private property is 6200 m^3 per year.

The forest stock of the municipality of Lučani is given in Table 1. In this table, the basic production indicators are given, which are: area P (ha), percentage share of state and private forests P(%) and predicted volume of logging V (m^3) for a period of one year. Table 1. Energy balance for biodiesel made of rapeseed and MJ/ha.

Table 1. Forest Fund of the Municipality

Ownership	P (ha)	P %	V(m^3)
State property	3709	23,75	2800
Private property	11914	76,25	6200
TOTAL	15623	100,0	9000

Energy potentials from the heavy tree from the regular farming of forests

Based on [2] in Table 2., the upper thermal power and the peak mass, for some trees represented, are given for the territory of the municipality of Lučani.

Table 2. Upper heat power and volume, for some trees

Tree type	**Upper heat power (MJ/kg)**		**Volume mass (kg/m^3)**	
	Wood	Bark	Wood	Bark
Beech	18,82	18,00	680	580
Oak	18,36	19,70	650	425
Black poplar	17,26	18,00	410	412
Prickly	19,66	21,20	430	340
Jelly	19,46	21,00	410	460
Pine tree	21,21	20,62	580	300

In Table 3., according to [4], heat power for different values of humidity of trees, as well as volume mass for different values of humidity of trees for the Municipality of Lučani, are given.

Table 3. Thermal power for different values of wood humidity

Type of wood	**Heat power (MJ/kg)**				**Volume mass (kg/m^3)**			
	Wood and humidity			Bark with 0% moisture	Wood and humidity			Bark with 0% moisture
	0%	30%	50%		0%	30%	50%	
Beech	18,82	11,87	7,7	17,00	680	798	1117	580
Oak	1836	11,80	11,50	19	650	750	980	425
Pine tree	21,21	12,87	9,50	20,62	580	750	980	300
Jelly	19,46	11,90	8,30	21,00	410	730	880	460
Prickly	19,66	12,57	8,28	21,20	430	542	759	340
Other trees	15	10	5	17,00	250	300	400	300

Based on [3], according to Table 3, the thermal power and humidity for trees that are cut in the territory of the municipality of Lučani were adopted and are given in Table 4.

Table 4. Thermal power and humidity for trees were adopted

Type of wood	**Adopted humidity around 30%**	
	Adopted heat power (MJ/kg)	Weight Adopted (kg/m^3)
Beech	12	750
Oak	12	700
Pines	13	600
Jelly	12	510
Prickly	13	550
Other trees	10	400

According to the available quantities in Table 1, as well as the adopted values for the thickness and weight of the wood from Table 3 and 4, the energy potentials of forest species that are cut for the territory of the municipality of Lučani (in MWh / year) are calculated, and those are given in Table 5.

Table 5. Energy potentials of forest tree species

Hardwoods	**In total (MWh/god)**
15623*12*700/3600	36453,67

Wood resident that are according to the use of the forests (seeds)

Wood residue that occurs during the use of forests (residue that occurs in cutting and making out of lining and spatial wood, hornbeam, granite, etc.).
The rest of the tree felling in the forests in the territory of the Municipality of Lučani amounts to about 10% (according to [2]), which is 1562.3 m^3, and the part that can be used for energy purposes is about 7%, which is 1093, 1 m^3 per year.

Energy waste continuous potentials are provided by the forest application

According to the available quantities of residues from forests in the territory of the Municipality of Lučani, 1093.1 m^3 / year, as well as the adopted values for the thickness and weight of trees in Table 4. and 5., these available energy potentials for the territory Municipalities of Lučani (in MWh / year), and they were given to the Table 6.

Table 6. Available energy potentials from residues in the case of noise cuts

Hardwoods	Total (MWh/god)
1093,1*12*700/3600	2550,56

Wood from forestry green vegetables (fragments of forests, whether based, forest vegetables, roads and et)

For calculating the available energy potential there are no recorded data on quantities and types of energy sources, but according to the recommendations of the relevant expert services from the Local self-government and the adopted values for thermal power, the energy potential is calculated, and the calculated values for the energy potential (in MWh / year) in Table 7.

Table 7. Energy potential of forest fragments

Fragments of forests	Total (MWh/god)
550*12*700/3600	1283,33

Wood and plant biomass through the keeping and cleaning magistral and other roads

On the territory of the Municipality of Lučani, adequate JKP to maintain urban green peony and roads, thus collecting wood and agricultural biomass that can be used for energy purposes. For calculating the available energy potential there are no recorded data on quantities and types of energy sources, but according to the recommendations of the relevant expert services from the Local self-government and the adopted values for thermal power, the energy potential is calculated, and the calculated values for the energy potential (in MWh / year) in Table 8.

Table 8. Energy potential of road cleaning

Type of energy source	Total (MWh/god)
Cropped grass	500
Wailing leaves	200
Treated trees	100

The removal which will be prescription of wood

Usually in sawmills of the total amount of wood that is processed between 50 and 65% of the commercial product, and the rest is wood residue. Thus, the wood residue that occurs in wood processing is within the range of 35% to 50%. We will accept that for the territory of the Municipality of Lučani, the rest in wood processing is about 50%.
A rough estimate, based on incomplete data, the energy potential of the wood residue in its processing in factories, from the territory of the Municipality of Lučani is about 5000,00 MWh/ year[1].

[1] The authors came to this data using some experiences from similar projects they were involved in in the Republic of Serbia.

Removal of agricultural production (rating, returning, viticulture)

Out of the total area of agricultural land used, from the local self-government of the municipality of Lučani, 206 ha or 2244 agricultural holdings, arable land and garden 6751 ha, 4071 agricultural holdings, meadows and pastures 7437 ha or 4519 agricultural farms, orchards and vineyard 2699 ha ie 4449 agricultural farms, 1392 ha plantation areas, 1307 ha, 1307 ha, vegetable areas, bosom and strawberries 49 ha (tomatoes 2 ha, cabbage 10 ha, paprika 1 ha, onion 1 ha) [7].
Of the total area under arable land and gardens of 6751 ha, under cereals and legumes there are 3618 ha, under peanuts 27 ha, under potatoes 997 ha, under industrial herbs 3 ha, and under fodder plant is 1852 ha and this mixture of grasses is 840 ha, corn for silage 226 ha, clover 332 ha. Also, the total area under the wheat is 799 ha, under the gardens it is 16 ha, under the barley 80 ha, under the oats it is 265 ha, under the corn for the grain is 2336 ha and under the other grain crops is 123 ha.
For now raspberries give yields about 10 tons, planted under a plum about 10 tons, planted under the blackberry about 7.5 tons [7].
Surveillance of surfaces under agricultural culture In municipality Lučani

Table 9. Survey of areas under agricultural crops

S.N.	Culture	AREA (ha)
1.	wheat	800
2.	corn	2300
3.	tooth	250
4.	barley	100
5.	potato	950
6.	apple	500
7.	pear	90
8.	sleep	1300
9.	raspberry	900
10.	blackberry	50
11.	strawberry	35

Potential energy sources and their areas under planting are obtained from the data: Agricultural Census 2012. year for the territory of the municipality of Lučani.
Lower thermal power from wood and agricultural biomass, according to [5, 1], are given in Table 10.

Table 10. Lower thermal power from wood and agricultural biomass

R. N.	Available Biomass	Lower heat power (MJ/kg)
1.	Wheat straw	14,00
2.	Barley straw	14,20
3.	Oat straw	14,50
4.	Straw straw	14,00
5.	Corn	13,50
6.	Maize corn	13,85
7.	Weed	14,70
8.	Sunflower stalk	14,50
9.	Shell sunflower	17,55
10.	Soybean straw	15,70
11.	Strawberry oil	17,40
12.	Stem hops	14,00
13.	Stem of tobacco	13,85
14.	Remnants of orchards in orchards	14,15
15.	Remnants of residues in vineyards	14,00
16.	Mushroom	23,00

The energy potentials of agricultural residues are given in Table 11, according to the data from the Population Census 2012, as well as the recommendations from [1, 7].

Table 11. Energy potentials from agricultural residues

Species crops	Available energy potential	Available energy potential
Cereals	2,1 t/ha	1150*2.1*14*1000/3600
Corn	3 t/ha	2300*3*13.5*1000/3600
Potato	1,5 t/ha	950*1.5*12*1000/3600
Strawberry	1,1 t/ha	35*1.1*10*1000/3600
blackberry	1,1 kg/m	50*12000*1,1*16/3600
Raspberry	1 kg/m	900*15000*1*15/3600
Fruits	2,1 t/ha	1300*2.1*12/3600
Other	0,1 kgm^2	no data

The values of thermal power from agricultural residues were calculated, the values of heat power, according to the available quantities and Table 11, were calculated on the treated areas from the territory of Lučani municipality (MWh /year) Table 12.

Table 12. Energy potentials from agricultural residues

Type of crop	Energy potential (MWh/god)
Cereals	9391,67
Corn	25875,00
Potato	4750,00
Strawberries	106,95
Blackberry	2933,34
Raspberry	56250,00
Fruits	20533,36
Other	negligible

NOTE: The remainder as a product of agricultural production can be used as an energy source according to [3], ¼ or ½ of the calculated energy values depending on the type of plant residues. The rest in cutting fruits, raspberries and blackberries can be used as a 100% energy source. Accordingly, the availability of waste agricultural energy for the territory of the Municipality of Lučani is given in Table 13.

Table 13. Total energy potentials

Energy source from the rest	Total (MWh/god)
Cereals (1/4)	2347,92
Corn (1/4)	6468,75
Potatoes (1/2)	2375,00
Strawberries (1/2)	53,48
Blackberry	2933,34
Raspberry	56250,00
Fruits	20533,00
TOTAL	90961,49

CONCLUSIONS

For the rational utilization of the available quantities of biomass as a fuel, as well as the residue from the use of forests when cutting and processing wood, from the municipality of Lučani, appropriate quantities and energy potentials from wood and agricultural biomass are defined.
On the basis of the obtained results, the energy potentials for the territory of the Municipality of Lučani in MWh/year. are:
- from firewood from regular forest management 36453,67 MWh/year.

- from the rest that occurs during the use of forests (the residue that occurs in the felling and production of lining and spatial wood, hornbeam, granite, etc.) 2550,56 MWh/year.
- from wood from extracurricular greenery (borders, forest plants along watercourses, roads, etc., 2550,56 MWh/year.
- from wood and agricultural biomass obtained by maintenance of plants along the main and other roads 800,00 MWh/year.
- from wood residues from wood processing 5000,00 MWh/year.
- from residues from agricultural production (crop, vegetables) 90961,49 MWh/year.

ACKNOWLEDGEMENTS

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SOME ASPECTS OF ABSORPTION COOLING

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Abstract: Some industrial process uses a lot of thermal energy by burning fossil fuel to produce steam or heat for the purpose. After the processes, heat is rejected to the surrounding as waste. This waste heat can be directly used for heating purposes and/or converted to an useful refrigeration as in absorption or adsorption refrigeration cycle. The absorption cycle operates under two pressure levels. The condenser-generator are located in high pressure level, the evaporator-absorber in low pressure level. The working principle is based on different boiling temperatures of the refrigerant and the absorbent. Actually, the thermal compressor uses a heat-driven concentration difference to move refrigerant vapor from the evaporator to the condenser. In this study has been presented working principal and importance of absorption cooling with classification.
Key words: Cooling, absorption, solar power

INTRODUCTION

It seems to be useful to give a comparison of absorption refrigeration cycle with the more familiar vapor compression cycle. Main components and the working principle of the absorption cycle is analogous to that of the vapor compression cycle with two main differences. Firstly, there is a thermal compressor, which consists of generator, absorber, heat exchanger, throttle valve, in absorption cycle instead of mechanical compressor in vapor compression cooling cycle. Secondly, absorption cooling cycle needs a secondary fluid as absorbent.
An absorption cooling machine would produce cooling energy for refrigeration, comfort cooling or process cooling purposes by using the residual heat from sources such as steam, hot water or hot gas. The common approach to explain the absorption refrigeration cycle is by comparing it with the more familiar vapor compression cycle, Figure 1 [1].
The working principle of the absorption cycle is similar to that of the vapor compression cycle with two main differences. Firstly, the vapor absorption cooling (VAC) system has thermal compressor instead of mechanical compressor in vapor compression cooling (VCC). Secondly a secondary fluid in addition to the refrigerant, known as liquid sorption medium or absorbent exists in VAC system [1]. The performance and efficiency of absorption systems is directly correlated with the chemical, thermo physical and thermodynamic properties of the working fluid. Many working fluids have been considered for absorption systems. The most common working fluids with practical application in absorption systems are H_2O-NH_3 and LiBr-H_2O [1]. Working fluids H_2O-NH_3 is suitable for refrigeration purposes and LiBr-H_2O is applicable for process and comfort cooling purposes over 4 ^{o}C, because water vapor is refrigerant in that case. The absorption cooling system will be explained in following sections with working fluid of LiBr-H_2O.

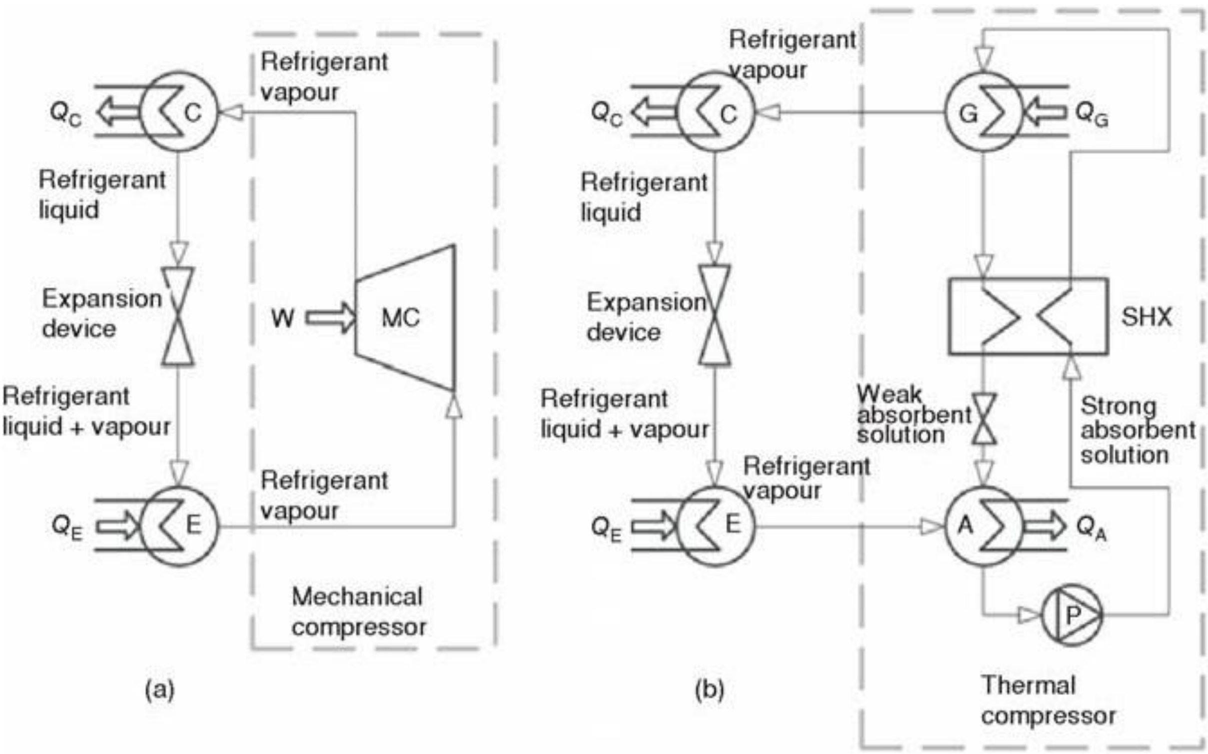

Figure 1. Comparative schematic of absorption cooling with vapor compression cooling system [1]

MATERIAL AND METHODS

Working principal

In its simplest design the absorption machine consists of an evaporator, a condenser, an absorber, a generator and a solution pump [2]. The working principle is based on different boiling temperatures of the refrigerant and the absorbent. External heat input in the generator causes that refrigerant is boiled out of a solution and compressed to the refrigeration vapor at higher pressure while the concentrated absorbent stays liquid. The hot refrigerant vapor flows to the condenser where heat is removed by external heat sink, condensing the refrigerant vapor to liquid. The high-pressure liquid then passes through an expansion device reducing its pressure to the evaporator pressure level. External heat input causes a refrigerant to evaporate. The low pressure refrigerant vapor is then passed into the absorber where it condenses diluting the concentrated absorbent coming from the generator. The diluted solution (rich in refrigerant) is then pumped back to the generator where it evaporates again, closing the cycle. In other words, the “thermal” compressor of the absorption cycle uses a heat-driven concentration difference to move refrigerant vapor from the evaporator to the condenser [1].

In the absorption cycle (Figure 1), the role of the mechanical compressor in compression cycle is replaced by “thermal compressor” which consists of generator, absorber, solution heat exchanger, solution pump and throttling valve. Just like the vapor compression cycle, the absorption cycle operates under two pressure levels. High pressure level (refrigerant separation side) corresponds to the condenser-generator while low pressure level of absorption process in vacuum corresponds to evaporator-absorber. The high pressure level is approximately ten times higher than low pressure level in order to allow the heat rejection of the refrigerant at commonly available temperatures [1].

Figure 2 shows the basic principle of an single effect absorption cooling machine Figure 3 presents functional schematic of double-effect absorption chiller, and Figure 3 gives scematic of direct-fired absorption chiller [3].

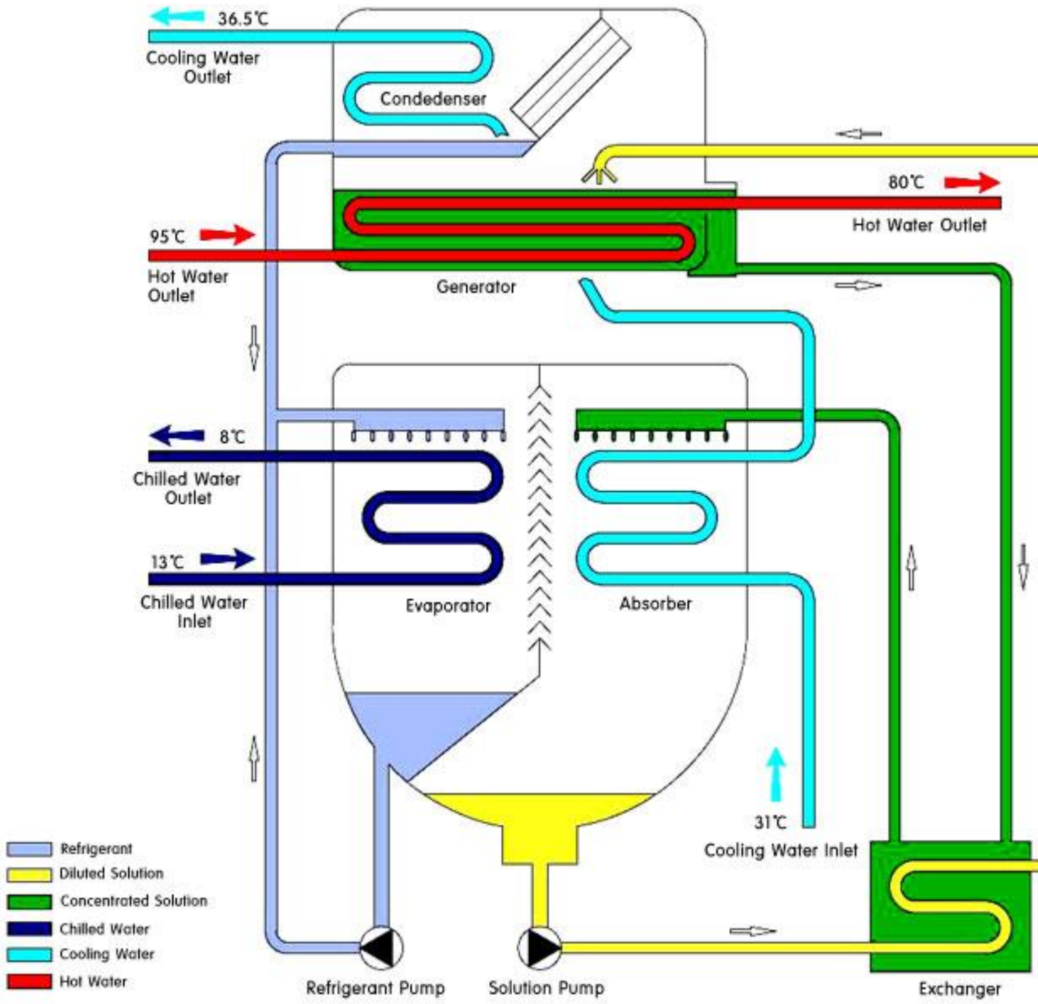

Figure 2. Schematic of hot water driven absorption chiller [3]

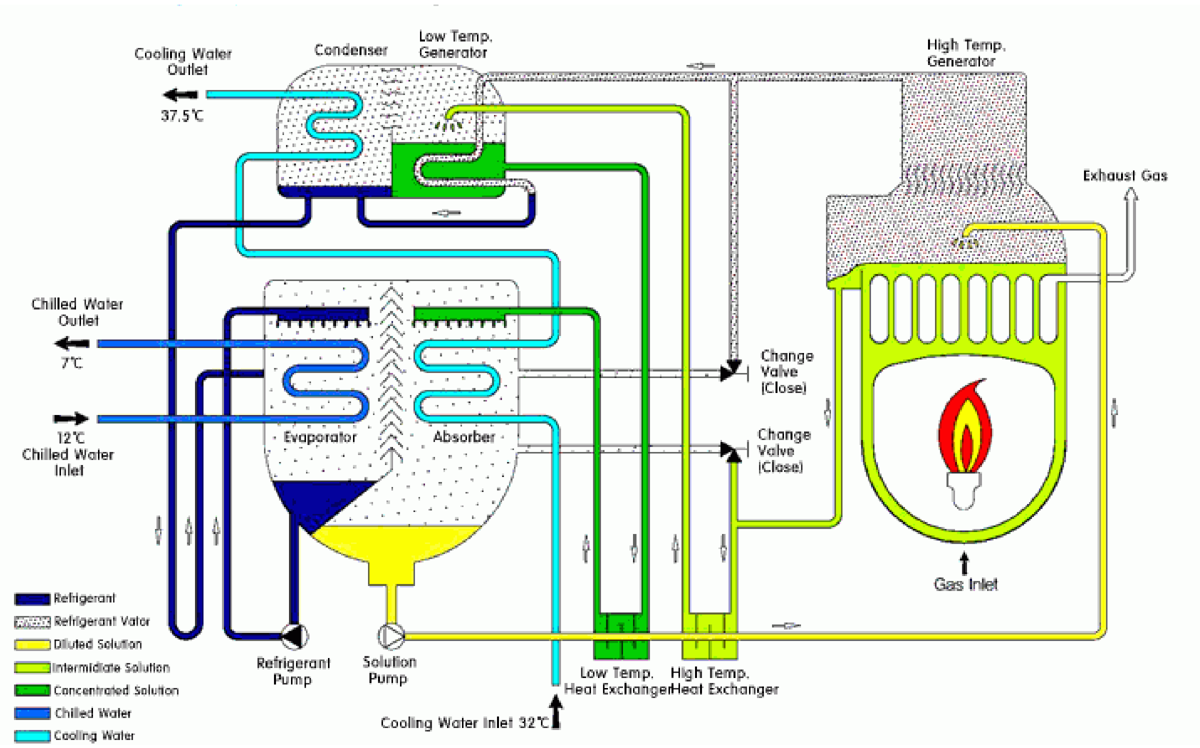

Figure 3. Scematic of direct-fired absorption chiller [3]

Classification

The absorption machines can be classified based on several criteria: main function, firing method, number of effects and stages, condensing method, working fluids, application, and capacity [1]. Most common classification are performed due to firing method and number of effect respectively as direct- or indirect-fired, and as single, double - or triple-effect. In direct-fired units, the heat source can be gas or some other fuel that is burned in the unit. Indirect-fired units use steam or some other transfer fluid that brings in heat from a separate source, such as a boiler or heat recovered from an industrial process. Hybrid systems, which are relatively common with absorption chillers, combine gas systems and electric systems for load optimization and flexibility [4].
The single-effect “cycle” refers to the transfer of fluids through the four major components of the refrigeration machine - evaporator, absorber, generator and condenser, as shown in the Pressure-Temperature diagram in Figure 4 [5]. Single-effect LiBr/H_2O absorption chillers commonly use low pressure steam or hot water as the heat source. The water is able to evaporate and extract heat in the evaporator because the system is under a partial vacuum. The thermal efficiency of single-effect absorption systems is low. Although the technology is sound, the low efficiency has inhibited the cost competitiveness of single-effect systems. Most new single-effect machines are installed in applications where waste heat is readily available. Single-effect chillers can be used to produce chilled water for air conditioning and for cooling process water, and are available in capacities from 7.5 to 1,500 tons.

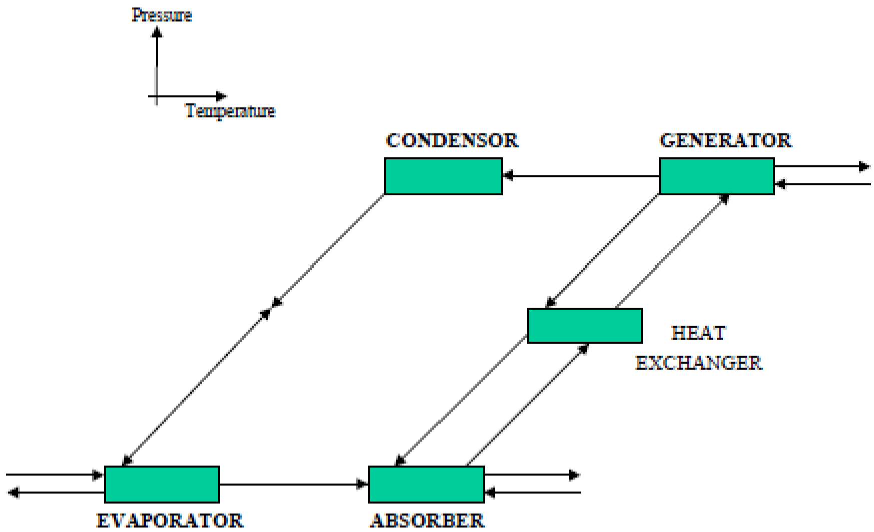

Figure 4. Single-effect absorption cooling cycle [5]

Figure 5 gives double effect absorption chiller in pressure-temperature diagram [5]. Double-effect absorption cooling cycles improve the performance of absorption systems by using the input heat twice A double-effect absorption system has two stages of generation to separate the refrigerant from the absorbent. The overall efficiency of the absorption system is increased by indirectly using the inputted heat a second time [6].

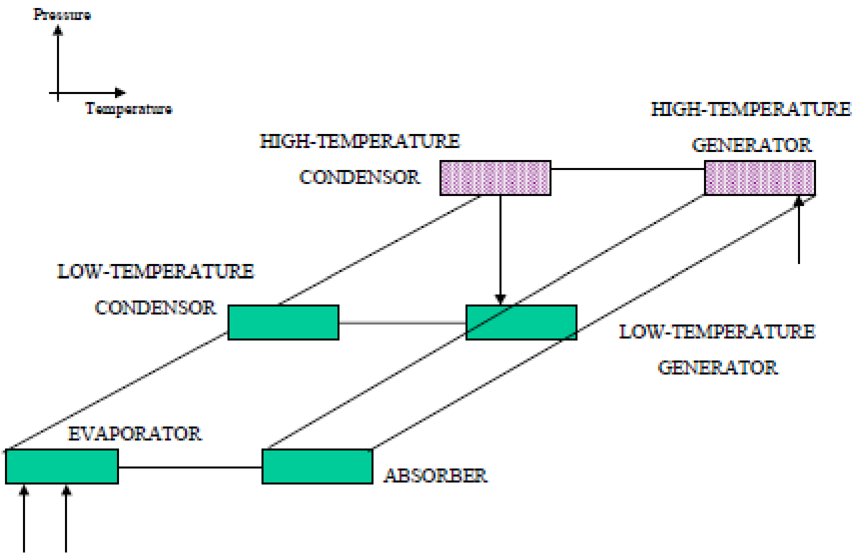

Figure 5. Double-effect absorption cooling cycle [5]

The triple-effect absorption cooling cycles are the next innovative stage over the double-effect. Triple-effect absorption chillers are under development, as the next step in the evolution of absorption technology. Figure 6 shows the triple effect absorption cycle on a Pressure-Temperature diagram. The refrigerant vapor from the high and medium temperature generators is condensed and the heat is used to provide heat to the next lower temperature generator. The refrigerant from all three condensers flows to an evaporator where it absorbs more heat. Two different triple-effect absorption chiller cycles are capable of substantial performance improvements over equivalent double-effect cycles. One uses two condensers and two absorbers to achieve the triple effect. A second, the double condenser coupled (DCC) triple-effect, uses three condensers as well as a third condenser subcooler. Triple-effect systems offer the possibility of thermal efficiencies equal to those of electrical chillers. The cost, however, will be higher, so system cost effectiveness will need to be evaluated on a case-by-case basis. The higher efficiency levels would open wider markets for absorption chillers.

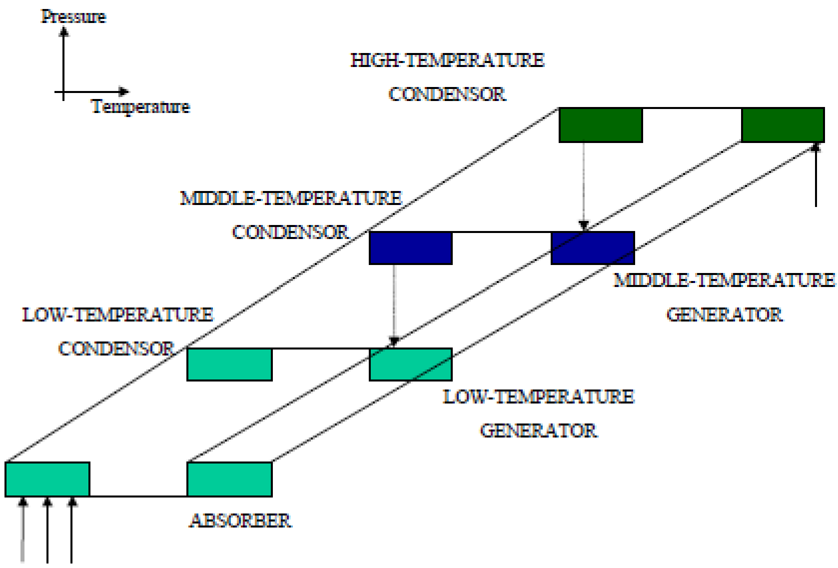

Figure 6. Triple-effect absorption cooling cycle [5]

RESULTS AND DISSCUSSION

The desire for higher efficiencies in absorption chillers led to the development of double-effect LiBr/H_2O systems. The double-effect chiller differs from the single-effect in that there are two condensers and two generators to allow for more refrigerant boil-off from the absorbent solution. Figure 4 shows the double effect absorption cycle on a Pressure-Temperature diagram (Anonymous 3, 1998:1). Figure 5 presents functional schematic of double-effect hot water driven absorption chiller (Anonymous 3, 1998:1). The higher temperature generator uses the externally supplied steam to boil the refrigerant from the weak absorbent. The refrigerant vapor from the high temperature generator is condensed and the heat produced is used to provide heat to the low temperature generator. These systems use gas-fired combustors or high pressure steam as the heat source. Double-effect absorption chillers are used for air-conditioning and process cooling in regions where the cost of electricity is high relative to natural gas. Double-effect absorption chillers are also used in applications where high pressure steam, such as district heating, is readily available. Although the double-effect machines are more efficient than single-effect machines, they have a higher initial manufacturing cost. There are special materials considerations, because of increased corrosion rates (higher operating temperatures than single-effect machines), larger heat exchanger surface areas, and more complicated control systems.

CONCLUSION

Efficiencies of absorption chillers are described in terms of coefficient of performance (COP), which is defined as the refrigeration effect, divided by the net heat input. Single-effect absorption chillers have COPs of approximately 0.6-0.8 out of an ideal 1.0. Since the COPs are less than one, the single-effect chillers are normally used in applications that recover waste heat such as waste steam from power plants or boilers. Double-effect absorption chillers have COPs of approximately 1.0 out of an ideal 2.0. While not yet commercially available, prototype triple effect absorption chillers have calculated COPs from 1.4 to 1.6. However, COP or system efficiency would not be main criteria for proper selection. System selection procedure would mainly be performed according to available heat source. Namely, it seems to be effective to prefer single-effect absorption cooling system in order to use of solar energy. It should also be taken into consideration for how to assess the waste heat simultaneously.

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THE ADVANTAGES OF INTRODUCING ENERGY MANAGEMENT IN INDUSTRY

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Abstract: The importance of increasing energy efficiency, increase and advantages of it by introducing energy management have been analysed in this paper. Companies use energy in various forms for their businesses, including electricity, gas, oil and steam. Energy reserves are constantly depleting and as a result energy becomes more and more expensive. Energy efficiency in industry is the right answer for growing financial pressure caused by increase in price of energy, and the need for organisation to present in public and to clients as environmentally responsible. The enhancement of energy efficiency relates to reduction of energy use for: production, service (heating, lightning, mileage and other) or for some conducted activities. For this reason the energy management is in the focus of all businesses worldwide. International standard ISO 50001 has the aim of introducing the system of energy management within organisations. Through the framework of energy management in organisations, as this standard recommends, organisations should set saving energy programmes by which energy efficiency and more competitive positions on the market are achieved.
Key words: energy efficiency, energy management t, ISO 50001

INTRODUCTION

People use renewable energy for transport, cooking, heating, cooling, production, as well as entertainment and other purposes every day. But the ways this energy is used and spent in many manners influences our lives and environment. So it is crucially important, not only to save energy, but also to be used in the most efficient way. Although energy losses can be only minimised and not completely erased, they can be decreased in various manners, by using different techniques and also by more careful and more optimum spending of a certain amount of energy needed for completion of some process. If it is used inappropriately, when there is a difference between conducted and used amount of energy, we have waste that leads to financial losses. Inefficient use of energy is a result of bad projecting, inadequate work process characteristics, bad maintenance, idle time or equipment work when not necessary.
Hiring experts for energy efficiency in contemporaty time became a necessity for companies in order to save money, and also to contribute to the environment. Energy manager, according to the Law on Efficient Energy Use, gathers and analyses data on the ways of energy use in the company, prepares plans and programs, recommends measures that contribute to the efficient energy use and delivers an annual report to The Ministry of Energetics.
Standard ISO 50001 sets the framework for managing energy in industrial plants, commercial, institutionalised and state infrastructure, and in entire organizations. The system of energy management is a system of organized energy management in a way that parties of the energy management system conduct legally prescribed obligations with the aim of achieving rational energy use with minimum costs. This international standard specifies demands for setting, applying, maintaining and enhancing energy management system, the role of which is to enable an organization to follow a systematic approach in achieving constant advancement of energy performance, inluding energy efficiency, use and consumption of energy.

ENERGY AND ENERGY EFFICIENCY IN INDUSTRY

Energy represents the ability of some body to perform work. We live in the world of energy and practically everything that suurounds us is based on energy use of some sort. Energy can appear in several forms [10]:

- potential energy (the effect of the position the object is in in relation to other objects);

- kinetic energy (the effect of object movement);
- chemical energy (the effect of chemical connections among object substance atoms);
- electrical energy (the effect of electrified objects);
- heating energy (the effect of object heat);
- nuclear energy (the effect of instability of atomic cores);
- electromagnetic energy (the energy of radiation, light, radio-waves or some other form).

When we talk about natural energy sources they are divided on:

- non-renewable energy sources – present resources once used and cannot be renewed. The supplies of non-renewable sources of energy are less and less every day due to the impossibility of their regeneration and greater consumption, and it is probable that the humanity will remain without these resources in the next century.
  - Fossile fuels (coal, oil, natural gas, oil shales),
  - Nuclear fuels
- renewable sources of energy – present those sources of energy that have the ability of total or partial regeneration. The reserves of renewable sources of energy are estimated to last several millions of years. Here we have:
  - sun radiation energy,
  - wind energy,
  - water power (energy of rivers, sea current and waves, high and low tides and similar),
  - internal Earth heat (geothermal energy).

As the natural forms of energy can very rarely be used without transformation (except the Sun heat, thermal springs and geothermal that can be used directly, we have common cases where transformation from one form into another has to be done several times in order to get the energy form used by end customers, what is called useful form of energy. The useful forms of energy are: [8]

- heat energy,
- mechanical energy,
- electricity and
- solar energy.

Two dominant and closely related problems faced by the world today are, on one side, lack and unsteadiness in energy supply and on the other pollution of the environment and climate changes as a result of excessive energy use. One of the ways for negative impacts to lessen and to positively influence the sustainable development is efficient energy use. Energetic efficiency presents the score of measures and activities in all fields of life whose aim is minimum energy consumption, with the condition of maintaining the same level of work and life, or even to be enhanced. It is not merely saving the energy that presuposes denials, but efficient use that contributes to enhancing the quality of work and living, and also to higher competitiveness on the market. [9]
The importance of energetic efficiency and rational energy management, at all levels, from local to state ones, is seen in providing steady energy supplies, cutting energy consumption and energy costs with achieving and maintaining the optimum quality of energy services and decreasing negative environmental impact with securing sustainable development.
The energy efficiency in industry can be achieved by energy production with the use of renewable sources of energy. For this reason solar panels on the roofs of industrial plants are proposed, the use of heat pumps for providing cheaper heating, as well as wind generators. The industry is one of the biggest energy consumers in our country, and achieving savings in the energy costs would lead to profit increase, which is a very important, main, reason for reduction. In certain statistics we can come across some data that with smart energy management in industry the consumption can be lowered down for even 20 to 30%.
Some of the most energy intensive industrial branches are:

- chemical industry,
- iron and steel production,
- glass production,

- colored metal production,
- food industry.

In these fields the application of energy efficiency can be beneficial in extremely short period of time.

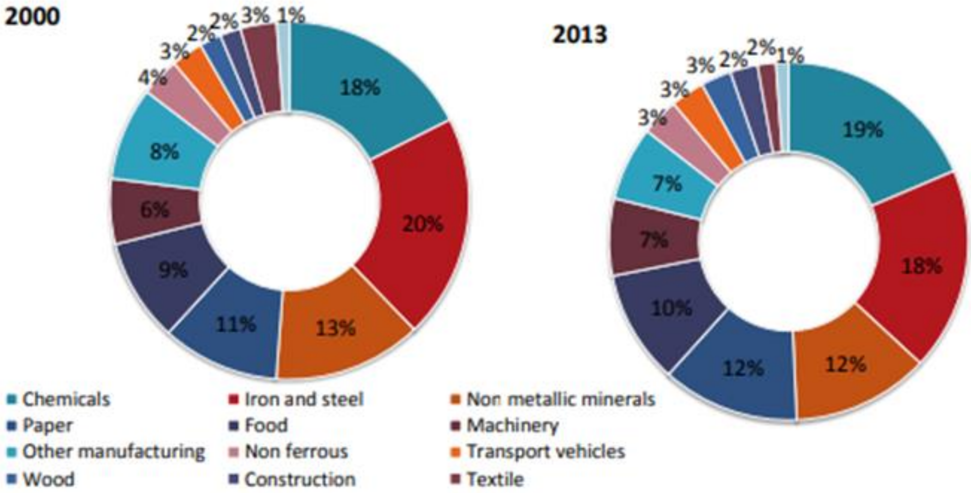

Figure 1. Distribution of energy consumption by industrial branch in the EU
(Source: ODYSSEE from Eurostat)

The problems that the industry in Serbia faces are: [6]
- low physical volume of production compared to normal;
- obsolete, used and energy intensive production and energetic technologies;
- financial problems of keeping the production and regular production and energy plants maintenance;
- systems for measures and regulation are obsolete and out of function;
- investment inability for renewing production and energy technologies;
- managers and experts are lacking with information about ways and measures for energy efficiency increase;
- the system of use and management monitoring are scarce;
- restructuring process;
- specific and huge energy consumption.

Achieving a positive result in energy saving in the industry is possible only by integrating significant factors, as well as with good expert knowledge in the field of saving industrial energy, thermodynamics, production technologies, energy measures, work organization, automatics and regulations, and also with energy costs/tariffs. In order to achieve energy saving it is necessary to undertake the following steps:
- make a record of existing state with necessary energy measures
- analyse existing state by processing available data
- calculate energy balances and numbers, find the point take makes losses and determine options for energy savings
- define the measures by which obvious energy losses are eliminated according to the priority and significance,
- define the enhancement of industrial processes with the aim of wiser energy use,
- reconstruct bad installations or appliances and introduce new energy efficient technologies and
- introduce energy management and energy manager to business

THE ADVANTAGES OF INTRODUCING ENERGY MANAGEMENT

Enhancing the efficiency of energy use does not include just the application of modern and new technical solutions, but also the need for quality energy management and trained staff to use the equipment and energy in adequate ways. For this reason energy management is being introduced in companies. Energy management is a system that is set in all the company structures with the aim of continuous decreasing the energy spending and maintaining achieved enhancement of energy efficiency. [7] It ensures that company continuously goes through the cycle of building the strategy, planning and implementing the actions and checking the results on the basis of which the new strategy is created. With adopting The Law on Efficient Energy Use in Serbia in 2013, the foundations for setting the system of energy management were established. Application of this law is aimed at the areas of industry, services, public sector, transport sector and households, and it is obligatory for local governments in charge of population of over 20000 people and big energy consumers in industry, commerce and service sectors. [4] The Law puts energy manager in charge of energy saving pprogramme. It is a person authorized by share-holders and that has a license for practicing this job. The tasks of energy manager are:

- gathering and analyzing data on ways of energy use,
- preparing plans and programmes of energy efficiency,
- proposing measures that contribute to enhancement of energy efficiency and
- making and delivering an annual report to The Ministry of Energetics.

There are many reasons for introducing energy management in companies, and one of the most important ones is the impact on the environment. Also, minimizing costs is another significant reason. Introducing energy management provides:

- monitoring the energy use in the company and various production units,
- monitoring the energy use in real time (when in some sector the consumption of energy drastically changes, the cause is immediately determined and the right steps can be undertaken at that moment),
- preparation of systematized and structured energy system documentation of the company.

The system of energy management in a company has various positive effects like: [2]

- direct effects of energy management: lower energy costs, energy saving and profit increase and
- indirect effects: better environmental situation, lowered costs for insurance and maintenance, better working conditions etc.

The application of continuous energy management in a company leads to cutting the costs as Picture 2 shows.

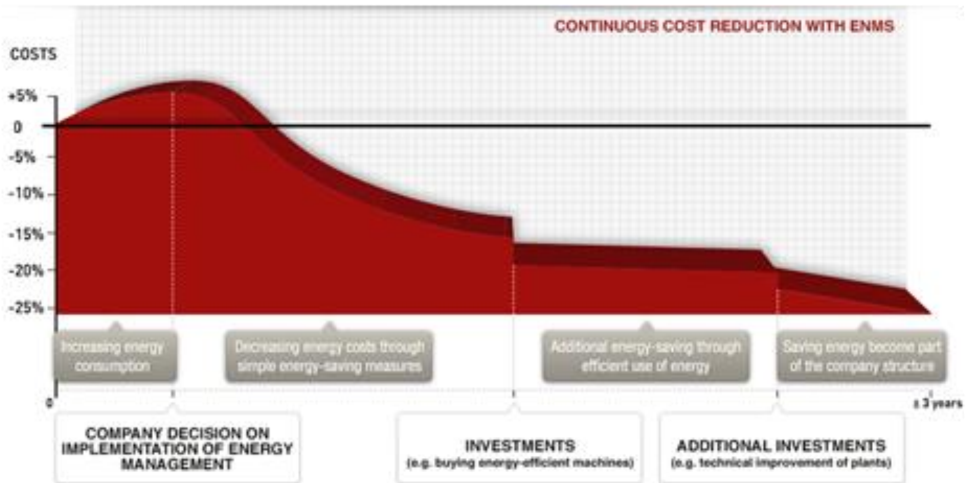

Figure 2. The effects of continuous energy management

Energy audit is the key for developing a programme for energy management. The aim of energy audit is to determine where, when and how the energy is used. This information is subsequently used for identifying possibilities of efficiency enhancement, deacreasing energy costs and lowering gas emissions of greenhouse effect that impact the climate change. Energy audit can also be used for testing the effects of energy management measures, after they have been introduced. Organisations that do the audit get significant experience in how to manage the energy consumption and its costs. Going through the audit process, employees start viewing the energy as a cost and they become more aware of how their everyday actions influence the energy consumtion of the enire factory.

STANDARD ISO 50001

International standard organisation (ISO) has identified energy management as one of five most significant areas that demands development and promotion of international standards. The new standard should provide technical and managerial strategies for increasing energy efficiency, cutting the costs and deacreasing negative impact on the environment to organisations and companies. Based on wider application through national economic sectors, the future standard can influence up to 60% of energy demand on the planet. Although it is primarily aimed for industry, the standard is applicable on any type of organisation that wants to manage energy and energy efficiency successfully. [5]
ISO 50001 is based on the management system model of continual improvement also used for other well-known standards such as ISO 9001 or ISO 14001. This makes it easier for organizations to integrate energy management into their overall efforts to improve quality and environmental management. ISO 50001 specifies requirements applicable to energy use and consumption, including measurement, documentation and reporting, design and procurement practices for equipment, systems, processes and personnel that contribute to energy performance. It is applied to all the variables that affect energy performance. This standard provides methodology for continual improvement in energy performance without explicitly specifying any performance criteria that has to be satisfied with respect to energy. This standard is based on Plan-Do-Check-Act (PDCA) continual improvement framework in the context of energy management. [3]

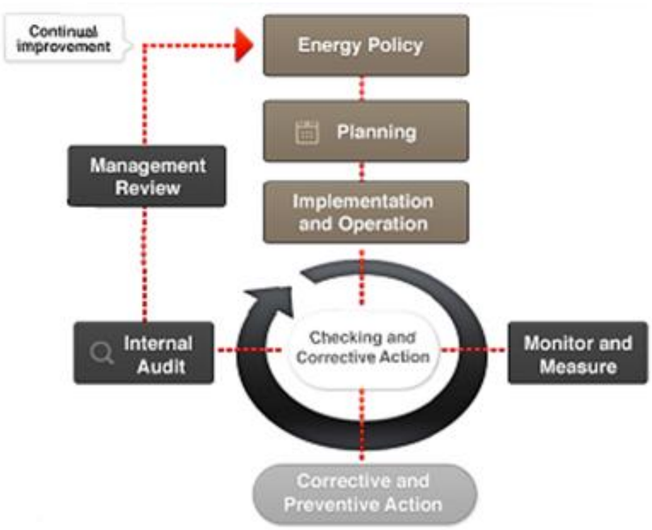

Figure 3. Energy Management System Model for ISO 50001

ISO 50001:2018 provides a framework of requirements for organizations to: [1]

- Develop a policy for more efficient use of energy,
- Fix targets and objectives to meet the policy,
- Use data to better understand and make decisions about energy use,
- Measure the results,
- Review how well the policy works, and
- Continually improve energy management.

ISO 50001 is based on the model of management system that organisations worldwide already understand and apply. It can make a positive difference for organisations of all types in very near future, while at the same time it supports long term efforts for enhancing energy technologies.

CONCLUSION

Non-renewable resources of energy make the biggest portion of energy in the world today. The supplies of non-renewable resources of energy are depleting due to continuous increase in consumption and their inability to renew. The main disadvantage of non-renewable energy resources is that by burning the fossile fuels (coal, oil, gas) into the atmosphere, great emissions of carbon dioxide are released (CO2). This is also the main problem with the use of fossile fuels viewed environmentally. The need to gradually make a transfer from non-renewable to renewable resources of energy with current technical and technological level is imperative for every and each community. Communities that will change the fastes in the direction of rational energy consumtion will be the leaders of development and also the richest and most desirable on planetary level.

The energy management system is compatible with the environment, and this means that with the efficient actions in production, transformation and energy consumption it decreases environment pollution. The aims of the energy management system and environment impacts are decreasing the pollution and operational costs. Imperative certainly has to be informing and training the people because their behaviour is crucial for energy impact and the environment.

The reason for introducing energy management in industry certainly should not present just formal application of legal directives, but also to enable rational use of energy resources, to continually conduct and monitor the measures of enhancing the energy efficiency and in the end to accomplish significant financial savings, to secure the profit.

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Session 3.

Designing and maintenance

MAINTENANCE OF IT INFRASTUCTURE

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Abstract: IT infrastructure maintenance is the key to ensuring business continuity. The IT industry follows certain standard IT infrastructure maintenance principles with a few variances, and the same standards are relevant in the context of various organizations. These practice can be customized based on the unique context of individual organizations. IT infrastructure maintenance can be divided into four broad areas: server, desktop, backup and security. Today's business conditions almost always require some maintenance method to prevent malfunction with dangerous consequences.
Key words: maintenance, server, backup, security

INTRODUCTION

Maintenance is generally defined as the implementation of the measures needed to make the technical systems work, or to carry out their tasks with sufficient security. The computerization of the operations of modern organizations has led to great dependence on the whole system of computer support. This support can be viewed separately, such as hardware, software, communications, security, licensing, but all these aspects are so interconnected that they can't be viewed isolated but just as part of the whole. In addition to interconnection, these systems are intertwined with other aspects of business, so a complex and comprehensive set of information is needed to select a strategy to maintain that system.
Approach to the maintenance of computer systems most often depends on the size of the organization. Computer maintenance is entrusted to one of the most professional employees in the area, third-party services, or specialized IT companies, and only large systems can afford a special IT service.

SERVER MAINTENANCE

Servers are used for very important tasks and contain very important data. Maintaining a continuous server operation and preservation data is an extremely important process. For special servers, which work with value, personal data and other important data, this is extremely important not only for the institutions and companies that work with these data but also for all those whose data is used - individuals, firms, banks, municipalities, states,…
Server failure may cause the following:

1. Power failure
2. Hardware component failure (power unit, motherboard, HDD, and so on).
3. Operational system and application software malfunction
4. Human factor - user mistakes.

The server maintenance goal is to enable the server to have a year-round availability with annual malfunction duration within tolerance (fault-tolerant). For the malfunction tolerance measure the following parameters are used [1]:

- Mean Time To Failure (MTTF),
- Mean Time To Recover (MTTR).

The goal of each system is to make MTTF zero using various methods of redundancy.

Securing the server from a power failure

The biggest cause of a server failure is a power failure. The UPS is a great solution for shorter power cuts since it is made up of batteries that can power the system for a certain period of time, which is enough to eliminate a shorter failure and properly shut down the server via the operating system. From a long power failure we can be protected by the use of a power generator. The best solution for power failure is a combination of these two systems, since the UPS has a quick response and maintains power until the generator is switched on and takes over all the load.

Securing the server from a hardware failure

If the hardware component is broken, it must be replaced with a new one. However, as the server needs to work without interruption, that hardware component must be present on the server and ready to work immediately. To eliminate or shorten server downtime, the hardware components should be:

- hot-spare - spare on the server. They turn on automatically in case of failure,
- hot-swap - replaceable without having to restart the server.

Also one of the solutions is to have a whole redundant matching server that would immediately replace the defective**.** This solution is called Cluster Server and can consist of two or more servers.
The Windows server supports two types of Clusters:

- Network Load Balancing: a simple fault-tolerant application server. This service allows TCP / IP applications to extend to 32 disks. If one server fails, the load and connections on that server are automatically deployed to the remaining servers without a specially assigned hardware.
- Failover Cluster uses a shared resource (disk area) between node clusters, which must have identical hardware and capabilities. This configuration gives little downtime and is designed for mission-critical applications and services.

The common cause of a server failure is a HDD (Hard Disk Drive) failure. The solution to this problem is the Redundant Array of Independent Disks (RAIDs) that consists of a set of 2 or more HDDs that are connected so that it can safely continue to work if one of the disks is broken. We differentiate hardware and software RAID fields. Hardware RAID is implemented using RAID Controller and is considerably more expensive, faster and better than software RAID.

Table 1. Types of RAID Fields

Type	Number of disks	Speed	Fault tolerance	Description
0	N	Largest	None	It's not fault-tolerant. The highest reading and writing speed.
1	2N	Good	Better	Mirror. Faster reading then a single disc but slower writing. A disk failure does not cause data loss.
3	N+1	Better	Good	The parity is on the byte level. Data is written to multiple drives at the level of bytes, while parity data is being written on a particular drive. Reading is faster but writing is much slower than a single disc. The failure of a disc does not cause data loss, but it significantly slows down the operation.
4	N+1	Better	Good	Parity at block level. Parity data is distributed to all disks.
5	N+1	Good	Better	Parity at block level. Parity data is distributed to all disks. Reading is much faster but writing much slower than a single disc. The failure of a disc does not cause data loss, but it significantly slows down the operation.

Table 1. Types of RAID Fields (continued)

Type	Number of disks	Speed	Fault tolerance	Description
10	2N	Largest	Better	Shared mirror discs (0+1) or mirror shared disks (10). Data is shared over multiple disks in the mirror or multiple disks are configured in the mirror. The failure of any disc does not cause data loss or slow down the operation. The failure of second disc may cause data loss. Reading and writing is faster than on a single disc.

Securing the server from operating system malfunction

Operating system failures can be caused by viruses or other malware. A simple way of keeping the current configuration is the System Restore feature, which automatically or manually create a snapshot of a system files which can be recovered by using certain procedures. System Restore performs the following tasks [2]:

- Restore the server to the previous state,
- Restore server without loss of personal files,
- Keeps the restore points over the last 1-3 weeks,
- Determines the dates assigned to return points,
- Ensures that all restores are reversible,
- Allows creation of multiple restore points: checkpoints the initial system.

Other ways of securing servers from downtime

Virtualization as an additional advantage also brings a simple and fast process of creating duplicates of virtual machines on other servers and media. The two most common virtualization environments are VMware and Hyper-V. Both virtualization environments have multiple ways to copy VMs: VM cloning, snapshot VM, moving VM. The following types of VM clones are: Linked Clone - a copy that shares virtual drives (VHDD) with the VM from which a clone was made; Full Clone - a separate, complete copy of VM that does not share anything with the VM from which a clone was made. The Snapshot VM copies the contents of the VM memory, the VM parameters, and the status of all VHDDs. AutoProtect can be deployed to take snapshots at certain time intervals. You can choose to take snapshots certain VHDDs. Snapshot can be taken while the VM is turned on, off or suspended. VM can be moved to another host with the same or different operating system. vSphere, as a server virtualization platform, provides additional capabilities for maintaining VM work. Migrating VM from one host or datastore to another can be done in several ways. The simplest way is Cold Migration that allows you to move VMs to another host or datastore when the VM is off, so only VM files are transmitted [3]. Something more complex is migration in a suspended state in which we have to take a care of the compatibility of old and new hosts (Suspended Migration). Resolving the deadlock server with virtualization method is much faster, cheaper and easier than restoring the hardware equipment and the necessary software in working condition.

COMPUTER MAINTENANCE

On maintenance of electronic components of computer systems should be taken into account from the earliest stages of computerization of business, because the initial savings later may prove to be a great burden, both financial as well as operational. For example, investments in UPS (uninterruptible power supply) is symbolic, and significantly reduces the chance of occurrence of a hardware failure. Basic diagnostics of computer systems can often be done by the users themselves, as hardware repairs are reduced to the replacement of components. It is not difficult to determine whether the cause of the failure, e.g. a faulty monitor, keyboard, or the fan on the processor. It is sometimes harder to determine if it is a software (defective driver) or hardware failure, rather than a component that is defective.

SOFTWARE MAINTENANCE

The only reliable way to ensure the security of digitally stored information is to make backup copies of data. The obligation to make backup copies can be introduced through a quality management system. To create a backup we can use portable media (USB flash drive, CD-RW, DVD-RW), and free or commercial services for storing data on the Internet (Dropbox, Google Drive, Microsoft Live, etc.). On servers, it is common to use RAID technology that ensures data backup redundancy for automated backup copies. It is also used backup to magnetic tapes that are stored by one of the storage systems (Data Protector Manager, Symantec Backup Exec, etc.). Lately RAID is used even on desktop computers, whether it is implemented through hardware (disk controller) or software (operating system). The main problem when using the application software is the transition to the new version when it occurs. Sometimes the new version is so different that it requires special training for users to learn a new user interface. Another problem is file formats, because they may not use all the latest version of the application, so it may happen that a document created with a new version can't be opened by users who still use the old version. As operating systems are exposed daily to malicious software attacks, it is important to ensure that patches are installed regularly.

BACKUP OF DATA

Protecting data by backing up data is a critical element of every ICT system. Permanent loss of even small amounts of data can be fatal for business. Data loss may occur during physical failure or damage to the hard disk or the media to which data is being recorded (disc brake, heavy strike, thunder stroke, power or current problems). Frequent cause of data loss is the insufficient level of security within the existing IT system, which is primarily concerned with the attacks of malware (viruses, malware, spyware).

Defining a backup policy

Backup Policy is a set of rules within a company or organization that defines storage-related activities. Before creating a backup policy, it is necessary to consider some very important facts:

- Frequency of backups - daily, weekly, monthly?
- Recovery point - Depends on the speed of data change and their importance. Can we allow data loss for the previous 7 days?
- Backup type - it is possible to set different types of backups (incremental-data storage that has been changed or newly-created compared to the last backup, full backup ...)
- Backup devices – tapes, NAS devices or backup devices?
- Backup to another location - this backup type is the safest one. The question is how often do we want it and where to make a backup?
- Online backup - do we need backup data in the cloud?
- Security - Do we want to make encryption when storing data?
- What do you want to store - documents, emails, databases?

How the backup system will look depends on [4]:

- Acceptable loss of data / transactions (RPO – Recovery Point Objective),
- Acceptable time without data / production (RTO – Recovery Time Objective).

Server virtualization has brought new and advanced options of the backup and recovery for virtualized environments but there are also specialized backup and restore solutions that use all the benefits of a virtualized environment to ensure business continuity.

Types of backups

Local data backup involves automatically storing data on another disk from a computer that contains the data that you want to store / save. This is the least secure way of making a backup of data. External backup data is most commonly used for daily / weekly / monthly data storage on an external (portable) disk. Cloud backup or storing data in the cloud is among the safest available means of data storage. Backup device is one of the most important factors when creating a backup policy. One of the storage device is a tape backup that is still, although now not as popular as it once was, a good choice for those who quite often do the entire backup. Portable Hard Drive is the simplest form of backup devices that are commonly used in small offices and companies with a small number of computers. NAS (Network-Attached Storage) devices are perhaps the best solution for medium and small businesses. NAS devices come in multiple variants, ranging from a 1TB available wireless hard disk to up to more terabytes of RAID devices designed for deployment within the company.

SECURITY

Nowadays, private and state organizations have large amounts of confidential information that needs to be adequately protected in order to preserve their confidentiality. Information is considered a resource today and the loss of confidentiality of some information has detrimental effect on the organization itself. Security policy is manifested as a set of rules, guidelines and procedures that define how the information system should be secure and how to protect its technological and information values. It tells users what they can do, what they can't do, what they have to do, and what their responsibility is (it imposes sanctions if the user fails to comply with security policy rules). Based on the defined rules, its task is to provide three unique properties of information: ***Confidentiality*** is the protection of data contained in the system from unauthorized access. Identification is the user login process to the system, where the system knows that such a user exists. There are several authentication methods. The most widespread method is to enter a password, but there is growing technology and equipment that transforms unique human traits, such as fingerprints or eye retina into digital signals. Confidentiality can be affected in several ways. These are the most common threats to confidentiality [5]: **Hackers** are people who exploit security vulnerabilities of the system in a way that unauthorized use system or dismantle it. Many hackers, except for security weaknesses of the system, using the method of discovering passwords of authorized users. Phishing is a threat in which a user via a password of another user gets the ability to access the system under a different name, and thus "opens the door" for performing malicious actions. **Unauthorized activity** occurs when an authorized user of the system uses the data for which he has no authority. Inadequate access control and data protection allow unauthorized access. **Copying data** may compromise confidentiality if the data is copied to a system with insufficient security protection. **Local networks** poses a threat because the data that travels over the network can be retrieved at any node. To avoid this type of threat, all secret data that should only be available in certain nodes must be encrypted. A **Trojan horse** is an application that is installed on a computer system after it is automatically launched by an authorized user and is programmed to copy data to unprotected system parts. Once launched, Trojan horse remains active on the system and constantly performs scheduled tasks.
Integrity [6] is the protection of data from deliberate or accidental unauthorized alteration. Key elements for achieving data integrity are identification and authentication of users. Since integrity is dependent on access control, it is important to positively and uniquely determine the identity of all users registered in the system. Basic principles for integrity control:
Granting access based on need. Users should get access only to the data they need to be able to fulfill their tasks. User access to critical data should be further limited by quality-defined transactions that ensure that user data can be changed in strictly controlled conditions in order to preserve data integrity. **Separation of duties.** To ensure that no individual has control of the transaction from start to finish, two or more people should be responsible for performing it. This prevents transactions from being used to perform their own interests, unless all responsible persons agree. **Rotation of duties.** Work obligations of individual employees should be periodically modified to control transactions for personal use was even more complicated.

Availability is a guarantee to authorized system users that their system will be available at any time they need it. The two most common causes of system unavailability are: **Denial of service (DoS)** is a malicious attack which aims denying legitimate users the ability to access (Internet) services (eg. Web server). The denial of service can be divided into two categories: attacks that exploit known bugs (glitches) in operating systems and servers. These attacks are used to "collapse" the program. Thus, the services provided by these programs are denied. **The denial of service attack by flood package** is attack that exploit the weaknesses of the infrastructure of the Internet and its protocols. Flood seemingly normal package exploit the resources of the program (the server). In this way, the services are denied to legitimate users.

Risk Analysis is a process aimed at identifying system vulnerabilities, detecting potential threats and adequately quantifying possible consequences in order to be able to choose the most effective method of protection or to estimate the justification for introducing additional countermeasures. There are two basic approaches to risk analysis: Quantitative analysis implies risk reporting at expected annual financial costs, while the result of the qualitative analysis shows only the relative value of damage caused by the action of some threat and the introduction of countermeasures. It should be borne in mind that this assessment is of a subjective nature and is therefore subject to errors. In principle, a combination of quantitative and qualitative analysis is an approach suitable for most companies. Although it is considered that security threats usually come from outside research shows that the highest percentage of security problems is caused by human error. They most often occur due to lack of attention and education of employees. The second major cause of system faults is equipment malfunction, followed by employees who use their position in the institution for their own benefit and employees who express their dissatisfaction with the company or the superior person in this way.

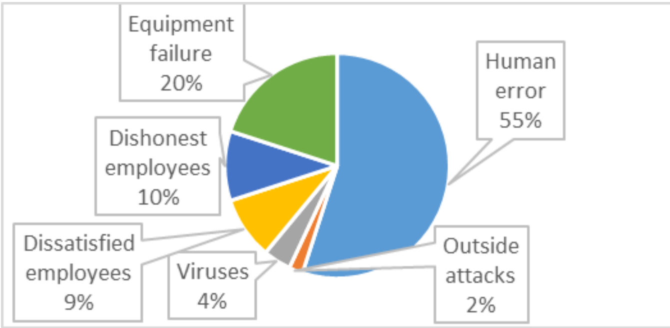

Figure 1. Security problems in large companies

Measures such as educating employees reduce the likelihood of their error which could jeopardize the integrity and security of the system. Placement of equipment on which data is stored in a separate room, regulations governing who can access it, controlling the conditions in such space, such as temperature and humidity, we achieve a longer service life of the equipment and thus the reliability of the system. The rarest, but attacks that usually cause the greatest damage are attacks from "outside". They participate in a very small percentage, with the aim of obtaining information, altering them or destroying them. The system defends itself from such attacks by controlling traffic from the Internet to the system and vice versa, preventing the installation of programs in the operating system or encrypting the data. In order to achieve maximum system security, it is necessary to pay attention to: **Physical security.** The basic feature of physical security is the protection of the physical part of the IT infrastructure, the building where it is located, the data storage media and communication equipment. Physical security measures include all the defensive measures taken to protect the computing infrastructure from natural disasters, environmental problems, accidents and intentional damage. **Safety measures for personnel.** The biggest threats to information systems are the people who are connected with it, through day-to-day work or through periodic maintenance. Some people are not qualified enough for a particular job and it may happen that such a person accidentally destroys the information and endangers the information system. Endangering the system is also possible by deliberate actions of the system user, either for pleasure, for personal gain or for any other reason. **Safety communication.** Network communication can be made with more secure access control, encryption of data that travels through the network, security walls, and other physical protection measures. Access control is an important factor in achieving computer security in the network environment. In order for access control to have its meaning, users must abide by the basic rules when keeping their password:

- Never store the password near the computer or terminal,
- The password must not be a user's name or an easy-hit idea,
- The password must not be saved in the file on the computer.

In addition to these rules, it is possible to define additional rules that control the system [7]: Passwords generated from the system; Minimum password length; Password lifespan; Limited number of attempts; Last Access Message; Encrypted and hidden passwords records; Password lock; Smart cards; Additional passwords; One-time passwords; Time-dependent passwords.

CONCLUSION

Maintenance of the IT infrastructure, in order to achieve high-availability systems, requires proper planning, design and installation of all system components. Without a well-designed system and all its associated components, it is not possible to maintain data integrity and high availability of the system. Building an efficient logical structure with proper security and access control is the first step towards maintaining data integrity. Here the biggest role play safety, not only to prevent unauthorized access but can also prevent or limit the accidental deletion of files and spread viruses and malware across the network. Also power problems can destroy all of our data. Unfortunately, preventing problems with the power supply is not as simple as installing the bias protector on each computer, but requires significant investments. As LAN grows in size and capacity, data backup issues become much more complex. Each complex technical system should be specifically analyzed to determine the optimal way of maintenance. The choice of maintenance strategy stems from the business strategy of the company. Today's business conditions almost always require some method of maintenance in order to timely prevent failures with dangerous consequences.

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DEVELOPING A SYSTEMATIC APPROACH TO PROJECT PORTFOLIO SELECTION IN PROJECT BASED ORGANIZATION

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Abstract: Selection of right sets of projects is considerably critical for organizations to successfully achieve their competitive advantages and corporate strategies. Due to limited resources and dynamic changes in business environment, this kind of selection is quite challenging for project based organizations. Beside one hundred selection tools and techniques, academics and practitioners have studied and recommended complex selection frameworks to facilitate the selection of right projects. This study is intended to better understand the academic and practical literature about project portfolio selection; study current practices of project selection that project based organizations in Iran are using; and propose a framework that is beneficially adaptable to these project based organizations. A case study strategy accessing qualitative data through observations and semi structure interviews is designed to investigate how project based organizations select their project portfolio under the current contexts of economy in Iran to ensure successful realization of their growth and development strategy. The recommendations resulted from literature review and investigations do not only support the investigated project based organizations to improve the quantity and quality of their investment project portfolio(s) but also facilitate possible adaptation to project portfolio selection by other corporations.
Key words: project selection, project portfolio selection, project based organization

INTRODUCTION

Recent studies show that many organizations have been trying to implement their corporate strategies through projects [1]. Hence selecting right projects and right mix of projects for the portfolio is considered as one of the most important tasks for the organizations to ensure the achievement of the corporate strategy within limited resources and capabilities of the organizations. Many discussions in the literature reveal that the right sets of projects for implementation of corporate strategies are importantly resulted from successful selection of project portfolio [2]. Our initial research and observation show that private project based organizations (PBO) in Iran also face this challenge of lacking a project selection framework or process. They do not have many experiences in selection of project portfolio as well as in application of selection tools and techniques [3]. Yet, these private corporations have to deal with the challenges of selecting the right projects in terms of time, cost, scope and quality to realize their strategy of growth and development. Therefore, our studying current practices of project selection in private PBO in Iran and proposing an adapted framework for project portfolio selection based on theoretical and practical review of literature will provide significant contribution to improvement of the quantity and quality of project portfolio selection in PBO in Iran which entails more widely application of project portfolio selection in the industry of project management and project portfolio management.

MATERIAL AND METHODS

Project Portfolio Management

Project Portfolio Management (PPM) is the centralized management of the processes, methods, and technologies used by project managers and project management offices (PMOs) to analyze and collectively manage current or proposed projects based on numerous key characteristics. The objectives of PPM are to determine the optimal resource mix for delivery and to schedule activities to best achieve an organization's operational and financial goals, while honoring constraints imposed by customers, strategic objectives, or external real-world factors. The International standard defines

the framework of the Project Portfolio Management [4]. Project portfolio management is project portfolio selection as it is understood as a dynamic decision-making process to evaluate, select and prioritize a project or a set of projects for implementation through allocation of constrained resources and alignment with corporate strategies. Companies use various project evaluation techniques to determine the feasibility and profitability of a project. The investor or decision maker needs tools to predict the profitability of proposed projects. A lot of methods and techniques are available for helping the investor to make wise economic decisions. These methods and techniques can be used to independent projects for determining whether or not to invest in each one [5]. Decision makers also use both quantitative and qualitative evaluation methods when considering new projects or investments. While qualitative methods vary depending upon an individual decision makers' viewpoint, quantitative methods have a more common basis. Methods of financial analysis that were frequently used include the Net Present Value (NPV), Rate of return, (ROR), Payback period (PP) and Benefit-cost analysis (B/C) [6].
Previously, it was tried to studying the project selection problem. Chen and Askin [7] proposed a mixed-integer programming (MIP) model with an NPV maximization objective function and used an implicit enumeration procedure to solve the problem. Liu and Wang [8] developed an optimization model for the project selection problem based on the Constraint Programing (CP) method using time-dependent resource constraints. Huang and Zhao [9] studied this problem in the absence of historical data for the problem parameters. They also developed a Genetic Algorithm (GA) to solve the suggested model. The Multi Criteria Decision Making (MCDM) prepares an effective frame for comparison based on the assessment of multiple conflict criteria and it is called one of the fastest growing areas of operational research. It has been shown as the most popular branch of decision making [10, 11]. In the literature review, there are some methods in MCDM approach that are available with different ways to categorize them. The MCDM prepares an operational structure for comparison on the basis of the evaluation of multiple criteria. MCDM has been one of the most well-known areas of operational research, as it is often recognized that many solid problems can be represented by several criteria. MCDM was also described as the most important branch of decision making [11]. The personal viewpoints and tastes have always involved and involve decision making processes leading to the respective selection and loss of incorrect alternatives and property. In order to deal with problems, it is important to consider criteria which can affect beyond alternative outcomes, choosing a decision making process [12].

Project Portfolio Selection Methods

Selection tools and techniques are used to facilitate evaluating qualitative and quantitative indicators of an individual project or a set of projects, whose results are consulted by the selection team for their decision making on project portfolio selection. Selection tools and techniques are grouped into methods or approaches such as financial methods (e.g. Net Present Value - NPV, Internal Rate of Return – IRR), strategic approaches (e.g. strategic buckets) or they are integrated into models which are often categorized into 2 main types: numeric and nonnumeric such as scoring models (e.g. weighted factor scoring model) or checklists (e.g. Yes / No questions) [13]. There exist many discussions on methods and models for project portfolio selection in the literature. For instance, Taylor [13] discussed good models which, whether nonnumeric or numeric, should have six basic characteristics as follows: realism, capability, flexibility, ease of use, cost-effectiveness, ease of computerization. The first five characteristics were suggested by Souder [14] and the sixth one was added by Meredith & Mantel-Jr [15]. Besides, in the discussion on choosing a project selection model, Meredith & Mantel-Jr [15] provided three explanations for their preference for weighted scoring models: first, the models enable selection teams to make key decisions on supporting or rejecting the projects based on the organizations' multiple objectives; second, they are easily adapted to changes in either management philosophy or environment; and third, they do not suffer from bias towards the short run, inherent in profitability models. Furthermore, Archer & Ghasemzadeh [16] did the extensive review on project portfolio selection tools and techniques [17]. They presented the advantages and disadvantages of each group of selection tools and techniques. For instance, the advantages of comparative approach include ease of understanding, ease of use, and allowing integration of quantitative and qualitative analysis; and their disadvantages are no explicit consideration of risks,

repetition of entire process when adding or deleting new projects, difficulty in use when involving a large number of projects for comparison; and incapability to identify really good projects. In addition, Graves and Ringuest [18] contributed considerable literature review on models and methods for project selection inclusive of two main streams: traditional management science stream and financial modeling stream. The authors presented the limitations and their suggested solutions of the models and methods that are related to mathematical programming; decision theory; and finance.
The AHP model developed by Saaty [19] is used to support decision makers to rationally select the best alternative based on the qualitative and quantitative approach. The goal, evaluation criteria and sub-criteria are set in the hierarchical structure for order ranking, alternatives or options comparison in pairs, and selection of the best alternative. The analytical hierarchy can be structured inclusive of strategy, finance, and risk aspects of projects. However, too many criteria with different level of importance may make the decision making process challenging and complicated [20]. Besides, as a result of selecting the best alternative, the AHP can help reduce the risk. Illustration example of project selection and application of AHP can be found in the work by Archer & Ghasemzadeh [21]; Martino [20].

RESULTS AND DISCUSSION

Case Study

There is a Telecommunication Company in each province of IRAN. They are all controlled by the Telecommunication Ministry. There is also a Telecommunication Office located in each city controlled by the main Telecommunication Company in its own province. The Telecommunication office of Bojnord, Iran, was started with 30 electromagnetic lines in 1935 and it was enlarged to 810 electromagnetic lines in 1975. In 2003, after increasing the demand for lines, the third telephone center with 10,000 lines was installed so the capacity reached around 35,000 lines. There were 26 contractors in North Khorasan Telecommunication Company. In fact, these selected construction contractors had recently taken at least one project so the data for this study was collected from those projects. The Data Collection Process was conducted by the researchers in a period of around six months under the supervision of the North Khorasan Telecommunication Company.
The main criteria for prioritization and selection are financial indicators, such as NPV, IRR and investment payback period. In addition, it is also important that the investment project is within its selected fields or sectors. This indicates that the project should be financially feasible and in alignment with strategy. It is very frequent that the corporation selected more investment projects than its resources and available capital. Within this large portfolio, the top management can decide the active investment project portfolio within a year or period of time. These active projects will be implemented as initial plan. The remaining projects will have delays or get little investment in order to keep the projects within the corporation. This means the projects are not implemented according to the plan and may be speeded up later when financial sources are available and the market conditions are more favorable for the projects. This is purposely done because investment projects are normally related to land and it is difficult for private corporations to get land use permit in Iran. Therefore, they want to keep all selected projects even they do not have enough resources to implement these projects at the same time. They can use these projects as a mean to attract more capital from other investors who wish to invest or through stock exchange market. It appears that there are two project portfolios in the corporation: active portfolio and selected portfolio. In selecting projects for the portfolio, the corporation also thinks about the interdependent effects between projects.

Selection Committee

The selection committee is usually constituted of the chairman and members of management board and individual investors. It is clearly noticed that there is no participation of middle managers in selection process. However, the chairman is the main agent. From the management point of view, we can state that the chairman has absolute power in making decisions on project portfolio selection within current organization structure and size. Investment opportunities require quick decisions on human and financial resources as they come and go very fast in accordance with changes in

investment conditions. The chairman can decide to postpone the implementation of projects, change project objectives, scope and also sell the projects to third parties when necessary. In addition to the chairman, members of management board in Telecommunication Company also participated in the selection process.
Thus, combining discussions in literature review and findings in current practice of selecting projects, we propose the following process or framework for project portfolio selection, which expectedly ensure successful realization of these PBO strategy. This process or framework can also be easily and practically adapted by other private corporations in Iran:

Step 1: Define and agree on corporate strategy and its priorities. This is especially important for strategy alignment and ensures that all members of selection committees share the same common understanding of the PBO's direction and priorities which is lacking in these PBO's corporations.

Step 2: Set up and approve quantitative (e.g. financial indicators) and qualitative (e.g. strategic fit) criteria addressing corporate strategy priorities.

Step 3: Categorize projects into subsets (e.g. strategic projects served for long-term strategy or tactic projects for short-term benefits)

Step 4: Evaluate and leverage resources for project portfolio including newly categorized projects and ongoing projects (first within subsets and then between subsets) in respects of strategic resources, internal capability and external capacity, existing and potential resources.

Step 5: Make decisions on selecting new qualified projects; terminating existing projects; and nurturing potential projects.

CONCLUSION

Project portfolio selection evidently contributes to success of project portfolio management and more importantly to achievement of PBO strategy. In order to ensure fruitful outcome resulted from effective and efficient selection of project portfolio, organizations need to develop or adapt a systematic approach to project portfolio selection. This systematic approach includes integration of three important factors of selection committee, methods or models; and processes or frameworks. Our research results show that complex processes or frameworks of project portfolio selection recommended by academics and practitioners better and best serve mature organizations. Our recommendations upon reviewing the literature and studying PBO case study are desirably beneficial and practically adapted to other corporations of Iran. Moreover, the results of findings and discussion have valuable and interesting contribution to approach of studying practices and best practices of project portfolio selection and project portfolio management in PBOs in comparison with approaches focusing in the literature.
During our research, we are aware of the facts that there is little academic and practical literature about application of project portfolio selection in Iran context; investment projects take long time to realize the corporations' strategy of growth and development; and that our recommended systematic approach to project portfolio selection has not yet practically applied by these corporations.
Further research is recommended to review successful implementation of corporations' strategy through the current selected project portfolio and new project portfolio using our recommended systematic approach; to conduct a survey to collect and analyze quantitative data for better and more reliable understanding related to practice and application of project portfolio selection by many other PBO; and to adapt this approach to other types of projects and a larger population of other corporations or different types of corporations in Iran and other countries with similar economic conditions. Last but not least, it would be of interest to see more studies of project portfolio management, especially project portfolio selection in other settings and other countries.

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AUTOMATIZATION OF MAINTENANCE AS INSTRUMENT COMPETITIVE ADVANTAGES OF ENTERPRISES IN TERMS OF GLOBAL CRISIS

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Abstract: New tendencies in the development of information technologies keep pace with the development of new business activities of enterprises, new production and information technologies that require continuous adjustment of the entire management instruments of the company in the line of realization of the set goals. The Republic of Srpska has partially established a legal framework, but it is not consistent with global business trends in the same way as the developed countries of the world. The use of information technology in business represents the reconfiguration of classic forms of business. In this paper, a study was conducted on the impact of information technologies on the competitive advantage of companies in the market on a representative sample of 136 economic entities in the territory of Republic of Srpska. The main objective of this research is to attempt to clarify the cause-and-effect relationship between the systemic management of the company's performance and the economic success of the company on the market in the conditions of the global crisis.
Key words: manager, competitive advantage of the company, information technology, the market.

INTRODUCTION

In daily carrying out of various business activities and processes, it is necessary to rationalize activities and processes that can significantly influence the competitive position of companies in the market [23]. One of the prerequisites for ensuring the competitiveness of companies on the market is managing your own performance [22].
Information technology plays a very important role in the development of innovations in the enterprise, both large corporations and micro, small and medium enterprises, and thus facilitate the growth and development of organizations of this century. The modern way of life demands from managers who manage business organizations, daily improvement and the introduction of newspapers into the management process. Nowadays one of the key elements for this is the application of information technology.
Everyday life is associated with the consumption of a large number of different products and the use of various types of services. Every person is aware of his needs for products and services, as well as the way of obtaining them. When we are aware of our needs with certain forms of value in exchange, the most common money, we buy what we want and what we need, and as such we become a qualified market participant in the capacity of a buyer. However, the market is made by those who offer products and services, and meet the requirements so that they can act on the market as vendors. Sellers must own a product and determine its value (price). From the foregoing facts, it is evident that there are rules of conduct on the market both for buyers and sellers who must both respect each other [13].
There are numerous definitions of the market in the optics, which in a small or a large extent try to show the essence of what makes the market. The market is an institutionally and technically shaped customer and seller contact point, which offers or searches for a certain type of goods from an indefinite partner in a specially equipped space for a certain period of time, for the purpose of exchanging money at a price that tends to equalize [13].
In order to raise the level of competitiveness and quality of business in accordance with world standards and standards, in an effort to make operation even more efficient, more operational and more successful, companies resort to daily use of information technologies [13].
Companies most often know who their competitors are, but there is a danger that unidentified competitors may, for various reasons, also be real competitors to the enterprise [13].

Entrepreneurial behavior is a way of thinking, committed to a creative and innovative approach to business, which increasingly takes on a form of corporate entrepreneurship. The ultimate purpose of the business is to achieve business success that is measured by the market position [8].
The basic reason for managing a company is the adoption of a number of business decisions that combine resources in the function of achieving business goals of the company, as well as achieving a stable position on the market. Managing the enterprise in modern economic conditions is oriented towards the future, as it incorporates all the elements that are a prerequisite for growth and development [8].

COMPETITIVE ADVANTAGE OF ENTERPRISE

The company can survive on the market only if it permanently meets the requirements of the penetrating market, and this can be achieved only through the continuous improvement of all business activities [7].
Today, many world companies face a trend of slow growth and boosted domestic as well as global competition [27].
Competitive advantage is the function of more efficient rendering of similar value to customers from competitors (low cost) or performing activities with similar cost but in unique ways that create more value for the buyer than competitors, and therefore can determine the highest price [12].
The competitive advantage in international frameworks is based on: innovations and product changes, inclusion of the internal value system, continuous improvement of operations, resource upgrading and global approach to the strategy [19].
Competitive advantage [16] it defines several factors: production conditions, human resources, knowledge resources, capital resources and infrastructure resources. Countries that have the most dynamic process of interaction of all these factors achieve success in the competitive advantage [17].
Companies that have a long-term competitive advantage usually generate high profit in business, compared to the average profits of other companies. Reasonable and rational management reinvests part of profit in strengthening the source of competitive advantage [27].
Modern trends have led to major shifts in understanding and achieving the competitive advantage of the company as the main bearers of international business activities.

STRATEGY OF MANAGEMENT AS COMPETITIVE ADVANTAGE IN THE BUSINESS OF THE ENTERPRISE

The survival and prosperity of the company on the market in the conditions of modern economy as an imperative is competitiveness. The competitive advantage is the decisive factor in the strategic action of the company, and its ownership is the basis for distinguishing successful from the unsuccessful company. Each strategy is based on building and maintaining competitive advantage.
The survival of the company on the market implies a successful competition with competition, which requires company managers to realistically assess the situation in the environment, the potential opportunities of the company, the real possibilities of competition with the reduction of the market and the positive business results. Today's modern information technologies have a strategic importance for the functioning of the company. According to [28], the influence of information technology on the company's business is based on the introduction of these into the development of products and services, the introduction of electro-line business as well as the contribution of cost reduction.
A greater focus on information technology in the company can greatly improve its competitive edge in the market. The introduction and application of information technologies can be successful only if the development of the information system is in line with the business system development strategy [2].
The competitive advantage is not a permanent category, but it is sustainable. The main goal of each company is to achieve, but also to maintain competitive advantage in the market, and it is achieved by innovation on the product or service.
What is most important for company management is to correctly set up information technologies in strategic planning and recognize their impact on the company's operations on the market in achieving a competitive position. Performance measurement has become the main component in developing the

company's strategy in the conditions of the global crisis, while maintaining the growth and high position of the company on the market.
Fujun X. Z. Q. W. [10] notes that managers can expect results in terms of the competitive advantage of investments invested in information technology when the application of information technologies in their company is higher than the average application in competition [27].

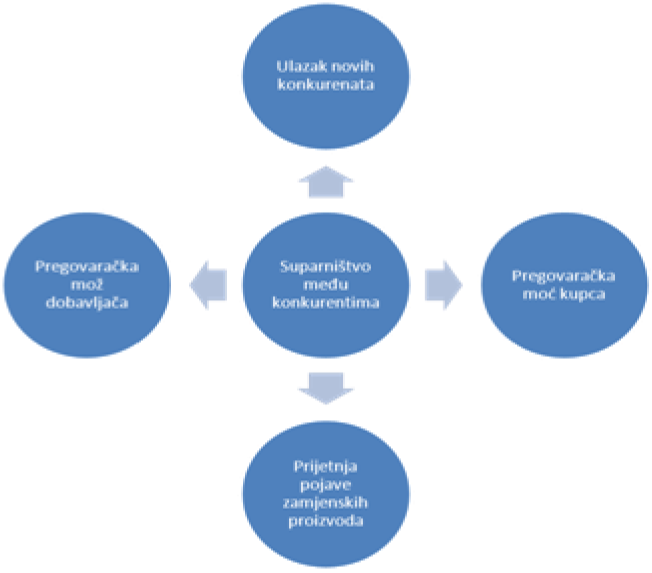

Figure 1. Porter's competitive power model [6]

Porter's competitive power model is one of the most common and most practical tools used in defining the business strategy of the company. According to him, the choice of strategy is based on a competitive advantage and a range. He cites two types of achieving a competitive advantage: on the basis of low costs or on the basis of differentiation.

THE ROLE OF INFORMATION TECHNOLOGIES IN THE PROCESS OF CREATING COMPETITIVE ADVANTAGES IN GLOBAL FRAMEWORKS

Information technology affects the business of the company directly and indirectly. Direct impact refers to the acceleration and improvement of production and business processes, which directly reflects the financial indicators in the company. The indirect impact of information technologies on business operations is realized through the influence of information technologies on various elements of organizational behavior on all three levels: individual, group and organizational, and these elements influence the financial performance of the organization.
In modern business, information becomes a strategic resource, so it is quite logical that the modern economy rests on the creation of information, their possession and exchange. According to Moshin et al. (2013) what is characteristic for this century, among other factors, by the uncertainties in business where the market is increasingly globalized and highly competitive, is that organizations make significant changes in their business strategies in order to align them with the requirements of a new competitive environment.
Modern information technologies are gaining importance every day, and they also lead to changes in the way the company operates and the competitive advantage of the company in the conditions of the global crisis. The emergence of electronic business defines the role of individual companies in the market, but it also offers certain advantages and benefits. The application of information technologies influences more efficient business, more successful flow of information, control of costs and thus on the competitive advantage of the company on the market. According to Vujović [28] of modern information technology and information systems based on them, they have a strategic importance for the functioning of the company.
The influence of modern information technologies on the competitive position of the company in the market influences in the sense that it changes the structure of the activity and the nature of

competition, creates a competitive advantage and launches completely new business processes and operations within already existing ones [16].
The importance of information technology for business management is reflected in the use of interactive forms of communication, the continuous increase in computer business process management, the development of databases and complex decision support systems, the development of networks for faster product provision, the use of computer-supported simulation processes in the domain of development and virtual reality techniques in testing the performance of a new product [8].
New trends in the development of information technologies keep pace with the development of new business activities of enterprises, new production and information technologies that require continuous adjustment of the entire management instruments of the company in the line of realization of the set goals.
According to data obtained from the Republic Statistical Office of Republika Srpska in 2014, significant use of information technologies in enterprises is evident in order to achieve competitive advantage on the market. However, in relation to other countries, it is also evident that Republika Srpska is lagging behind in applying them.

Influence of information technologies on the competitive advantage of companies in Bosnia and Herzegovina - empirical research

The conducted research on the impact of information technologies on the competitive advantage of the company on the market was conducted on a representative sample of 136 economic entities in the territory of the Republic of Srpska.
The relatively high return rate of correctly filled questionnaires (68% - 136 questionnaires) can be explained by the fact that the questionnaire is sent to experienced managers and executives who are familiar with the issues of this research. Survey questionnaires were sent to respondents mostly via e-mail, post or in person. The survey process was conducted in the period from the beginning of September to the end of December 2016.
The impact of information technology on companies in the Republic of Srpska, in the conditions of the global crisis, has a number of other advantages reflected in the modernization of business activities with a reduction in the number of employees, better financial performance of the company, more rational use of resource capacities, as well as better distribution of materials and goods. In the Republic of Serbia, 93% of respondents of business entities confirmed that they use modern information technologies in their business. The questionnaire is addressed to executives and company managers who are intensely using information technology in carrying out everyday tasks. Using the modern methods of descriptive and quantitative statistics, the data submitted are processed.
The main goal of the conducted research is to obtain data for the purpose of defining the role of information technologies on the competitive advantage of companies in the market in the conditions of the global crisis. In addition to the stated goal of this research, other goals of the research related to the impact of information technologies on the reduction of the needs for recruitment of accounting officers, automation and faster recording of business events, improvement and development of financial reporting, improvement and development of the accounting analysis, increase of productivity of labor are defined. employees, business development in the near future and others. In the first part of the questionnaire, general data on surveyed subjects were collected, such as name, activity, ownership and number of employees within the company.
The distribution of surveyed subjects by activity they perform is shown in the following graph.

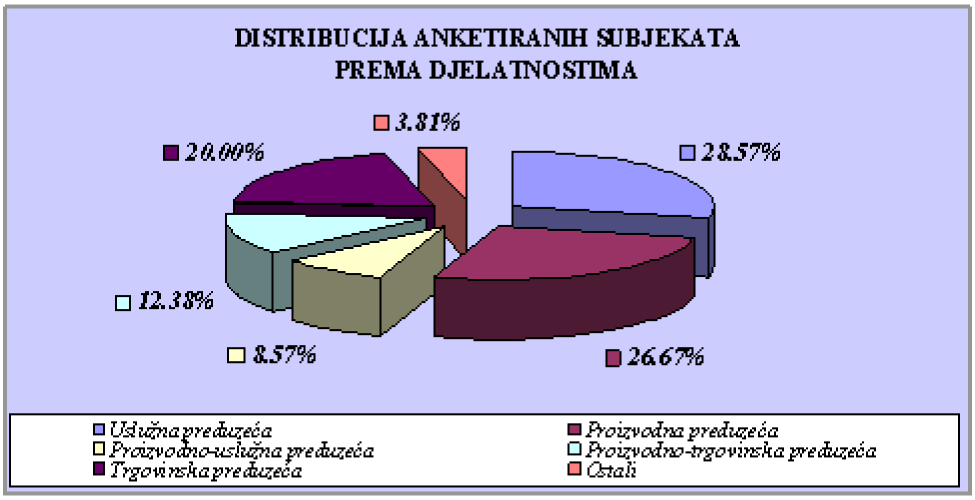

Figure 2. Distribution of respondents by activity

Based on the obtained results of the surveyed subjects according to the activities they perform, it can be concluded that the structure of the sample is satisfactory due to the level of deviation from the ideal values and the conditions under which the survey was carried out. The research is focused on defining the role of information technologies in the process of achieving and maintaining the competitive advantage of companies in the market in the conditions of the global crisis. A particularly important determinant of the surveyed subjects is the number of employees employed. The research is focused and implemented within small and medium enterprises, public institutions, financial institutions and associations, and the like. Considering the existing business environment, the number of employees within the surveyed subjects is quite diverse, as shown in the following chart that presents the distribution of surveyed subjects according to the number of employees.

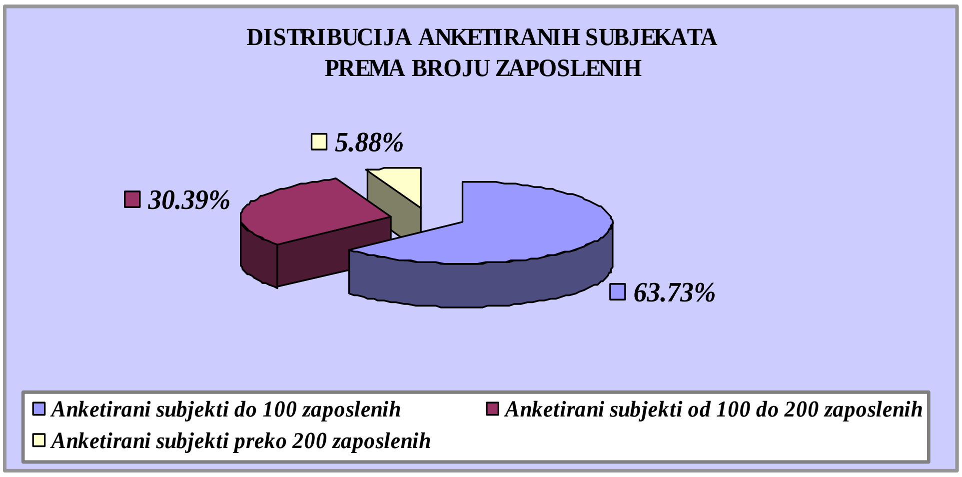

Figure 3. Distribution of respondents by number of employees

Distribution of submitted questionnaires according to the number of employees shows that the surveyed subjects that employ up to 200 workers dominate. Taking into account the difficult economic situation in the immediate environment, the presented distribution is expected and quite real. Considering the share of surveyed subjects according to the number of employees in the observed population, it can be concluded that for the purposes of this survey, the sample is representative.
The research is focused on defining the role of information technologies in the process of generating a large number of real-time information, their impact on improving the efficiency of business operations on the market, as well as the impact of information technologies on the quality and speed of achieving competitive advantages of the company in the market. Taking into account the professional qualifications and experience in performing managerial tasks, it can be concluded that the results of

this research are based on information from competent practitioners. In the next part of this paper, we will present the individual results of empirical research related to the impact of information technologies on the competitive advantage of the company in the conditions of the global crisis.
Modern technology with fast-paced step upgrades all business functions in a very complex economic environment. In this regard, the standards of managerial work are becoming more and more complex in the process of achieving a competitive position on the market. Taking into account the accelerated development of information technologies, we will present the results related to the contribution of information technologies to reducing the need for employing associates in enterprise management: 7.84% of respondents confirmed the outstanding contribution of information technologies to reducing the need for hiring associates in enterprise management, 66.67 % of respondents confirmed the significant contribution of information technology to reducing the need for employment of associates in enterprise management, 25.49% of surveyed subjects confirmed the partial contribution of information technologies to reducing the need for hiring associates in enterprise management, there were no respondents who confirmed that information technology in general do not contribute to reducing the need for hiring associates in company management. Based on previous data, the results of this part of the survey have confirmed the significant contribution of information technology reduction her need for hiring associates in company management, while responses that confirm exceptional and partial contributions are much less present.
Based on the very rapid development of information technology, the results of the research related to the contribution of information technologies to the reduction of employees in the management of the company have confirmed a significant contribution to reducing the needs for work force, as much as 48.69% of respondents confirmed that the introduction of information technology indicates the need to reduce the number of employees in the management of the company, 36.2% of respondents confirmed that they contributed partially, 15.11% confirmed a remarkable contribution, while 5.4% of respondents considered that information technologies had no impact on the reduction of employees in management enterprises.

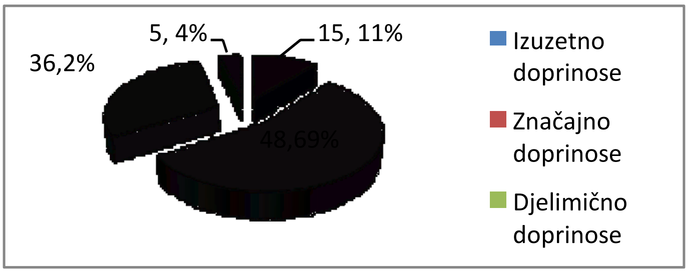

Figure 4. Influence of information technologies on reduction of employees in management [6]

An empirical research on the impact of information technology on the competitive advantage of companies in the market in the conditions of the global crisis has confirmed their significant influence on maintaining a competitive position on the market. The conducted research is shown in Figure 5 where it is clearly seen that the majority of subjects surveyed, as much as 66%, agree that information technologies greatly contribute to achieving and maintaining competitive position of the company on the market.

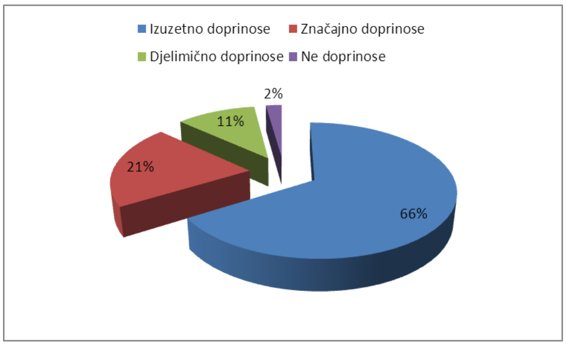

Figure 5. Influence of information technologies on achieving and maintaining competitive advantage of the company [6]

Used information technologies in modern business operations and their application in each business segment significantly improve the organization's economy. Intensive application of information technologies for the purpose of obtaining up-to-date data and their analysis, and accelerated and facilitated expansion of business into new markets, while reducing the distance among business entities, therefore, the company requires greater flexibility and directly affects their competitiveness.
The competitiveness of these companies depends on the value of the technology used, and their market sustainability depends on the speed and applicability of innovations in which the decisive role has a human factor or knowledge.
The intensity of changes and qualitatively changed business conditions emphasize the special importance of the communication system in order to facilitate the interaction and connection of all elements of the system and the environment. Taking into account the above, it can be noticed that the advancement and development of information technologies in the process of crushing competitive advantage greatly contributes to increasing the profitability of business, ie strengthening the competitive position of enterprises on the domestic and international market in the conditions of the global crisis.

CONCLUSION

Everyday competitive conditions and market conditions require rapid and continuous change in organizational behavior within the company in order to meet the needs of successful business operations on the market, as well as maintaining a competitive position. From the conducted research, it can be concluded that all activities of the state should be directed towards creating a more favorable economic environment for business operations on the world market, while providing conditions for enterprises for daily modernization of business with the application of information technologies.
Companies that use the use of information technologies for their strategy to achieve the competitive advantage of the company, in relation to the traditional way of doing business, have increased volume of work, higher profits, more are dedicated to customers, all of which results in increased competitiveness on the market in the conditions of the global crisis.
In order to maintain its competitive advantage, the company must constantly outperform its business rivals. Research has shown that more and more small and medium-sized enterprises recognize the value of using new technologies, as well as an advantage they can acquire over competitors. The most important thing is that managers in the company correctly position the information technologies and recognize their influence on the business and structure of the company.
Based on the controversial research in this paper, it is evident that company managers in the Republic of Srpska are aware of the role and importance of information technologies in improving their business results in order to achieve a competitive position in the market, and at the same time they consider that the introduction of information technologies in enterprises represents long-term investments.
An important segment of the conducted research is the views of surveyed users of information systems who believe that the application of information technologies is extremely important and necessary in the everyday work of the company. Companies in the Republic of Srpska that have chosen the use of information technology as the strategy for achieving their competitive advantage, in relation to the traditional way of doing business, make more profits and turn more to customers and their needs.

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EXPERIMENTAL MEASUREMENT OF SLIDING BEARING TEMPERATURE USING THERMOGRAPHY

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Abstract: In this paper is shown an example of the use of thermography in the measurement of temperature of the sliding bearings. The temperature is very important by sliding bearings, so it is necessary to measure frequently and the contactless gauges allow it in a very simple way. This paper shows that the measurement is bit dependent on the manufacturer of the camera that measures the temperature, it is important that the camera is intended for such measurements and that the basic parameters such as emissivity and measurement distance are well adjusted. Different camera manufacturers enrich accessories, which certainly helps users to handle the camera more easily, but from the aspect of temperature accuracy, cameras of the same characteristics give approximately similar results.
Key words: thermography, temperature, sliding bearings

INTRODUCTION

The bearings are machine elements whose task is to enable the relative movement of the rotary parts while simultaneously transmitting the load between them and securing their position [1]. The usage of sliding bearings is very present in practice, because of very long lifetime. There are radial and axial types, but in this paper the radial sliding bearing has been considered, only. Radial sliding bearing load capacity is a force that radial bearing can transfer within his lifetime. According to previously mentioned, operating temperature must not be overstepped under that force, there must not be higher then allowed abrasion and cubical sliding couple material destruction [2].
The most important part of the sliding bearing is a sliding pair. In the radial bearing, the slip pair consists of the shaft sleeve (1) and the bearing sleeve (2) (Figure 1). The basic dimensions of the radial sliding bearing are the diameter of the sleeve d, the internal diameter of the split diameter D and the length of bearing B.

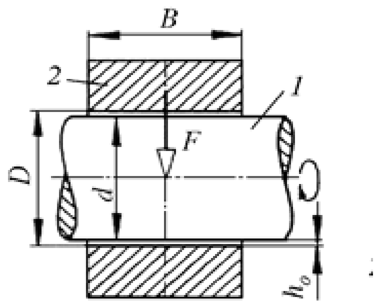


Figure 1. Schematic of radial sliding bearing

Frictional heating and the temperature rise in a sliding contact is a fascinating, and often passionately debated, area of study [2,3,4]. To obtain a more quantifiable indication of temperature, direct contact thermometers are often used; a safer method than using the back of your hand, but with some similar safety concerns. Infrared thermometers are often used for hazardous and difficult to access applications. However, infrared thermometers measure the average temperature of an area and, for accurate measurements, the user often has to be close to the application. Thermography allows you to visualise heat. The application's infrared radiation is converted by a thermal camera to a visual image. The different temperatures are indicated as different colors or shades of grey. Thermal cameras allow temperature comparisons over a large area, allowing potentially troublesome hot spots to be found

quickly. If cost of the thermal camera is offset against savings in reduced downtime and maintenance costs, generally a short payback period is realized [5, 6].
In this paper is shown an example of the use of thermography in the measurement of temperature of the sliding bearings using two different IR Camera.

MATERIAL AND METHODS

The measurement of sliding bearing operating temperature was performed on the testing table in Laboratory of Applied Mechanics and Mechanical construction on Faculty of Mechanical Engineering in East Sarajevo.
Basic characteristic of slider bearing used for this study (Figure 2) are:

- Mareial: The sliding bearing, made of CuSn legure,
- Dimensions: BxDxd=27,6x30,022x30 mm
- Lubricate: Multifunctional Lithium lubricant, made by „Optima Modriča" (temperature range -20 ° C to 120 ° C)
- Method of lubrication: The lubrication of the bearing was carried out manually, only once before the test

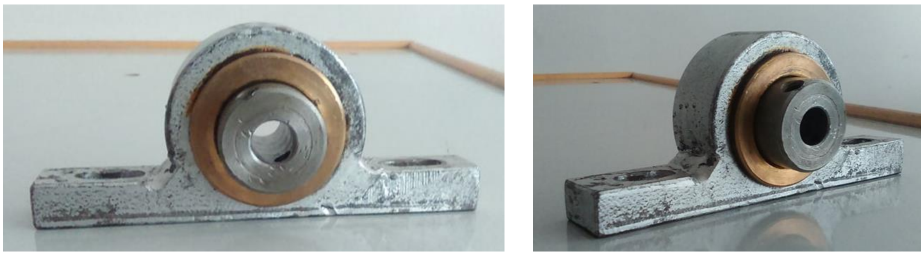


Figure 2. Radial sliding bearing

The speed of the shaft on test table is regulated by the frequency regulator connected to the electric motor. The shaft of the electric motor is connected via a claw coupling to the shaft on which the known load is located. The shaft is supported in one place via the roller bearing type SKF IAR 203 / 12-2F, and on the other via the aforementioned sliding bearing for which the temperature is measured. Sliding bearing is positioned at position 2 of the test table. Basic elements of the test table are shown on Figure 3.

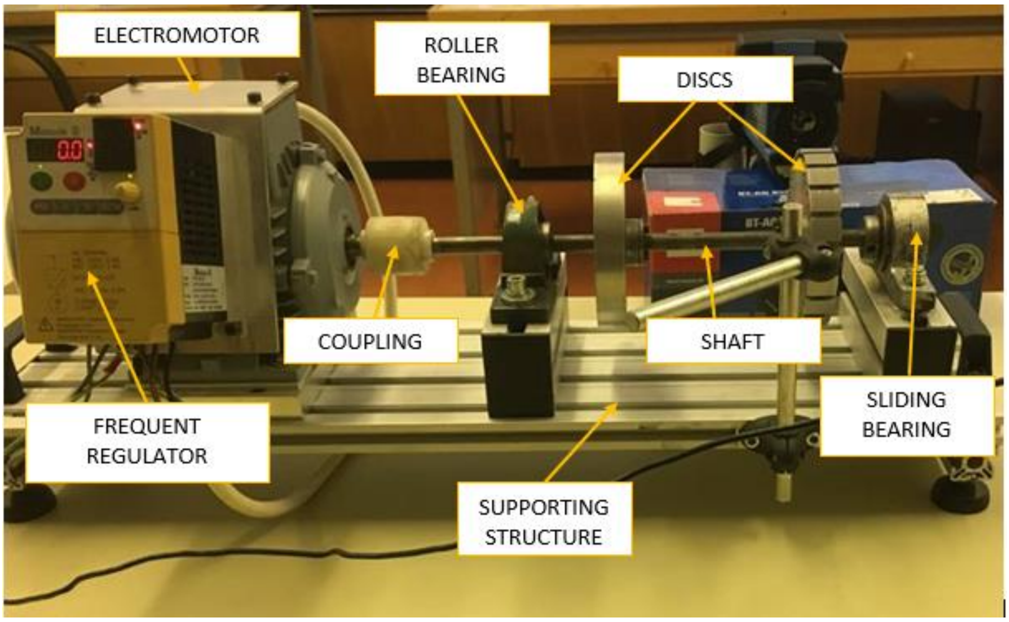


Figure 3. Test table with the basic elements

For the contactless measurement of the temperature of the slide bearing, two IR (Infrared) cameras, one manufacturer of the FLIR (model E4), and the other SKF (model TKTI31) were used (Figure 4). The basic characteristics of the FLIR camera are shown in Table 1 and of SKF camera in Table 2.

Figure 4. Thermal cameras: FLIR (left) and SKF (right)

Table 1. The basic characteristics of the FLIR camera [7]

	IR Resolution	80x60
	MSX Resolution	320x240
	Thermal Sensitivity/NETD	<0,15 ºC
	Display	3.0 in. 320 × 240 color LCD
	Field of view (FOV)	45° × 34°
	Operating Temperature Range	–20° to 250°C
	Accuracy	±2% or 2°C
	Spotmeter and Area	Center spot; box with min./max
	Emissivity	from 0.1 to 1.0

Table 2. The basic characteristics of the SKF camera [8]

	Thermal detector (FPA)	384 x 288 uncooled FPA microbolometer
	Theoretical spatial resolution IFOV	3.46 mrad
	Thermal sensitivity	NETD ≤60 mK (0.06 °C) at 23 °C (73 °F)
	Display	3.5 in. color LCD
	Field of view (FOV)	25 x 19°
	Operating Temperature Range	–20 to +180 °C Standard mode 100 to 600 °C High temperature mode
	Accuracy	±2% ot 2°C
	Measurement modes	Up to 4 movable spots. Up to 3 movable areas and 2 movable lines (maximum, minimum and average temperatures). Automatic temperature difference. Hot and cold spots. Visual and audible alarms. Isotherms.
	Emissivity	from 0.1 to 1.0

EXPERIMENTAL TESTING

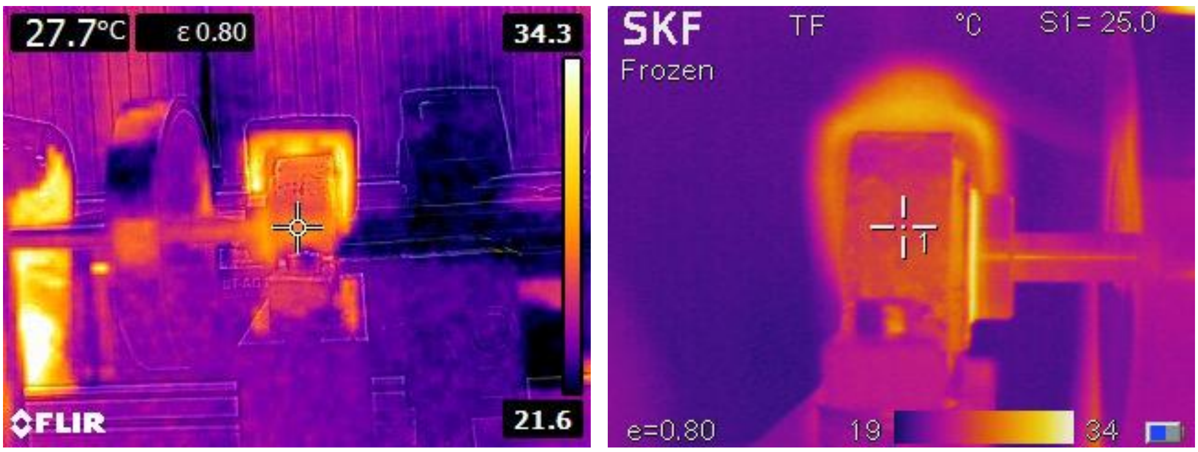
For the purpose of simultaneous measurement of temperature on the slide bearing, the IR cameras are positioned one against the other at a distance of 0.3 m from the sliding bearing. The operating temperature of the sliding bearing is measured for an angular velocity of 25 Hz. The emissivity on both IR cameras is set to a value of 0.8.
Starting the measuring from the sliding bearing room temperature, its operating temperature was recorded on every 20 s, until the moment of maximal value. After that, the tasting table electromotor was turned off and operating temperature was recorded during cooling of sliding bearing, also, on every 20 s. The temperature was manually read, i.e. the operator read and recorded the temperature from the camera screen (Figure 5), so it is necessary to take into account possible errors of reading the operator.

Figure 5. IR camera screen during measurement

The test lasted a total of about 2 hours and 30 minutes, with the preparation of a test table, lubrication of the bearings, adjustment and positioning of the cameras, and finally by measuring the temperature. The measurement process lasted 6540 s, which is 1 hour and 49 minutes.

RESULTS AND DISCUSSION

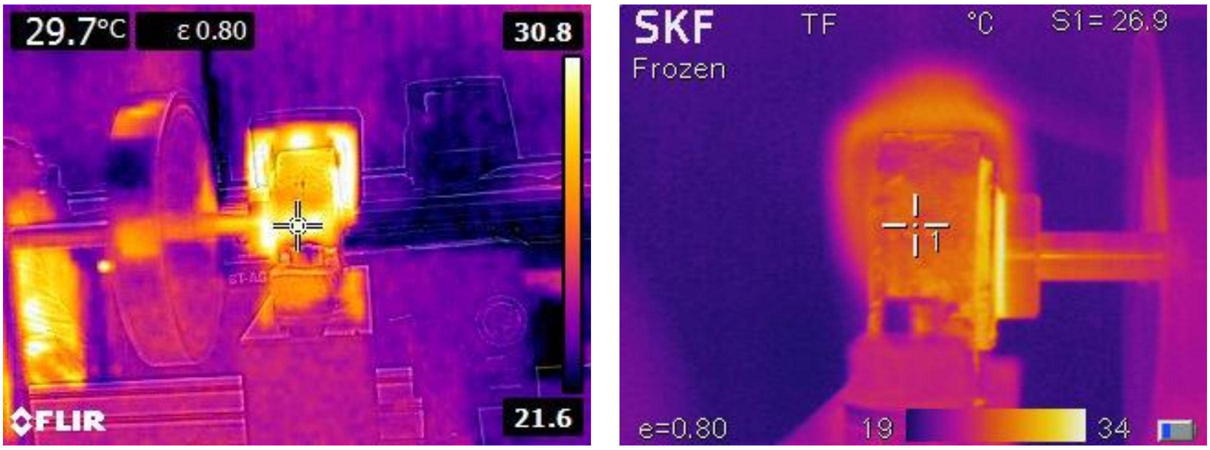
During measurements of the temperature of the slide bearing on both cameras, IR images were made to clearly indicate that the measurements were performed at the highest temperature location. After 400 seconds, the first images were made, showing that the temperature measured with the FLIR camera was 27.7 ° C (Figure 6a) and the temperature measured by the SKF camera was 25 ° C (Figure 6b).



a) b)

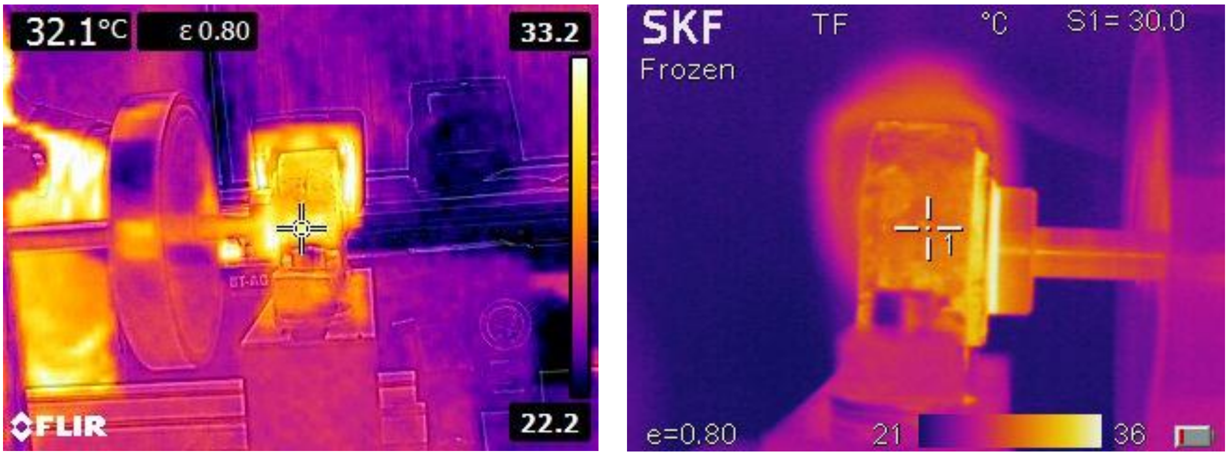
Figure 6. IR sliding bearing image after 400 s operating: a) received by FLIR camera; b) received by SKF camera

Using the same methodology was made the images after 1800 s (Figure 7), 3800 s (Figure 8) and 4800 s (Figure 9) operating. The selection of the moment of imaging is random, and the showen images were not processed in image processing software.



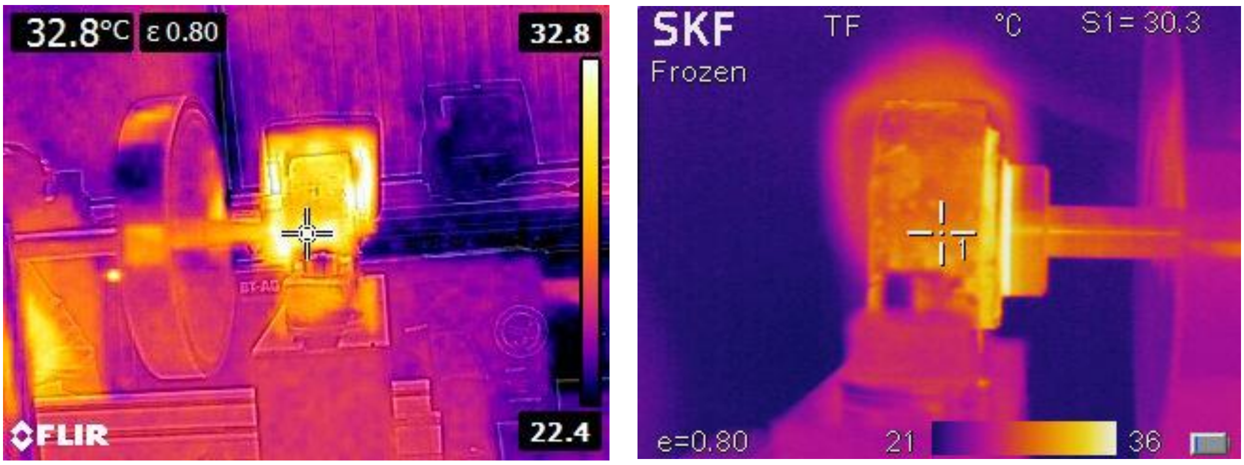
a) b)

Figure 7. IR sliding bearing image after 1800 s operating: a) received by FLIR camera; b) received by SKF camera



a) b)

Figure 8. IR sliding bearing image after 3800 s operating: a) received by FLIR camera; b) received by SKF camera



a) b)

Figure 9. IR sliding bearing image after 4800 s operating: a) received by FLIR camera; b) received by SKF camera

Before analyzing the images themselves, it should be noted that the temperature range around the sliding bearing is not from the temperature bearing than from the opposite IR camera, so it can be ignored. Temperature recording is performed at points so that the influence of external elements on the measurement is minimized.

Observing the images, it can be clearly concluded that the image obtained by the SKF camera with higher resolution and better quality, the reason is reflected in the fact that the SKF camera has optical adjustment and focus, i.e. is not a free type of focus, but a manual. A better resolution of the image does not necessarily mean more precise measurement, because the images only serve to display the measurement results.

The aim of this experiment was, on the one hand, to determine the possible difference in temperature measurement using an IR camera from two different manufacturers of very similar characteristics, and also the aim was to determine whether the sliding bearing is evenly heated on both sides. In order to see more clearly the difference in the obtained temperatures, the temperatures obtained by measuring, using MS Excel, show the temperature diagram shown in Figure 10.

The measurement started with a room temperature of a sliding bearing of 22.5 ° C, and both diagrams (Figure 10) clearly show the warm-up time, the thermal stability, and then the cooling period of the bearing. The bearing temperature thus obtained shows that the bearing is in good condition and is well lubricated. It should be noted that the temperature is only one of the parameters for determining bearing failure.

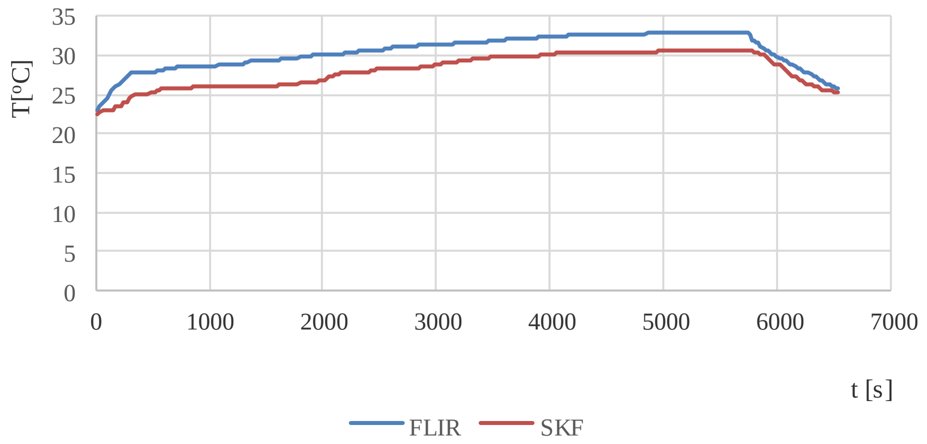


Figure 10. Slide bearing operating temperature diagram obtained with FLIR and SKF IR cameras

With the diagram it can be noticed that the temperature obtained with the FLIR camera is about 3 ° C higher than the temperature obtained with the SKF camera. If it is known that the accuracy of both cameras is about 2 ° C then this difference is acceptable. It is interesting to note that the difference all the time was constant with less falls, which also indicates possible uneven heating of the bearing. On the other hand, if it is to analyze the reasons why there is a difference in temperature, then the following reasons can be stated:

- Possible operator errors in the measurement;
- Due to manual lubrication, lithium fat did not evenly spread through the bearing;
- The cameras were fixed, but due to the large vibrations during operation, it is assumed that the cameras were moving a little
- Advanced camera settings have not been checked, so differences in these settings are possible;
- Due to the influence of external elements.

CONCLUSION

The main advantage of using thermographic cameras is the quick and easy detection of errors, where a long-term process of checking and correcting errors can be avoided. Errors can be detected before equipment failure or other types of losses occur. This reduces maintenance costs, increases the lifetime of equipment and productivity.

This experiment shows an example of the use of thermography in measuring the temperature of the sliding bearings. Temperature is very important in the case of a sliding bearings, it is often necessary to measure it, and the contactless gauges make it very simple and precise. This paper shows that the measurement is bit dependent on the manufacturer of the camera that measures the temperature, it is important that the camera is intended for such measurements and that the basic parameters such as emissivity and measurement distance are well adjusted. Different camera makers offer extra accessories, which certainly helps users to handle the camera more easily, but from the aspect of temperature accuracy, cameras of the same characteristics give approximately similar results. It is recommended that contact heat meters are used to control contactless temperature gauges if more accurate measurement is required.
The future research should be planned so that on the same side of the bearing, and again under the same conditions, the same examination is performed in order to confirm in another way the previous hypothesis. Also, for the purpose of a clearer identification of all influential parameters on thermography, i.e. measurements using an IR camera, it is necessary to perform tests on several different technical systems, and in order to verify these results, use contact heat meters.

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OPTIMAL STRATEGY FOR TECHNICAL SYSTEMS MAINTENANCE BY USING MARKOV CHAIN

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Abstract: Significant economic effects and reduction of exploitation costs through timely detection of possible causes of failure of technical system components can be achieved through the application of methods and means of technical diagnostics. In addition, diagnostics and defining causes can be achieved during the system's own exploitation or in the context of standstill and overtime. Significant application of technical diagnostics is also in the forecasting of short-term and long-term reliability of the technical system and its optimization, most often by economic criterion.
This paper analyzes the current solutions of diagnostics of complex systems with multiple failures, as well as the behavior of the diagnostic system on the case of bearing points of circuits suitable for overhaul.
Key words: maintenance, reliability, technical diagnostics, Markov process, bearing

INTRODUCTION

Measuring methods in determining the technical system, which are a set of special procedures in which the relationships of some measured values are defined, can be absolute and relative, contact and contactless, etc. The basic characteristic of the method of testing without material destruction is the direct execution on the control objects, without taking a sample and destroying them. On the other hand, testing materials by material destruction is the determination of material properties, through the use of samples taken from the particular part. Modern testing techniques with materials destruction enable testing of the following properties: strength properties, high temperature stability, plasticity, fracture resistance, surface oxidation resistance, resistance to intercrystalline and voltage corrosion, material weldability, relaxation, etc. [1, 2].
In this paper, a theoretical and mathematical tool for the control of complex technical systems are presented. Also the principles for one criteria and multi-criteria optimization of diagnostics of complex systems with multiple failures are given.

MATERIAL AND METHODS

The Markov method of random processes is based on stochastic processes whose future state depends only on the current state. We call this property a memoryless property. Poisson's process has the same property, so Poisson's process is a special kind of Markov process. Markov processes can have a discrete or continuous set of states. In this paper, processes with discrete chain states are observed. Regardless of whether they are continuous or discrete by parameter, chains change the state in discrete points in the index set T (uncontinuously). By using these models, system circuits on machine systems are later analyzed [3-5].
In general, Markov random process describes the behavior of a stochastic system, in which the appearance of the next state of the system depends only on the direct pre-state of the system. That is, a random process $\{\xi_t\}\ t \in (0,T)$ we call Markov, if for any moment of time n in the interval (0,T) t1<t2<…<tn for the conditional distribution of probability, the relation is true. The Markov process will be if and only if it has Markov property:

$$P\{\xi_{t_n} = x_n \mid \xi_{t_{n-1}} = x_{n-1},...,\xi_{t_0} = x_0\} = P\{\xi_{t_n} = x_n \mid \xi_{t_{n-1}} = x_{n-1}\} \quad (1)$$

for all possible values of random variable values $\xi_{t_0}, \xi_{t_1},..., \xi_{t_n}$. The behavior of the system at this point in time t_{n+1} is described by the probability transition matrix. By knowing the final probability matrix, the "boundary" behavior of the considered system can be predicted.

The basic form of Markov random processes is classified according to the given values in time and numerous numerical sets. According to this classification there are [5,6]:

- Discrete processes with discrete time,
- Continuous processes with discrete time,
- Discrete processes with continuous time and
- Continuous processes with continuous time.

SOLVING THE PROBLEM OF MARKOV PROCESSES WITH DISCRETE STATE AND DISCRETE TIME

From the definition of Markov process, it follows that the random process is a family of random variables, $\{\xi_{t_n}\}$, where $t_0 < t_1 < \cdots < t_n$ is a moment of time, it will be Markov process then and only then, if it has Markov property. Within this chapter, using the criterion χ^2, it was established that a set of values of one diagnostic criterion $\{\xi_{t_n}\}$ is a family of random variables [7]. In addition, in the problems of diagnostics, the manager has no knowledge of the previous state of the machine system, therefore Markov property appears not only as the necessary limitation of application, but also significantly in practice.
When considering the deformation model of complex systems and the study of the dependence of vibrations and time, a scale of possible states is proposed, according to which system state can be classified into one of three possible classes. Despite the fact that the family of random sizes $\{\xi_{t_n}\}$, characterizes values of unique diagnostic criteria, continuously, on the system zone E1-E2-E3 the boundaries can be selected, in that way that many standard criteria $\{\xi_{t_n}{}^*\}$ would be discrete. Thus, in keeping with Markov random classification process, Markov random processes with discrete states (time) can be used to solve the problem of complex systems diagnostics. On the other hand, the measurement of different parameters of the diagnostic system arises with a certain discretion. Thus, the states of most systems can be adequately described by the Markov process with discrete state and discrete time. The answer to the question of choosing the most justified and efficient maintenance strategy, depending on the specificity of the production, can be obtained by using the Markov process, of revenue type.
A more detailed consideration of the diagnostic system behavior on the case of bearing points of circuits. Describing the bearing deformation model, three possible states of the diagnostic bearing (E1, E2 and E3) are distinguished. Immediately after installation, the bearing is in position E1. The minimum wear of the bearing is in the state of E1, and it is characterized by normal operation, passes into the zone of the initial defect E2, and then in the E3 zone of intense wear. In the intense wear zone E3, there is an emergence of bearing from the machine, followed by its replacement to the normal exploitation zone E1. Different types of repair work, such as replacement of lubricants, change of impermeability and others, can "bring" a diagnozed bearing into a "better" state, i.e. reduce the index of the current state. Thus, bearings from the intense wear zone E3 can be "moved" into the E2 defect zone or even in the normal E1 zone of exploitation. In some cases, technical maintenance results can not be reflected on the state of the diagnozed bearing, then its condition remains unchanged. Similar happens for the wear of the bearing, which can be so insignificant that it will not change its current state [2].
Let us return to the problem of choosing an optimal maintenance strategy when using the Markov type of process with discrete state and discrete time [7]. Let's look in more detail the basic models of maintenance of complex systems: reactive, planned and proactive maintenance. To increase the tracking, the behavior of the diagnozed model in the form of transverse graphics is presented, whose peaks represent the state of the Markov chain (E1, E2, E3), and the arcs correspond to the positive elements of the matrix, [2].

Reactive (corrective) technical maintenance

Reactive technical maintenance is applied with inexpensive equipment. For this type of maintenance routine repair and inspection is not provided, and exploitation is performed until the machine is completely disabled. The wear of machine bearings, which has been maintained, in reactive form, goes from the state E1 to E2, and then into E3 (Figure 1).

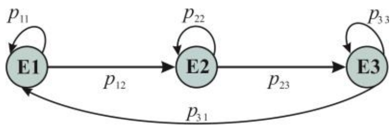

Figure 1. Transition graph in reactive maintenance mode

In each of the states E1, E2 and E3, the system can be at any time. The transition from E3 to E1 is an emergency maintenance repair. Figure 1 presents a transition graph describing the observed system, which is used by the reactive maintenance form, [2].

Proactive (preventive) technical maintenance

In Serbia, one of the most commonly used types of technical maintenance of different technological equipment is planned technical maintenance. All repairs are strictly regulated and performed at certain intervals, regardless of the current technical condition. Proactive maintenance is when, as a measure of the wear of machine bearings, the maintenance transition from state E1 to E2 is shown, and then in E3 (Fig. 2).

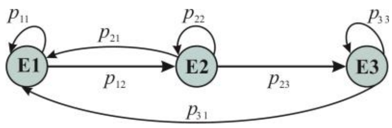

Figure 2. Transition graph in proactive maintenance

In each of the states E1, E2 and E3 system can be at any time. Since regular maintenance is performed regardless of the technical condition, proactive overhaul (transition in state E1) can occur from any condition (E1, E2, E3). In Figure 2, a transition graph of a system is shown which describes the transition of the considered system, that is proactively maintained [2].

Predictive technical maintenance

The most efficient form of technical maintenance of industrial equipment is predictive technical maintenance. All repairs (replacement of lubrication, replacement of bearings, etc.) in the system of predictive maintenance are performed as a real necessity. Therefore, the wear of machine bearings, maintenance in the system of predictive technical maintenance goes from state E1 to E2, whereby as a rule, replacement of lubricants is carried out. The system can go into state E1 or remain in state E2. With the further wear of bearings, the system passes into E3. In the event that the lubrication is repeated, the system has not gone into E2 state, the bearing is replaced (transition to state E1). In each of the states E1 and E2, the system can be at any time. Figure 3 presents a transition graph for describing the considered system, which serves as a predictive form.

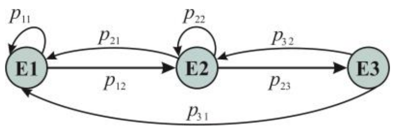

Figure 3. Transition graph in the case of predictive maintenance

In order to determine the probability of transitions and to determine what is best from the economic point of view, it is necessary to set up a maintenance strategy and to statistically monitor the system. The paper presents the data necessary for a diagnostic criterion, a compiled matrix of transient probability and a practical solution to the problem of choosing an optimal maintenance strategy.

Figure 4 represents the percentage representation of bearings in the total sample; 17 bearings operate normally from a total of 33, which is a percentage of 52%, 9 bearings are in failure pending state or in percentages 27%, 7 bearings are in a failure state, representing 21%, [2].

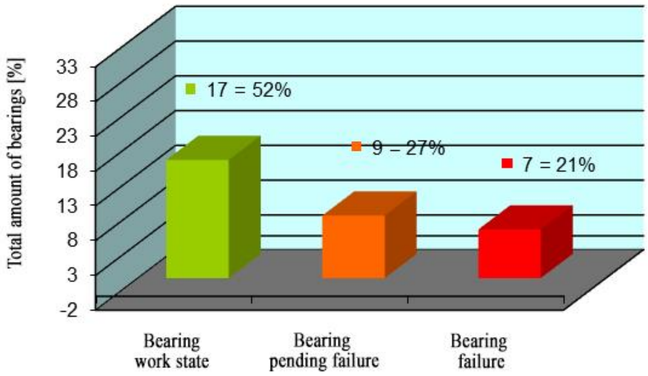

Figure 4. Bearing stats based on VDI assessment

RESULTS AND DISCUSSION

In order to solve the problem of determining the optimal bearing maintenance strategy with Markov chains, a detailed theoretical review was given on the problem of reactive (replacement after failure), proactive (replacement and lubrication in a certain period) and predictive (replacement and lubrication as needed) maintenance and where the solution is supported with appropriate graphs. In this paper, a whole group of observed bearings was divided into 3 groups, and on each group was applied a maintenance strategy (tables 1, 2 and 3).

Table 1. Bearings that were kept reactive

Number	Vibrations *V* [*mm/s*]	Vibrations *H* [*mm/s*]	Vibrations *A* [*mm/s*]	Temperature *t* [°*C*]
1	0,63	0,73	0,9	41
2	1,64	2,45	1,04	58
3	**7,88**	**11,19**	**8,08**	**77**
4	6,37	8,71	6,95	71
15	**7,84**	**12,28**	**8,61**	**80**
16	6,15	9,33	7,67	72
19	**8,82**	**12,88**	**7,95**	**75**
23	**7,97**	**9,82**	**11,97**	**73**

Table 2. Bearings that were kept proactive

Number	Vibrations *V* [*mm/s*]	Vibrations *H* [*mm/s*]	Vibrations *A* [*mm/s*]	Temperature *t* [°*C*]
5	0,98	1,17	1,06	53
6	1,95	2,33	2,79	62
7	6,15	5,97	8,77	66
8	**10,88**	**11,4**	**9,25**	**82**
17	0,51	0,44	0,4	49
18	0,95	1,69	0,82	52
22	0,99	0,89	0,92	50
24	5,95	8,46	5,24	67
29	0,16	0,13	0,19	35
30	0,17	0,19	0,25	37
31	0,21	0,41	0,55	48
32	1,89	3,66	2,44	63
33	**2,89**	**3,27**	**4,53**	**75**

Table 3. Bearings that were kept predictive

Number	Vibrations V [mm/s]	Vibrations H [mm/s]	Vibrations A [mm/s]	Temperature t [°C]
9	0,84	0,75	1,12	42
10	0,77	0,51	0,49	39
11	5,63	8,02	5,58	65
12	5,77	8,89	6,39	68
13	0,67	0,75	0,64	41
14	1,09	1,46	0,93	55
20	6,78	8,27	6,11	70
21	0,57	0,69	0,61	40
25	1,11	1,22	1,63	56
26	2,83	2,08	1,86	61
27	**7,47**	**4,13**	**3,78**	**79**
28	2,22	3,56	4,91	65

The transition probability matrices (strategy iteration strategy) for each strategy are labeled $\boldsymbol{P}^1$-reactive, $\boldsymbol{P}^2$- for proactive, $\boldsymbol{P}^3$- for predictive maintenance. The results were obtained on the basis of the above mentioned research, [2].

$$\boldsymbol{P}^1=\begin{pmatrix}0,25 & 0,75 & 0\\ 0 & 0,33 & 0,67\\ 0,5 & 0 & 0,5\end{pmatrix} \quad \boldsymbol{P}^2=\begin{pmatrix}0,38 & 0,62 & 0\\ 0,375 & 0,375 & 0,25\\ 0,5 & 0 & 0,5\end{pmatrix} \quad \boldsymbol{P}^3=\begin{pmatrix}0,33 & 0,67 & 0\\ 0,375 & 0,25 & 0,375\\ 0,33 & 0,67 & 0\end{pmatrix} \quad (2)$$

To determine the optimal strategy for maintaining diagnostic bearings, it is necessary to estimate the costs that each strategy requires. Unfortunately, the solution to this problem is impossible without the analysis of financial data. At present, at the most of the companies, access to these data is limited. Prices and costs differ from company to company, and it is very difficult to find some general values. The following prices were used in the paper [2, 8-12]:

- Maintenance costs (lubrication, etc.) - 4 euros per piece per year.
- Costs of regular replacement -11 euros per piece per year.
- Extraordinary replacement costs -16 euros per piece per year.

Based on the above mentioned data a cost matrix is given (method of strategy iterations) for each of the following strategies: $\boldsymbol{R}^1$- for reactive, $\boldsymbol{R}^2$- for proactive, $\boldsymbol{R}^3$- for predictive technical maintenance.

$$\boldsymbol{R}^1=\begin{pmatrix}0 & 0 & 0\\ 0 & 0 & 0\\ 16 & 0 & 0\end{pmatrix} \quad \boldsymbol{R}^2=\begin{pmatrix}0 & 0 & 0\\ 11 & 0 & 0\\ 11 & 0 & 0\end{pmatrix} \quad \boldsymbol{R}^3=\begin{pmatrix}0 & 0 & 0\\ 4 & 4 & 4\\ 11 & 4 & 0\end{pmatrix} \quad (3)$$

Calculated values for the required parameters, for each of the strategies, the expected revenue v_i^S and limitation of the probability of the passage π_i^S, by means of which the required values are obtained, are shown in Table 4. In Table 5, the letter S = 1, 2, 3 denote - the maintenance strategy number, and i = 1, 2, 3 - the number of states.

Table 4. Strategy results

Strategy S	**Expected costs**			**Stationary probability**		
	v_1^S	v_2^S	v_3^S	π_1^S	π_2^S	π_3^S
1	0	0	8	0,27	0,31	0,42
2	0	4,125	5,5	0,403	0,398	0,199
3	0	4	6,31	0,36	0,46	0,18

Parameters v_i^S in the table were obtained using the formula $v_i^S = \sum_{j=1}^{m} p_{ij}^S r_{ij}^S$, while the parameters π_i^S were obtained from the system of matrix equations:

$$\begin{cases} \pi^S \boldsymbol{P}^S = \pi^S \\ \pi_1^S + \pi_2^S + \ldots + \pi_m^S = 1 \end{cases} \tag{4}$$

For each strategy, the expected costs were calculated E^1, E^2 i E^3 from the formula.

Based on the equation of mathematical breakdown $E^S = \sum_{i=1}^{m} \pi_i^S v_i^S$ we get the expected expense for each strategy individually (in euro per bearing), precisely E^1 = 3,36€; E^2 = 2,74€; E^3 = 2,97€.

The best strategy of the mentioned transition matrix will be the one that minimizes maintenance costs. In this case, this is another strategy, i.e. proactive maintenance strategy. The economic justification of the choice of the system at these prices is the best and amounts to2.74 €.

Figure 5 represents the expected cost of reflecting one bearing depending on the choice of the strategy, regardless of whether the bearing is crippled or not.

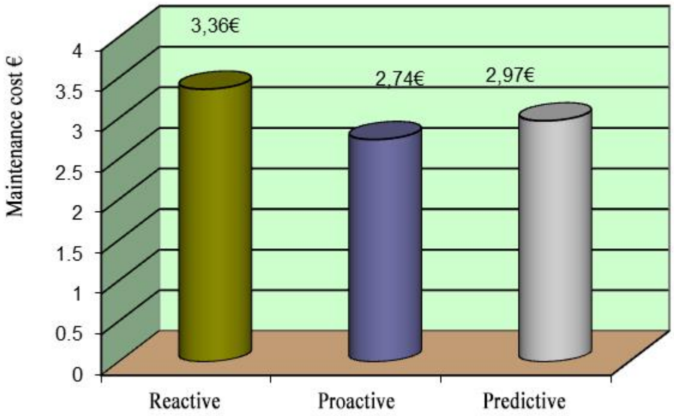

Figure 5. Costs of maintenance strategies

The costs of one strategy are significantly influenced by market prices of elements and labor costs. As prices over the year can vary by more than tenth percent, so can the cost of the strategy be significantly changed. For example, if the cost of maintaining the bearing was 3 euros instead of 4 euros annually, this would significantly change the choice of the strategy. In that case, the costs of predictive maintenance would be reduced to 2.39€, which would promote this strategy in the most economical, most cost-effective, and therefore the most efficient, [1, 2, 11,12].

CONCLUSION

The analysis of the methodology and statistical solutions, and the economic effects that have been carried out in this paper, revealed a number of advantages of practical application of this mathematical apparatus for practical solving of the problem of diagnostics of complex systems in work. The costs of the maintenance strategy were calculated. The accuracy of the obtained results was confirmed, i.e. practically complete diagnostics and maintenance data, as well as system reliability.

By the method of vibrodiagnostics, as methods of preventive maintenance of energy machines, and the analysis of Markov processes, experimental verification of the proposed method was carried out on the example of assembly of knotted points of bearings on machine systems.

Calculation of the reliability indicator was carried out using analytical and empirical relations, using the Markov chain method, where the matrix of probability was obtained for each strategy for maintenance of the technical systems. An own model of economic effect was obtained for an optimal strategy for maintaining diagnostic complex systems. By calculating it was examined which method of maintenance is most favorable and economically most profitable.

The obtained results of maintenance of diagnostic bearings show that proactive maintenance significantly reduces maintenance costs, increases the safety and reliability and life span of the entire system. That proactive maintenance is economically most cost effective as it minimizes the costs of maintaining technical systems.

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Session 4.

Oil and Gas Engineering

APPENDIX TO RESEARCH OF ENERGY EFFICIENCY OF PETROLEUM INDUSTRY OF SERBIA PETROL STATIONS

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Abstract: The paper shows the measures implemented by NIS (Petroleum Industry of Serbia) company in order to increase energy efficiency emphasizing the scope of work of petrol stations. Defined measures application is analyzed by showing interdependence of energy performance indicators (EnPI) with regard to realized income. The results have shown that EnPI is being reduced by income increase which leads to conclusion that defined measures under the current conditions of business dealings contribute to more rational use of energy and savings in business dealings.
Key words: optimization, energy efficiency, petrol station, rationality

INTRODUCTION

Sustainable development has been a fundamental principle of European Union since 1997 whereby an emphasis is placed on the priority areas of the sustainable development such as climate changes, health of citizens, sustainable transport, natural resources and energy production from renewable resources. According to numerous studies, it is possible to save minimum 20% of energy even though it is necessary to invest significant funds in new, energy efficient equipment and energy services in order to realize these potential savings. Considering fast increase of energy demand, especially in developing countries, energy efficiency must be one of the main global policies trying to harmonize the increased needs in order to encourage development and improve life conditions of all citizens on one hand, and fight against global warming and heating on the other hand [6]. Particular emphasis is placed on the producers obtaining energy from fossil fuels which are required to obtain part of energy from renewable sources or to help the development of technologies for producing this type of energy by financing.
Although it is a global problem, effective actions within the field of energy efficiency require general structural frame. Only by combining measures at different levels (national, regional, local), it is possible to use all potential and make serious steps towards putting an end on natural resources consumption trend in the scope greater than the Earth is able to renew in exactly the same period (Earth Overshoot Day).
Serbian energy policy is primarily directed towards: development of energy infrastructure, energy sources diversification in order to provide secure supply, modern technologies introduction within energy sector, reduction of final energy consumption increase, energy efficiency increase as well as increasing the use of renewable energy sources. There is a possibility of implementing numerous measures at local levels bringing them closer to the citizens so that by changing certain behaviour patterns, everyday activities should be directed towards rational energy use not only at work place, but also at home. As it can be seen, energy efficiency represents the sum of intentions and actions in all areas of life for the purpose of the ultimate aim of minimal energy consumption with the set requirement that level of work and life remains the same or becomes better. It does not mean that energy saving should imply renunciation but that its efficient use may contribute to improving the quality of life and work as well as the greater production competitiveness.
NIS is one of the greatest vertically integrated energy companies in Southeast Europe. Elementary business activities are exploration, production and processing of petroleum and gas, wide range of petroleum products trade as well as energy projects realization. The company owns processing complex in Serbia including two plants in Pancevo and Novi Sad, plant for LPG (Liquefied Petroleum Gas) production as well as retail network of petrol stations in Serbia and neighbouring countries. As such, the company recognized the importance of energy efficiency improvement contributing to secure energy supply, standard increase, reduction of import dependence and reduction of negative effects on

environment so that certified energy management system was established as far back as 2013 (EnMS) in compliance with the requirements of standard SRPS EN ISO 50001:2012.
Energy efficiency increase and energy management represent one of the strategic aims of the company, which are implemented through programmes for energy efficiency increase by introducing the practice of saving and rational use of energy at the level of the entire company as well as by the implementation of new technologies that would reduce energy consumption.
Energy policy is based on the responsible energy management and continuous improvement of energy efficiency in all production processes, plants and facilities. With an aim of preserving energy resources and reduction of negative impacts on environment, implemented activities refer to the following:

- Improvement of energy efficiency within all organizational units of the company
- Reduction of negative impacts on the environment coming from plants and facilities
- Setting and review of aims in compliance with best world practice for the industrial branch to which it belongs
- Establishment, application and continuous improvement of energy management system in all organizational units of the company
- Fulfilment of legal obligations in terms of energy use and energy efficiency
- Energy consumption monitoring and energy base establishment
- Determining and monitoring of key indicators of energy performances (EnPI)
- Reconsideration of energy consumption
- Establishment of appropriate reporting system
- Taking corrective measures for improvement of energy efficiency and energy management system maintenance
- Taking preventive measures and continuous improvement of energy management system [3].

Along with development and improvement of energy efficiency management in the processes of production of all stated company segments, there is also an arising need to pay equal attention to slightly smaller energy facilities such as petrol stations, the number of which in Serbia is 330. By investing in modernization, development and improvement of efficiency of retail network, simultaneously implemented measures are those for energy efficiency increase, programmes management and projects for rational use of energy.
The aim of implementing the mentioned activities is the achievement of better economic benefit for the organization through implementation of cost-effective measures for improving energy efficiency i.e. the use of renewable energy sources thereby not disturbing the quality and quantity level of services or products offered to the consumers by the company (Figure 1).

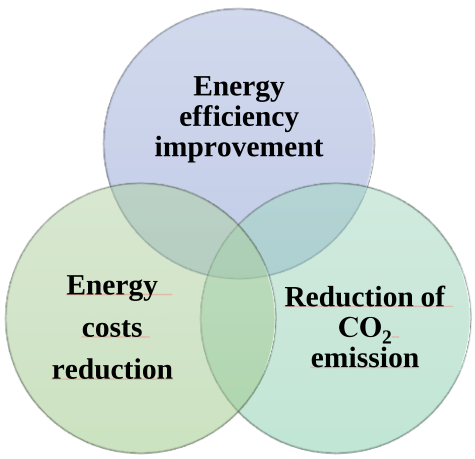

Figure 1. Fundamental benefits from the application of energy management system

MATERIAL AND METHODS

Energy planning, measures defining and reconsideration in NIS

Activities of energy planning process in the company are implemented within the procedure of business planning on the level of all organizational sections of the company and imply the following:

- Identification of legal and other regulations
- Energy review
  - Collection of data on the consumption and energy use manners
  - Identification of significant consumption and energy use
  - Possibilities for energy efficiency improvement
- Defining:
  - General and separate energy aims
  - Action plan of energy efficiency
  - Energy saving program and energy efficiency increase

Upon implemented planning, measures taken comprise investment and organizational and technical measures. Investment measures imply investing in improvement of technical and technological characteristics of plants and equipment, new technologies application, projects for the use of waste fuels for the production of electricity and heat, introduction of automated monitoring system of energy balance and projects for the use of alternative / renewable energy sources.
Organizational and technical measures imply regular control and maintenance of equipment and installations, complying with the recommendations on rational energy use (computers, elevators, lighting, air conditioning system, water consumption, fuel consumption), training of employees within the field of energy efficiency as well as actions taken to increase employees' awareness of the effect of their everyday activities on reducing energy consumption.
Energy review process represents the procedure which, through measurement and analysis of the current energy consumption, identifies the areas of significant energy consumption and measure for improving energy performance. Subject matter of energy review refers to all plants and facilities including related equipment and all processes as well as employees representing the important factor which has an impact on energy efficiency.
On the basis of the collected data, energy consumption trends are analyzed and significant energy consumption areas have been determined (plants, facilities, equipment, processes and employees).
By identifying the areas of significant energy consumption the requirements for defining energy performance indicators are acquired (EnPI) as well as the comparative energy values arising from the same for each separate plant, section and facility. When defining EnPI, it is necessary to be guided by certain criteria which implies that it should be easy for understanding, measurable, actual and not expressed in large number so that measuring and obtained results would be as representative as possible (Figure 2).

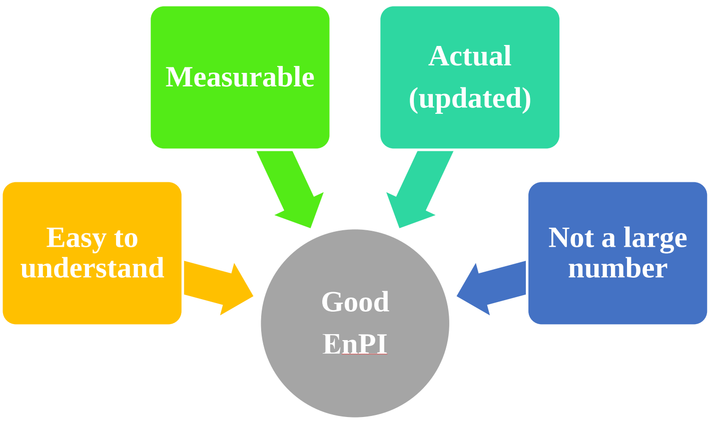

Figure 2. Criteria for defining energy performance indicators (EnPI)

Finally, on the basis of the identified significant energy consumers, priority energy consumers in need of energy performance improvement are identified through realization of identified measures for energy performance improvement.
In addition to regular energy review carried out in compliance with the defined plan and legal obligations, extraordinary review can be done as well. Extraordinary energy review is done in case energy performance shows significant deviations and changes but only for those areas of significant energy consumption in which significant deviations or changes in energy performance have arisen [3].
A comprehensive improvement of energy efficiency is accomplished in this way.

RESULTS AND DISCUSSION

Based on analysis of the existing state of affairs in the retail facilities and equipment, energy use and consumption, significant energy use and consumption areas are identified as well as the possibility for improvement of energy efficiency of retail facilities, general and separate energy aims are determined, measures for energy efficiency increase are defined and appropriate indicators of energy performance are chosen (EnPI) and measures and effects of implemented measures are monitored through them.
Organizational and technical measures for energy efficiency increase at petrol stations, also having an impact on raised awareness and competences of the employed within the field of energy management are introduced as the recommendations for all employees at petrol stations as follows:

- Cooling and heating devices (central systems, air conditioners, heating bodies) should be used so that temperature in the facility is within 20-22 °C
- Doors and windows on the facility should be closed in case cooling and heating devices are turned on
- Outer lighting should be turned off from the morning till twilight except for the case of reduced visibility due to bad weather
- Interior lighting depending on the facility structure should be either turned off or turned on to the extent enabling normal facility functioning
- Within the facility, lighting should be turned off in all rooms when there is no necessity for it – toilets, warehouses, auxiliary rooms etc.
- All fridges/refrigerated showcases should be turned off in case they are not used at the moment for sale of additional assortment
- On the facilities selling LPG, it is necessary to pay attention that LPG pump does not function in manual but in automatic mode [5].

Additional measures implemented significantly influencing the increase of energy efficiency and reduction of consumption at petrol stations are as follows:

- Reactive energy compensation
- Implementation of outer and interior LED lighting
- Reduction of approved power

Key activities necessary to be implemented with an aim of adequate monitoring of the process implied are as follows:

- Securing the adequate mesuring point and measuring equipment
- Securing the reliability of measuring equipment
- Measuring and entry of data in compliance with defined plan
- Data analysis
- Energy performance analysis - Achievement review EnPI

Implemented measures accomplishment is shown through interdependence of energy performance indicators with regard to accomplished income.

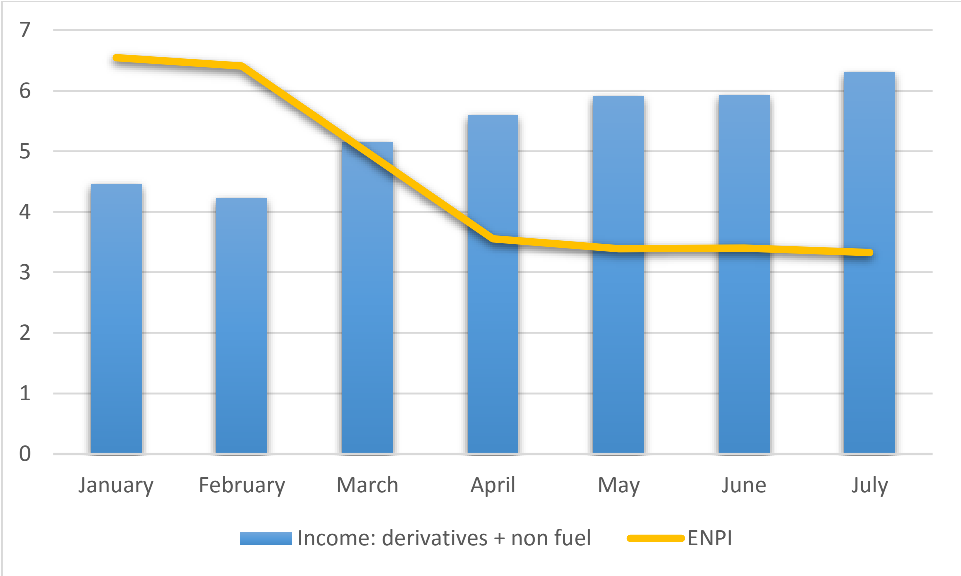

Figure 3. EnPI with regard to the achieved income

On the basis of the observed data for the period January - July 2018 (Figure 3), it can be seen that EnPI is being reduced by an increase of income. As income increase in sale of petroleum products and additional assortment and services at petrol stations also implies increased energy products consumption at retail facilities which is reflected through greater use of technical and technological equipment and resources, EnPI reduction precisely shows that saving and rational energy use is achieved by the efficient resources management. On the contrary, income increase would lead to an increase of EnPI which in that case would indicate the need for additional measures introduction and implementation control for the purpose of energy efficiency increase of retail facilities.
On the basis of the aforementioned, it can be realized that measures implemented with an aim of energy saving at the retail facilities, directly affect decline in operational costs of business dealings and therefore increase the income which the company obtains.

CONCLUSION

Measures taken for the purpose of achieving energy efficiency of petrol stations are directed towards reduction of technical and technological resources resulted in reduction of costs along with simultaneous maintenance of the quality and level of business dealings and services provision at retail facilities. Foreseen and long-term investment into construction of new facilities built according to the principle of energy efficient facilities, reconstruction of existing facilities and procurement of new equipment are carried out through continuous investments into retail network development in compliance with the company development plan. All mentioned activities significantly rationalize energy consumption and represent the base of sustainable business dealings.
In order to realize energy policy as successful as possible, NIS is guided by the following principles:

- Management and employees directly and actively participate in improvement of energy efficiency, application and constant improvement of energy management system
- Full control within energy production and consumption is implemented through technological processes improvement, new technologies introduction, monitoring and reporting the achieved results
- Continuous investment into programmes and projects for improving energy efficiency
- Continuous improvement of energy consumption monitoring system and reporting on all levels are carried out for the purpose of providing support to operational management of energy systems and bringing decisions within the field of energy management
- Energy costs are reduced, competitiveness and profit growth is increased
- Advantageous environment is created in order to motivate the employees and form positive habits in everyday work through training and providing information for the employed [3].

Reduction of costs of business dealings, energy efficiency increase, competitiveness increase, environment protection as well as improvement of company image are directly influenced by complying with the provisions of Standards for energy management system ISO 500001.
In order to successfully implement the measures for energy efficiency increase, it is of utmost importance that the employees are aware of its importance as well as that they rationally refer to energy consumption in everyday work which is best achieved by communication, education and programmes for raising awareness of energy efficiency significance that the company continuously implement by motivating its employees to contribute together to set strategic goal.

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OPTIMIZING THE MAINTENANCE PROCESS OF PETROL STATIONS OF PETROLEUM INDUSTRY OF SERBIA

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Abstract: This paper investigates certain possibilities of optimizing the maintenance process of petrol stations of energy company NIS (Petroleum Industry of Serbia). Maintenance system is analyzed by presented monitoring of suspension due to technical factors and the most frequent causes of direct trade loss in case of suspended operation at petrol station are defined. The results have shown that the primary cause based on the number of suspensions does not have a dominant impact on trade decline. As a matter of fact, the most critical suspension is the factor having a slightly smaller number of suspension hours but the malfunction of which directly affects the suspension of the entire retail facility operation consequently followed by the loss of trade.
Key words: Optimization, Maintenance, Petrol station, Improvement

INTRODUCTION

Considering the global market development including a constant struggle for acquiring new customers and keeping those already existing, market competition can be won only by the companies which besides constant investment into development of new products and services offered to their consumers, recognize the importance of managing various activities intended for preserving physical goods and technical means along with constant care for environment protection and protection at work thereby securing the safe working environment to the employees.

Aiming to satisfy an increasingly finicky market striving for continuous innovations and production increase followed by minimum costs, organization and efficient management of the maintenance processes represent one of the key segments for reducing costs and thereby for profitability increase. Complex work resources, characteristic for the industry of production, processing and trade of petroleum require continuous maintenance technology improvement followed by the constant investment into both, development of new solutions based on technological development and into the processes of automation and development of information technologies in order to control and manage the entire process more efficiently. Investment into maintenance processes represent a long-term, cost-effective investment which provides energy companies with the possibility to efficiently manage maintenance processes, reduces the accidental events likelihood, great plants operation failure, reduces the environment pollution and increases the industrial safety and protection at work for the employees.

As NIS is one of the greatest vertically integrated energy companies in the Southeast Europe, its basic business activities are exploration, production and processing of petroleum and gas, trade of wide assortment of petroleum products as well as energy projects realization. It owns processing complex in Serbia including two facilities in Pancevo and Novi Sad, facility for the production of LPG (liquefied petroleum gas) as well as network of petrol stations in Serbia and neighbouring countries [1].

Retail network in Serbia comprises 330 petrol stations accomplishing annual trade of about 3.3 million tons a year. In compliance with the adopted strategy, NIS is going to continue investing into modernization, development and improvement of retail network efficiency as well as increase of market participation not only in Serbia but also in the neighbouring countries. Along with development and financial growth plans, the focus is on the improvement of maintenance and management system of exploiting petrol stations equipment along with optimization of the operational performances of business dealings also being in accordance with technical and economic justifiability.

Any failure in the operation or damage of the facility at petrol stations directly causes sale suspension and trade decline, increases the possibility of injuries at work or affects dissatisfaction of the customers or in an extreme case their loss. Consequently, significant attention is devoted precisely to the processes of organizing maintenance of equipment and facilities of petrol stations, their optimization, automation and analysis of suspension causes.

MATERIAL AND METHODS

Maintenance and exploitation of petrol stations

Technical and investment maintenance of equipment and facilities of NIS petrol stations is organized so that it enables efficient, reliable and safe exploitation and is carried out by means of preventive (periodical) and corrective (upon call) maintenance.
Technical maintenance of NIS petrol stations includes the following:

- Maintaining devices for intake, storage and sale of petroleum products at petrol stations;
- Maintenance of facilities and infrastructure at petrol stations;
- Control and supervision of works carried out at petrol stations;
- Preparation of the plans for preventive examinations and maintenance, plans for cleaning and certification of tanks, certification of fuel dispensers, measuring devices and measuring equipment in compliance with legal regulations.

In compliance with the Standard for energy management system ISO 50001 defining the guidelines for the rational energy management, all employees as well as third parties are obliged to comply with the principles of the energy efficiency and recommendations for efficient energy use in the course of construction, reconstruction, technical maintenance and everyday operation of petrol stations.
Standard ISO 50001 helps the company to reduce the energy consumption using the best practice for the management of energy, measuring and reporting system as well as the promotion of energy efficiency in the supply chain.
By complying with the provisions of the Standard for energy management system, direct impact on the business factors is accomplished as follows:

- Reduction of the costs
- Sustainable business dealings
- Environment protection
- Improvement of the company image

Preventive (periodical) maintenance is carried out through implementation of defined periodical examinations and in compliance with the requirements of the legal regulations and comprises maintenance of the equipment, area and building of the petrol station.
In case of any noticed defect which disables safe or normal exploitation of the equipment, in the course of mandatory daily examination carried out on a daily basis, the responsible and authorized person shall report the failure which, at the same time, represents a mandatory step in case of corrective, i.e. maintenance upon call.
In addition to the preventive and daily examinations, extraordinary examinations are also carried out after bad weather or after HSE accident causing or which could cause damages of separate elements of the facility or equipment construction. Mentioned examinations shall be carried out after breakdowns within systems supplying heating, water and energy, within telecommunication networks and in case of detected deformities of building and facility base.
Defects ascertained in the course of regular or extraordinary examination of the facility are recorded through Orpheus Web application (Image 1).
Person in charge chooses suspension type from the drop-down list and terms entered in each of below offered options are exclusively those disabling sale at petrol station due to any reason. Precise date and time of suspension duration shall be stated for each type of suspension and more detailed explanation may be added into the note box. It is necessary to choose the option “Entry” at the end of each entry per type of suspension.
Data recorded through Orpheus Web application represent the base of further analysis of suspension occurrence causes in operation of petrol stations, estimation of costs and losses as well as planning future measures in order to eliminate causes which may influence the suspension occurrence.

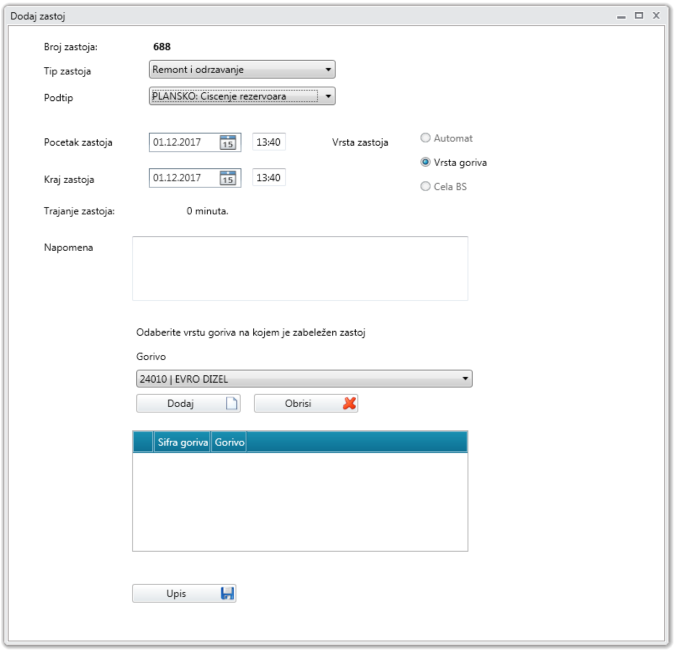

Figure 1. Example of recording suspensions through Orpheus Web application

KPI maintenance and exploitation of petrol stations

The aim of maintenance procedure of NIS petrol stations is their optimal operation having minimal suspensions in operation and minimal costs of maintenance within the foreseen budget along with care of environment protection and protection at work. KPI process of maintenance (Table 1) is measured according to the number of hours of suspension due to technical deficiencies and on the basis of the maintenance costs compared with the business and quarterly plans [2].

Table 1. Key indicators of maintenance process accomplishment

Name of KPI	Determining KPI	Measuring unit of KPI	Source of data
Suspension monitoring	Number of hours of suspension due to technical deficiencies	h	Orpheus Application
Technical maintenance costs	Maintenance costs compared to BP and QPR	rsd	EBITDA

Report on monitoring of suspended operation of petrol stations (January - July 2018)

The report on monitoring of suspended operation of petrol stations in the concrete example comprises the sum expressed in the hours for the observed period from January - July 2018 per type of suspension due to technical deficiencies or planned repair and maintenance (Table 2).

Table 2. Statistics of petrol station operation suspension

Suspension code	Name of Suspension	Hours of suspension
1	Power outage	470:15
2	Management system malfunction	161:05
3	Faulty automat	675:43
4	Technical malfunction of the equipment	0:00
5	Planned repair and maintenance	389:40
6	Unforeseen repair and maintenance	10:25
7	Reconstruction/Rebranding	6:50
	Total for the period January-July 2018:	**1713:58**

Collection, processing and analysis of data are carried out on a weekly basis and subsequently on a monthly, quarterly and yearly basis. As the suspended operation of petrol station represent one of the significant factors having direct impact on the realized trade, maintenance process, on one hand, may have a great impact on the losses in business dealings in case of inadequate maintenance processes management or, on the other hand, may achieve significant savings and reduce operational costs of business dealings providing that the entire process is managed in a planned way taking care thereby of respecting legal regulations and international standards.

RESULTS AND DISCUSSION

By analyzing the obtained results (Image 2), four dominant reasons for suspension are noticed:

1. Faulty automat
2. Power outage
3. Planned repair and maintenance
4. Management system malfunction

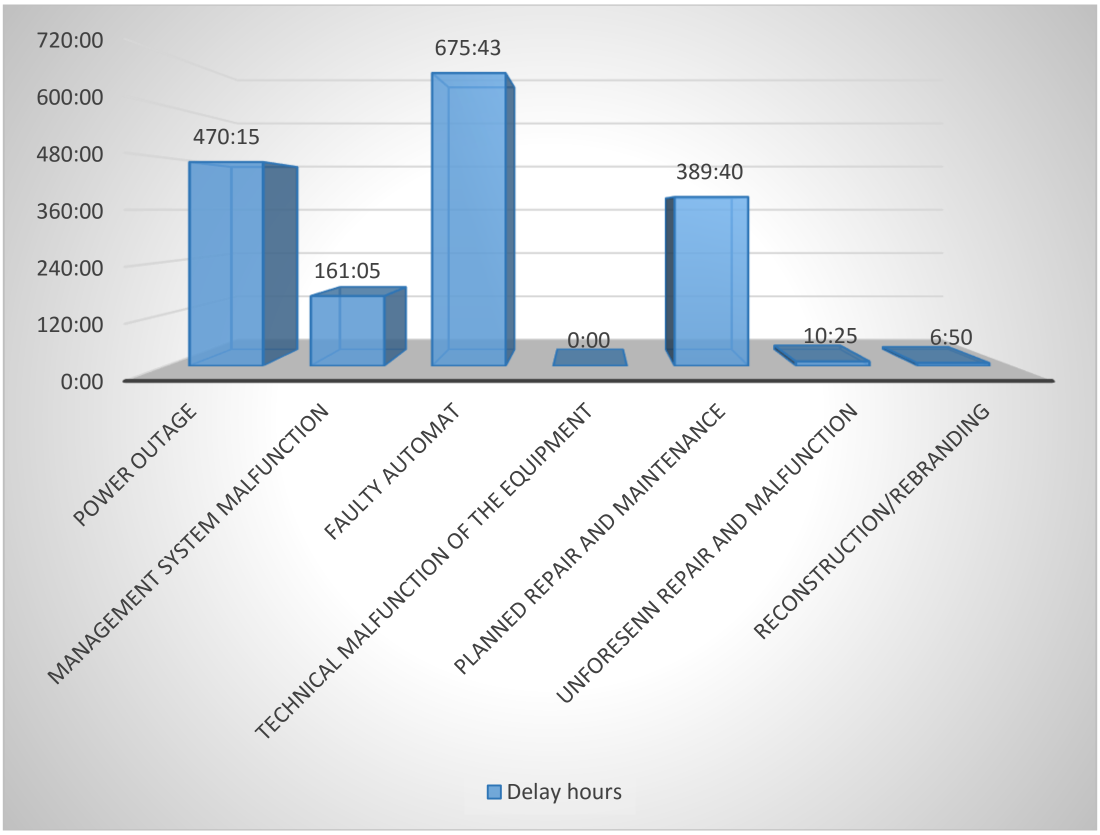

Image 2: Distribution of suspensions in petrol stations operation according to suspension type

Although “Faulty automat” constitutes the greatest part in suspension, this suspension type does not significantly influence the quality of operation and eventual loss of trade since it implies suspension per one fuel pistol and considering that petrol station has even up to 13 fuel pistols, this type of failure does not represent critical suspension.

Certainly, providing that the preventive examinations are introduced as well as the replacement of consumable equipment (straps, pistols, hoses), failures would be significantly reduced but they would be followed by the additional increase of preventive maintenance costs.

"Power outage" represents suspensions in operation on which the company neither has the influence nor is able to prevent them. They are most frequent in case of weather disasters or breakdowns on the power plants for power production and supply. The problem of power outage has been overcome by the construction or purchase of mobile generators. Considering that the installation of generators in all petrol stations would be economically inefficient, their installation is done only in the most frequent

facilities which at the same time have the greatest influence on trade while an adequate number of mobile generators is provided for the needs of other petrol stations.
"Planned repair and maintenance" comprises suspensions due to calibration of devices and cleaning tanks. Providing that the mentioned works are carried out at night in the night mode, safety risk would be significantly increased followed by simultaneous increase of costs for services. In order to reduce mentioned suspensions impact on trade of derivatives, the activities in this segment of maintenance are organized in the periods of less consumer frequency at retail facilities so that the partial suspension in operation, for example of one filling site, has the least impact on the sale loss.
Although “Management system malfunction” has slightly lesser share in suspension, it represents the most critical suspension of operation since its breakdown terminates the operation of the entire facility. The systems for management comprise IT systems (fiscal cash registers, printers, computers and DOMS controllers enabling interconnection of different types of equipment at petrol stations).

Besides the four mentioned first ranked suspensions, they also occur due to the following:

5. Unforeseen repair and maintenance
6. Reconstruction/Rebranding
7. Technical malfunction of the equipment

"Unforeseen repair and maintenance" which in a concrete example represent the activity within maintenance in case of breakdown, as it can be seen, amounts to 10:25 hours for the period January – July, which on average represents 1:46 hours of suspension on a monthly basis. Mentioned suspension cannot be considered as hazardous to undisturbed operation of the facility and the entire retail network.
"Reconstruction/Rebranding" represents the category of the foreseen suspension of operation and is carried out in the afore-planned periods and terms.
As it can be seen on the basis of the given distribution of suspensions in the operation of petrol stations according to the type of suspension (Diagram 1), last ranked one is "Technical malfunction of the equipment" having zero hours of suspension since there are no suspensions due to it. Therefore, it can be concluded that maintenance service in charge of the organization and control of processes, performs an adequate planning and management of preventive and foreseen maintenance processes thus minimizing the suspensions of retail facilities operation which may be caused by technical and technological malfunction.
To conclude, although placed in the fourth place according to the number of suspension hours, interrupted operation due to management system malfunction (IT system) may be considered as the most critical taking into account that it results in termination of the entire operation at the retail facility. Necessary measures imply hardware improvement by investing into modernization of computer equipment, fiscal printers and network equipment followed by simultaneous investment into development and training of the employees so that they would be able to recognize and remove shortages as soon as possible upon their occurrence.

CONCLUSION

Aiming to efficiently manage petrol stations maintenance process, continuously implemented activities are as follows:

- Plans for the use, maintenance and certification of measuring and regulation equipment are prepared
- There is a continuous monitoring of equipment and devices development in terms of maintenance, exploitation, ecology and safety
- Equipment unification is carried out
- Unique records of the technical and technological equipment base is kept
- Control, monitoring, recording and informing related to reporting breakdowns at petrol stations are carried out and elimination of the same within defined deadlines is monitored.
- Power saving is secured by complying with the Standards for power management system ISO 50001.

In addition to the mentioned activities, systems in use are also those for derivatives leakage detection thus reducing the possibility of losses and secure the protection as follows:

- Sensors under pump devices and in tank manholes
- Double layer of tanks including under-pressure, overpressure and electrical unit controlling the pressure and alarms in case of change
- Electrical measuring probes having derivatives leakage alarm built-in.

All facilities also contain fire-protection systems thereby providing property protection, reducing the possibility of breakdown and risk to life not only of the employees but also of the customers:

- Fire-protection switchboard
- Fire-protection devices
- Hydrants
- Smoke detectors in petrol stations facility
- Equipment and devices for anti-explosion protection

As one of preventive and planned maintenance processes, regularly implemented activities are in compliance with the provisions of standards SRPS ISO 60079-17: Recommendations for examination and maintenance of electrical installations within hazardous premises - apart from mines thus securing regular control and raising the protection level of electrical equipment in ’’Ex’’ performance.

Considering territorial indentation of retail facilities in the territory of Serbia as well as impossibility of unifying all facilities and equipment, the service in charge of technical maintenance of NIS petrol stations, through activities and measures implemented, successfully manage petrol stations maintenance process to a considerable extent. Continuous investments into innovations, development of new solutions, compliance with international standards and process automation result in notable elimination of profit loss due to operation suspension as well as mistakes thus achieving maintenance costs reduction. Previously mentioned facts also result in taking care of energy efficiency, environment protection and safety at work along with simultaneously achieved increase of credibility, competitiveness of business dealings and reputation that the company has in the market.

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SPECIFIC CONDITIONS OF OIL SPILLS CLEANUP AT THE ARCTIC SHELF AND RISKS CONNECTED WITH THEM

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Abstract: The article considers the problems of oil spills liquidation at the Arctic shelf. A brief analysis of the specifics of the hydrometeorological conditions of the Arctic seas and its impact, both on the possibility of occurrence and on the process of detection, localization and liquidation of oil spills is given. The questions of probability estimation and damage assessment from oil spills in the Arctic shelf are considered.
Key words: oil spills, Arctic shelf, damage

INTRODUCTION

There are several specific conditions of the Arctic seas that have a negative impact on the effectiveness of oil spill cleanup [1, 2]:
- difficult meteorological conditions (fogs, low clouds, low temperatures in winter, frequent storms, etc.);
- small depths in coastal zones and other navigational hazards;
- difficult ice conditions;
- poor transport infrastructure;
- significant distances between potential oil spills and concentration of forces for oil spills liquidation;
- a small number of deep-water, sheltered from the waves bays, where it would be possible to deploy resource bases;
−lack of sufficient forces for oil spills elimination and the difficulty in determining their quantity. The combination of these factors gives a synergetic effect of reducing the effectiveness of the work [3].

The presence of fog makes it difficult to use aircraft for monitoring oil slick. Due to the remoteness of the take-off areas and the locations of aircraft, long periods of ‘flying’ weather are required that in the Arctic are rare and short.

Ice is also an insurmountable obstacle for cleanup operations. Developed technologies for spills localizing exist only in continuous ice, but for bit and solid ice, these technologies cannot be used. The vastness of the basin, the small number of sheltered harbors and the weak transport infrastructure of the Arctic region make it very difficult to create a network of equipment bases and a grouping of ships that can quickly focus in the area of work. Nowadays the delay in starting of full-scale liquidation work in remote regions of the Arctic can be up to several days

Data about the dynamics of oil spill propagation resulting from rare field observations, satellite imagery and computer modeling using geoinformation systems can complement each other by increasing the accuracy of forecasting the dynamics of spreading and migration of an oil spill, but not completely predict it [4].

MATERIAL AND METHODS

Assessment of the probability of oil spills at the Arctic shelf

For assessing risks of oil spills at offshore projects, especially at large ones that are more than 700 tons, it is necessary to consider accidents during drilling and fishing operations, as well as accidents while transporting oil by pipelines and tankers.

The probability of accidents at oil pipelines is determined, as a rule, by one kilometer of the route. Thus, for submerged areas [5] it is recommended to take the value 1.4 · 10-5 per km / year, while for

land sections of pipelines with a diameter of more than 24 inches, the frequency of accidents is higher by – $2{,}5\cdot10^{-4}$ at 1 km / year.
The development of oil projects at shelf will lead to an intensification of oil transportation by tankers. However, tanker accidents are the most common causes of large oil spills (in hundreds of thousands of tons) in the sea. One of the most "expensive" accidents was the accident with the tanker Exxon Valdiz in the waters of Alaska in 1989. Exxon's losses were about 9 billion dollars with a spill of 37,000 tons of oil [6].
According to the data given in Table 1, large oil spills are most likely in case of navigational accidents with tankers - grounding, hull damage and collision. Such accidents are typical for complicated ice and navigation situation in the Arctic.

Table 1. The probability of accidents during oil transportation by tankers [7, 8]

Established and emergency situations		**Probability of spills per tanker per year according the volume of the spill (t)**				
		< 7	7-700	700 - 5000	> 5000	Всего
Operations	**Loading, unloading**	$1{,}6\cdot10^{-2}$	$1{,}7\cdot10^{-3}$	$6{,}9\cdot10^{-5}$	$2{,}9\cdot10^{-5}$	$1{,}8\cdot10^{-2}$
	Bunkering	$3{,}1\cdot10^{-3}$	$1{,}4\cdot10^{-4}$	0	0	$3{,}3\cdot10^{-3}$
	Other operations	$6{,}7\cdot10^{-3}$	$2{,}7\cdot10^{-4}$	0	0	$7{,}0\cdot10^{-3}$
Accidents	**Collisions**	$8{,}8\cdot10^{-4}$	$1{,}4\cdot10^{-3}$	$3{,}5\cdot10^{-4}$	$1{,}5\cdot10^{-4}$	$2{,}7\cdot10^{-3}$
	Strand landing	$1{,}3\cdot10^{-3}$	$1{,}1\cdot10^{-3}$	$4{,}2\cdot10^{-4}$	$1{,}8\cdot10^{-4}$	$3{,}0\cdot10^{-3}$
	Case damage	$3{,}2\cdot10^{-3}$	$4{,}2\cdot10^{-4}$	$1{,}7\cdot10^{-4}$	$7{,}4\cdot10^{-5}$	$3{,}9\cdot10^{-3}$
	Fires and explosions	$8{,}6\cdot10^{-4}$	$9{,}2\cdot10^{-5}$	$7{,}7\cdot10^{-5}$	$3{,}3\cdot10^{-5}$	$1{,}1\cdot10^{-3}$
Other reasons		$1{,}3\cdot10^{-2}$	$9{,}3\cdot10^{-4}$	$1{,}4\cdot10^{-4}$	$6{,}0\cdot10^{-5}$	$1{,}4\cdot10^{-2}$
Total		$4{,}5\cdot10^{-2}$	$6{,}1\cdot10^{-3}$	$1{,}2\cdot10^{-3}$	$5{,}2\cdot10^{-4}$	$5{,}3\cdot10^{-2}$

Damage assessment of oil spills at the Arctic shelf

Along with the probability of oil spills, it is necessary to assess the probable damage from it. The maximum losses occur when oil reaches the coastal zones and the coastline. It is especially important to know which banks are or may be contaminated. In the international practice, the indexing of coasts (from 1 to 10, as their vulnerability increases) is used [9]. The maximum index is assigned to the swampy, sheltered from the excitement of the shore, overgrown with vegetation of shallow lagoons. Vulnerability of coastal zones depends on climatic conditions. Thus, based on the damage assessment studies that have been carried out as a result of oil spills in the Arctic seas and Prince William Sound (Alaska), it is concluded that the consequences of oil spills affecting the subarctic coastal environment can last much longer than in temperate latitudes, because of the slower pace of ecosystem restoration. [10,11] If such banks are polluted, not only large environmental damage is expected, but also significant costs for their purification. In addition to the geomorphological characteristics of the coast, the vulnerability is affected by the concentration of marine inhabitants that may suffer as a result of pollution. Thus, oil ingress into the estuarine zone of the river can make it completely harmful for spawning, which will have long-term consequences, and oil spills in places of mammal or bird accumulation can lead to their mass death. Assessment of the impact of oil spills on marine ecosystems and bioresources was elaborated in detail in [12], and biodiversity of the Arctic seas of the Russian Federation is clearly illustrated in [13]. The main conclusion of these studies is the assessment of Arctic ecosystems as extremely vulnerable to oil pollution.

CONCLUSION

With other equal parameters of intensity of offshore oil fields development, the risks associated with large oil spills in the Arctic significantly exceed the analogous indicators for more moderate climatic zones. While the integral indicators of the probability of a major oil spill lie in a fairly "quiet" range of "possible events" (one event in the range of 100 to 10,000 years), but the consequences of such incidents are difficult to assess because of their scale. Therefore, it is difficult to recognize the existing risks as "acceptable"

All measures for ensuring environmental safety in the implementation of oil projects at the Arctic shelf can be divided into organizational arrangements and scientific and technical research.

Among organizational arrangements there are:

- the formation of a regulatory field in oil spills cleanup area and ensuring readiness for such incidents;
- development of Management System for the liquidation of large oil spills at seas, involving organizations and resources from areas with a high concentration of potentially hazardous oil production and transportation facilities;
- creation of a network of warehouses (including floating ones) with equipment (with the financial support of oil companies), the creation of "response groups" involved in liquidation operations, the organization of their trainings.

Scientific and technical research should be focused on the following areas:

- development of methods for predicting the spread of oil spills in iced seas and remote tracking methods for oil spills in conditions of limited visibility (including using unmanned vehicles);
- development and production of fundamentally new means of large capacity (up to 5 tons) for the delivery of resources to work sites that ensure safe movement through water, swamps, broken and solid ice;
- development of new methods and means for localization and liquidation of oil spills at sea in conditions of broken solid ice and low ambient temperatures.

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PROBLEMS OF ELIMINATION OF OIL SPILL EMERGENCY AT THE ARCTIC SHELF

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Abstract: This article is devoted to the problems of oil slicks spreading in water areas among ice and to modern methods of their detection. The review of the existing methods of oil spills localization in Arctic seas is provided in the article. The analysis of their distinctions, advantages and disadvantages from the point of applicability in the conditions of lowered air and water temperatures is given. The major factors reducing efficiency of each method are noted and recommendations about the choice of an optimum way of oil spills elimination in Arctic seas are made.
Key words: oil spills, emergency, elimination, Arctic seas.

INTRODUCTION

Emergency oil spills that take place on venues of oil extracting, transporting and processing industry are very harmful to ecosystems. This problem causes breaking of many natural processes and significantly changes conditions of organisms dwelling. This leads to negative economic and social consequences.
Due to the current tendency of extraction transfer of hardly removable hydrocarbons to the Arctic shelf this problem acquires special relevance. Decrease of possible negative consequences in the severe Arctic conditions that are characterized by hardly recoverable and vulnerable ecosystems becomes one of the most important problems of oil industry. [1]
Emergency spills on water basins cover significant areas. If the oil slick from one ton of the poured oil on the land can occupy up to 0,1 sq.km, then the area of a slick of the same volume on quiet water reaches 12 sq.km. Waves and wind aggravate the situation. It is also necessary to mention that the area of oil spill among ice that is characteristically to Arctic seas in waving and windy conditions difficult gives in to assessment.
Dynamics of oil slick spreading is necessary for expeditious localization and elimination of a slick. Both observations are needed: predicted ones that based on various mathematical models and natural ones.

MATERIAL AND METHODS

Modern technologies of a space radar-location with application of locators with the synthesized aperture have brought remote sounding of the Arctic water areas to qualitatively new level. [2] However, the main problem of their use in the Arctic seas is the complexity, and in some cases even impossibility of direct detection and exact assessment of oil spills parameters among ice covering. [3]
Despite mentioned disadvantages of satellite monitoring, accumulation and analysis of the data obtained with its help is useful for creation of the basic data that is applicable at mathematical modeling of oil spill spreading in ice seas, especially in case of depressurization of the sea oil pipeline under ice. [4]
Thus, the data obtained as a result of rare natural observations, pictures from satellites and mathematical modeling supplement each other and with high probability can predict spreading of an oil slick during time. All this leads to improvement of quality of the made plans for elimination of oil spills emergency and to the more exact determination of required forces and funds for their realization.
Localization of a spill is traditionally carried out by installation of floating booms. [5] However, their effective usage is complicated because of weather conditions and an ice cover in Arctic seas. Waves and additional ice loads on booms cause ablation, oil duck and raise requirements of durability and reliability to booms and technical connections.

Nowadays the main methods of oil spills emergency elimination in seawater areas are thermal, mechanical and chemical.
Recently the special popularity is gained by a method of bacteriological destruction due to use of various oleophagous organisms. In the low temperature conditions of the Arctic shelf when oxidizing processes are considerably slowed down, these microorganisms make an essential contribution to oil decomposition. This way of oil spill elimination has essential potential in the Arctic water areas. However, it demands the considerable volume of the multiple researches that con-firm its efficiency. Therefore, it is more necessary to analyze traditional methods that are used at northern water areas.
Combustion of oil is one of the most widespread elimination methods that has been used since the 1960s. Burning on the place requires two components: fire-resistant booms and igniters.
The main characteristic of the correct burning is spot thickness. If the oil layer is rather big, then top layer freely burns, and lower is the insulator of heating transfer. It reaches preservation of low water temperature. However, if the layer gets thinner and heat exchange with the environment is more active, it can serve as the burning termination reason.
World scientists believe [6, 7] that this way is rather effective, especially in pack ice of various density, but its efficiency depends on initial conditions: time of response to an oil slick, thickness of a spot and wind speed.
It is possible to refer fire danger, toxicity, a small "temporary window" on open water, special requirements imposed to booms design and low efficiency to disadvantages of this method. Formation of a cancerogenic deposit after burning makes up to 25% of the slick volume, and the rest after burning by different estimates can reach up to 50% of volume.
During mechanical removal of oil from water surface oil localization with the help of booms and gathering by petrocatchers (skimmers) are carried out. At first, the area of an oil slick spreading is reduced. Then layer gets thicker that facilitates operation of skimmers. After that, skimmers collect oil that comes to containers located on the vessel with its further utilization.
Depending on properties, amount of spilled oil, ice covering and weather conditions, various types of skimmers (different in design principle of working) are applied. It is established that their usage is most effective in case of fast reaction of the vessel with a complete set of the equipment and in water that is completely free from ice.
However tests of skimmers of various designs that were held among ice covering authorized by the American department of surrounding environments protection in 2013 have shown their efficiency only at considerable (25 mm) thickness of a film and at small ice concentration (the unity was 3 points).
It is possible to carry small volumes of collecting, existence of a residual film, labor input and low efficiency in ice conditions that is influenced by waves, temperature, viscosity of collected product and existence of a snow and ice cover to the main disadvantages of mechanical method. [7]
Within a chemical method, it is possible to allocate use of sorbents and dispersants. However, sorption properties of the known sorbents seriously depend on viscosity of the collected oil that in the conditions of the lowered temperatures has key value. Besides, the sorbent impregnated with oil has to be mechanically collected from a surface of the water. This leads to various well-known problems.
Dispersants are the means that intensify natural dispersion of oil in the thickness of water. Use of these means is recognized as an ecologically acceptable and very effective under certain conditions way of elimination of oil spill emergencies.
Dispersants are irreplaceable when as a result of strong wind and adverse sea conditions mechanical collecting of oil and burning it out becomes unsafe or inefficient. They promote division of oil into the smallest drops that quickly break in water to safe concentration that considerably accelerates the natural bio-degradation of oil proceeding even at low temperatures in the Arctic conditions.
Spreading of oil, its drift and processes of degradation have unique features in ice cover conditions. Temperature depending on which properties of oil (viscosity, density, a superficial tension) change, direction, current force and wind have a great influence on spreading processes.
Oil, getting on a limited water surface with floating ice, appears under ice, on the ice surface and inside ice. Oil is exempted from an ice cover only in the spring and it can occur for several hundreds or even thousands of kilometers from the place of leak. As a result, the huge territory of the ocean that was earlier clean is polluted.

Besides, oil in congestions of fragments of sea ice and under them remains fresh and dispersed during longer period, than in other areas because of the lowered speed of evaporation, bigger thickness of the oil film and smaller intensity of hashing interfering oil emulsification. Joint migration of a dispersant and oil with ices potentially allows to continue dispergating after their thawing.

It is possible to refer increase of dispersants efficiency in case of wind speed and wave height increase that is typical to northern water areas to ad-vantage of dispersants use in comparison with application of mechanical collectors skimmers and burning. [7]

Thus, the chemical method with application of dispersants can be considered as the most acceptable in struggling against oil spills in the Arctic shelf.

It is necessary to mention that broad use of dispersants restrains by a number of factors. First, it is an insufficient study of their behavior in ice conditions. The compounding of dispersants, as a rule, is not universal. Environment conditions, physical and chemical properties of dispersed oil and oil products have considerable impact on dispersants efficiency. Besides, a number of re-searchers believes that use of dispersants in the Arctic with use of the existing technologies of dispersion is rather complicated. [6]

Broad application of dispersants is limited by their toxicity. So, in the USA and Canada dispersants are used only for elimination of oil spills emergencies weighing more than 30 tons and over sea depth over 150 m. However, the preliminary analysis of the existing dispersants of global manufacturers has revealed a tendency to the outlined decrease in their toxicity. For example, dispersants of the second generation of Corexit 9527, Magnus, Varine cieanez Smilh herdez are much less toxic in comparison with the predecessors - Corexit 7664, Corexit 9500, BP 1002 and BP of 1001.

CONCLUSION

It is possible to assume that it is possible to receive a dispersant without any components containing the chlorinated hydrocarbons, benzene and phenolsin the nearest future. This dispersant will have similar characteristic with dispersants of the second generation. They will be capable to struggle against oil slicks in ice conditions. Development of new compounding will allow to use dispersants in the conditions of lowered temperatures and small salinity effectively.

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Session 5.

Engineering management

REALIZATION OF ONE SMART ENVIRONMENT FOR AGRICULTURAL PRODUCTION

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Abstract: One of the biggest problems of agricultural producers in Serbia is insufficient efficiency in the utilization of natural resources. This results in fewer yields or products of lower quality, which reduces earnings and competitiveness in the market. This paper presents the creation of a smart environment, made up of physical objects and a web application, intended for agricultural production with application to the cultivation of various plant crops. The Web application "Pi-Sense" is intended to facilitate and automate primitive jobs, such as regulating the temperature in a greenhouse. The said environment provides support for tracking and controlling conditions in which the selected plants are being grown over a network, as well as sending warnings about various discrepancies and irregularities. Ensuring optimum conditions increases the quality and efficiency of production.
Key words: smart environment, web application, agricultural production

INTRODUCTION

The emergence of the Internet has contributed to the development in many spheres of life of a today's man, making a great impact in the development of the business environment. Information, its availability, collection and exchange, as well as the development of the necessary knowledge for interpreting it, enable the success of a business enterprise, and the Internet has become a perfect place and a tool for it [1]. By integrating web applications and physical devices that are connected and communicated over a network, we get something that is known as a smart environment [2]. A smart environment allows us to exchange data that was not previously possible, which leads to increased productivity, the creation of new business models and new sources of revenue [1]. In technologically developed countries, smart environments are increasingly present, and their importance in the life of citizens and the functioning of the state is noticeable [3]. The development of smart environments has been enabled by IPv6 protocol that is able to allocate an IP address to virtually anything, LTE technology that allows wireless transfers of large amounts of data at high speeds and similar modern technologies. With the development of microcontrollers, microcomputers and various types of sensors, the possibilities for use of such applications in almost all spheres of life are also increasing – for example in smart homes, smart management, energy management, transportation, agriculture, livestock, etc [4].
This paper presents the development of a smart environment in agricultural production. There is a tendency for young people to move out of the villages and show disinterest for agricultural production, which can be very demanding and difficult, and financially difficult to pay off. The development of Internet technology has brought light to development of agricultural modernization [5]. More recent technical solutions, which certainly include smart environments, can greatly facilitate and improve agricultural production [6]. Unfortunately, a large number of agricultural producers do not know that such solutions exist, or they do not understand how they can be used. There is also a belief that large financial investments are necessary, and that such systems are complicated for operation and maintenance. The implemented smart environment that allows optimal plant cultivation is very easy to use and consists of cheap components that cost less than $10. In the development of the application, a combination of Python, PHP and JavaScript programming languages and MySQL database management system was used. The following sections will explain which environments and devices were used and why.

SYSTEM DESCRIPTION

Web application "Pi-Sense" is intended to facilitate and automate primitive jobs, and in this particular case it is related to agriculture. The application consists of 3 modules: for temperature, users and settings. Each of these modules is protected and cannot be accessed until a user is created by the administrator. The "Pi-Sense" application is designed and implemented for the purpose of better cultivation of plant crops from the very start and providing uninterrupted growth, which later leads to maximum income [7]. The implemented smart environment enables monitoring of the current temperature and air humidity in the greenhouse, as well as these data statistics for the past day. It is possible to add programs (the type of plant that is grown) and all parameters associated with that program, as well as editing and deleting them. Only authorized users can access the application with the appropriate parameters that are controlled. The main functionality of this application is that the system automatically turns the heating on and off when the temperature falls or reaches the maximum value and notifies the user if there is a drastic change in temperature, that is, if the temperature goes out of the range of optimal values and the temperature tolerance values defined in the program that is currently active.

The idea for the project itself came from personal needs. After analyzing the existing and available solutions, Sense Hat was selected as the solution that fits the most. Sense Hat is a module, or an electronic board that connects to Raspberry Pi and has various sensors, joystick and a multicolor pixel network that work as a small screen. Sense Hat was specially made for the Astro Pi mission, which launched several such devices into the space for various tests and measurements. Aside from this purpose, Sense Hat can be used as a weather station and deploy in the application described in this paper. However, Sense Hat has many other functionalities that we did not need, and that increase the price of the product. Financialy considerably more favorable variant was one sensor and a LED light (from the foundation Raspberry Pi) that cost order of magnitude less, and can meet the basic needs defined by the user. Bearing in mind the nature of Raspberry devices where the restrictions are minimal,which gives us great freedom in terms of engineering and allows us to use them for various functions described in the next chapter, it is clear that a simpler and cheaper option can be a great solution for personal needs and beyond. Considering that we did not find a product that has a specific function and purpose that we needed, we made the application "Pi-Sense", whose block diagram is shown in Figure 1.

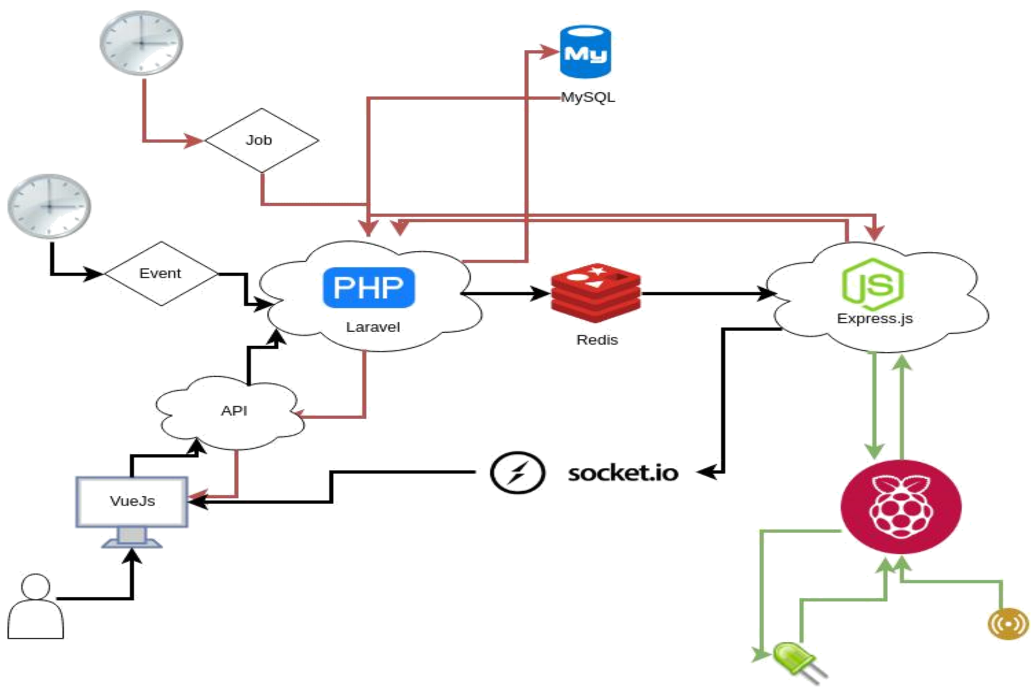

Figure 1. A schematic view of used technologies

Making applications is based on WEB technologies, mostly because of their availability and ease of use for the end user where only the Internet connection and a browser are needed. Thus, the purpose of this application is to be available in the web browser on your mobile device, which is possible with the current code base, with minimal extensions.

Work environment

The application consists of several layers, of which three are used for the server part of the application:
1. PHP - Laravel Framework
2. NodeJs - Express Framework
3. Python

For the communication layer between the server languages, as well as the communication of the client part with the server, the following technologies were used:
1. Redis
2. Web sockets
3. API (application programming interface)

The programming language used for the client side is JavaScript - Vue.js Framework
On the server side data are stored in a MySQL database, which is administrated by the DataGrip tool from JetBrains and partly by Laravel where the migrations (existing tables and columns in them as well as the type of data that can be stored in the column) are defined.
In addition to the software part, the application also has hardware, which consists of:
1. Raspberry Pi
2. DHT11 - Sensor for measuring temperature and air humidity
3. Proto board
4. Pi Cobbler – Raspberry Pi and proto board connector
5. All accessories - cables, resistors, led lights

SYSTEM DESIGN

Laravel framework is in charge of the API part of the application, manipulation of all stored data, initiation of background tasks that are used to read data from the sensor and store them, as well as processing the initial HTTP requests by the client. When the user types the initial URL in their browser Laravel is in charge of processing that HTTP request, and the application returns to the Home page which contains SPA (single page application). Vue.js framework is in charge of this application, as well as further navigation and processing of HTTP requests.
There are two types of background activities that are run every minute and every hour:
1. Activities that are run every minute serve to check whether a measured temperature is in the range defined by the minimum and maximum temperature, to turn the heating on or off depending on the current temperature and to notify the user by a phone call if the temperature difference is greater than tolerated. Scanned data are sent to the client side in the same pace via web sockets, in order to display them in real time.
2. Activities that are run every hour serve for storing data to the database for further processing and statistical purposes.

Express.js framework is in charge of controlling the GPIO (General-purpose input / output) pins located on Raspberry Pi through which it is connected to the sensor and the LED light located on the proto board, specifically for executing the python script that reads data from the sensor and the script that controls the lamp. The communication layer between Laravel and Express.js is Redis. Laravel tasks, when initiated, send a message through Redis to Express.js which listening and waiting for this message and which then continues to process the request and returns the necessary data.

Laravel Framework

Laravel is an open source framework for PHP language [8]. It uses the MVC architecture (Model View Controller) that separates between the logical layer and the layer of presentation. In practice, this allows web pages to contain a minimum code script because PHP scripting is separate from the presentation.

- Model represents the data structures. A typical model features functions that enable retrieving and inserting data from and into the database
- Controller works as an intermediary between the model and the view, processes HTTP requests and generates web pages.
- View serves to present data to the user. View is commonly a webpage, but in Laravel it can be a fragment – a header or a footer, a RSS page or any other web page.

Laravel helps us to program in PHP programming language better and simpler. It adds modularity and the code becomes more readable and simpler for changes and corrections. The advantage of this framework in relation to others is that it is:

- Free
- Very easy to install and configure
- Thoroughly documented
- It has excellent community support through a large number of forums
- Includes a large number of libraries and features useful for application development.
- Fast and easy – initially it contains a small number of libraries, and others are loaded as needed
- Generates clean and 'Search engine friendly' URLs that help with listing in search engines

All the directories can be divided into three groups:

1. Directories whose content is most oftenly changed (controllers, models, views, events, jobs), these are the files that the user needs to create or adjusts to their needs
2. The vendor directory contains the very core of the framework with the main classes needed for its work, as well as libraries that we install as needed.
3. Directories that contain the files that have already been written in, but they need amendments and changes (lang, config, errors).

In this smart environment, Laravel has the role of the main initiator of all events, responds to all client requests, and storages/retrieves data from the database.

NodeJs - Express Framework

NodeJs is a "low-level" I / O mechanism with the HTTP module [9]. If we use only the HTTP module, many jobs such as parsing data, cookies, sessions, etc. ... would have to be done manually. ExpressJs allows us to avoid this and deal with specific things.
NodeJs is in charge of responding to Laravel's requests for reading data from the sensor and forwarding them through a web socket to the front part to display it to the user. NodeJs has an open connection to Redis where it constantly listens for a message from Laravel and then retrieves the necessary data and continues to work with them.

Redis

Redis is an open source, key/value database that uses computer memory (RAM) to store these data [10]. It is also used as a message broker, which is implemented in this application. Redis is an intermediary between Laravel and Express.Js. Since there is no direct connection between these two programming languages, Redis is the perfect solution for communication and data exchange. Each of these languages has its advantages and disadvantages and in combination, they enable the realization and implementation of various programs together.

Redis has "channels" to which Node.js snaps, and Laravel sends a message to a particular channel, so it is exactly recognized what the message is and what needs to be done when it arrives.
Redis is extremely fast because it stores all data in RAM memory so it is very reliable and works in real-time environments.

Web sockets

Web Sockets is an advanced technology that allows an interactive communication connection to be opened in real time between a client (web browser) and a server. We can send messages to the server and receive event-driven messages (replies from the server to the sent messages).
Web sockets in the "Pi-Sense" application serve to display the data read from the sensors and display them to the end-user in real time. Data is received from NodeJs and is displayed in the application immediately.

API (application programming interface)

The development of the API is one of the most popular ways in practice both at the individual and company level. The API is part of a remote server that accepts requests and sends replies to them. This allows complete separation of server and client logic and brings the following benefits:

- Unburdening the server
- Better application scaling
- Modularity of the application
- Access from web browsers and from mobile devices (Andorid and iOs)

In the "Pi-Sense" application API is the agent between VueJs (front part) and Laravel (back part). Each request from the client uses the API and sends a request to the Laravel application, which again, after processing the request, sends a response to the client via the API. The client receives the requested results, or if an irregularity occurs, the error is displayed to the user in an understandable manner.

JavaScript - Vue.js Framework

Vue.js is one of the new software technologies used worldwide for web development and user interfaces. Vue.js is actually a JavaScript framework with a variety of optional user interface building tools [11]. One of the biggest advantages of using Vue.js is that it uses components that are separate entities and can be used countless times in the application wherever there is a need for them. Within one component there is everything that is needed, which is:

- JavaScript
- HTML
- CSS

Because of this, there is no need to write a special CSS and create a large file that is hardly sustainable in the majority of cases.
The purpose of VueJs is to display all necessary information to the user, allowing them to interact with the background of the application. Web Sockets are also present here (on the client side, a client's Web Socket script is running) and awaiting a message from the server. After receiving the message, further control over the data is taken over by VueJs and it displays it to the user in a proper way.

RaspberryPi

Raspberry Pi is a cheap computer (microcontroller) size of a credit card that connects to a monitor or TV, and uses a standard keyboard and a mouse. It has features similar to a desktop computer, from Internet browsing and high definition video reproduction to creating tables, text processing, and game play.

For the purposes of this application, the Raspberry Pi 3 Model B was used, as shown in Fig. 2, where it acts as a stand-alone web server [12]. It uses nginx as an HTTP server that processes requests and then sends them to be executed on PHP or NodeJs depending on the request.

Figure 2. Raspberry Pi with accompanying equipment

Aside from the listed used items, it also has a MySql database for data storage and PM2 in it [13].
PM2 is a process manager for NodeJs and a production tool that is raised automatically if for some reason the server drops and reboots. It has a load balancer built in, which is used if the traffic is very large, so the server instances are raised to multiple machines and work together for better performance and in order to respond to all the incoming requests.
In the end, a display of the temperature values shown in Fig. 3.

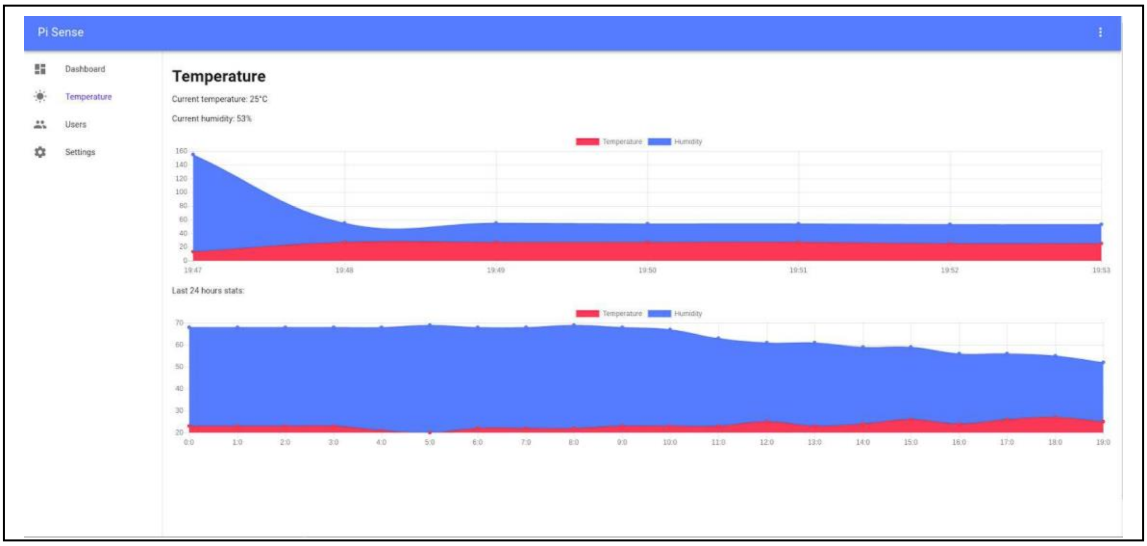

Figure 3. Temperature - pages

CONCLUSION

Serbia has great agricultural potentials that are not nearly as used as they could be. Smart environments enable the cultivation of the best quality organic products that can be competitive all over the world with their quality and price. With relatively small investments, small farmers can also have their own smart environment systems and monitor the cultivation of their agricultural crops. With the help of data processing, the right cultures for planting and cultivation on the parcels can be selected, as well as the best possible solutions for certain types of agricultural crops grown. An additional benefit for both small and large agriculturists is in reducing the costs of fertilizing and watering the agricultural plots. The data, collected through these smart systems, can have a wider use for other manufacturers, if it was available to them. A smart agricultural environment can ensure the progress of the agricultural sector and improve the standards of agricultural producers with maximum utilization of natural resources.

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TOWARDS SMART ONTOLOGY BASED PROCESS FOR BUILDING RECONSTRUCTION

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Abstract: This work represents method of easier and faster way to gain knowledge about historical buildings. The 20 % facilities in Republic of Slovenia were built between 1857- 1948 while 75 % of all were built before 1989. In the Regional Archives there are many fewer plans. And data base is sufficient of data. Exploring historical is financially demanding and time-consuming – it lasts for 9 months to 2 years.
By Knowledge Management technology which based on databases, enable discovering new knowledge and predicting new solutions. This paper represents our way to collect and search new knowledge about historical building.
Key words: historical building, knowledge management, database

INTRODUCTION

During reconstruction and maintenance of buildings we need to collect information about building in a faster and easier way. One of the most important reason why we need to do is BIM. By introducing BIM technology, investors realizing that there are fewer additional and unexpected works, and thus less additional costs. Construction contractors register fewer disruptions in the project, and easier and more efficient planning of work and matters regarding material, [1]. In order of the implementation of the European Public Procurement Guideline, [2], it may be required in the future, that projects for the renovation of historic buildings and cultural heritage facilities are made with BIM or similar tools. Therefore, it is necessary for the historical objects to fill the gaps brought by the lost plans and to shorten the phase of analysis of the existing object. The main phase in the project of reconstruction of the historical building is the analysis and research of the existing building, [3]. Research relating to any segment of the renewal of facilities is carried out individually, and the results of research, together with the executed project, usually end up in drawers of individual companies or offices at the local or national level. Detection of historical values during reconstruction, renovation or conservation of a building presents an increase in the risk for the investor and a disruption of the project for the contractor. Reconstruction projects compared to the projects of the new building are not only more complex (because of the interaction between the old and the new), but they are also more demanding. This is mainly due to the lack of knowledge of materials, construction laws and interactions between them, [4]. By introducing advanced knowledge management technologies based on databases, ontologies, and methods of artificial intelligence, we can, by searching for patterns of common characteristics, fill the gap that appears due to insufficient information about the historic building or the cultural heritage building, even where the projects have been lost over a long period of existence.

MATERIAL AND METHODS

Common characteristics

What do have together the objects in Figures 1 and 2?

Figure 1. Kočevarjeva 4

Figure 2. Kajuhova 13 (photo by Daniela Dvornik Perhavec, 2018)

The design planes of these objects are shown in Figures 3, 4 and 5.

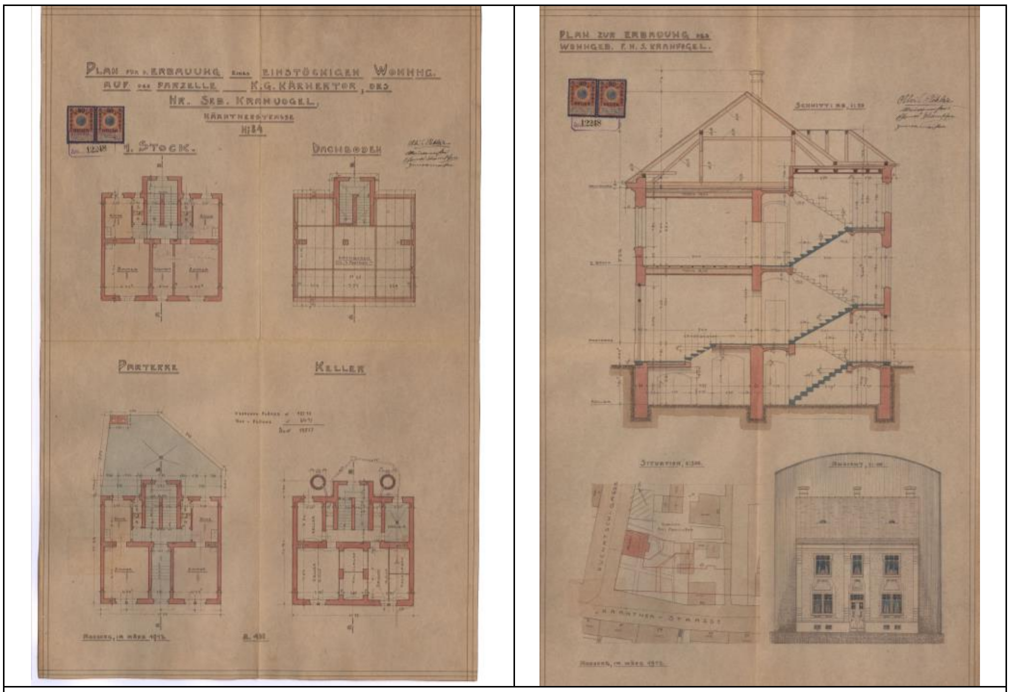

Figure 3 and 4. Design planes from building Kocevarjeva 4 from 1912 (vir: Pokrajinski Arhiv Maribor SI_PAM/0011/034/00001 MA/315-004.jpg and 006.jpg).

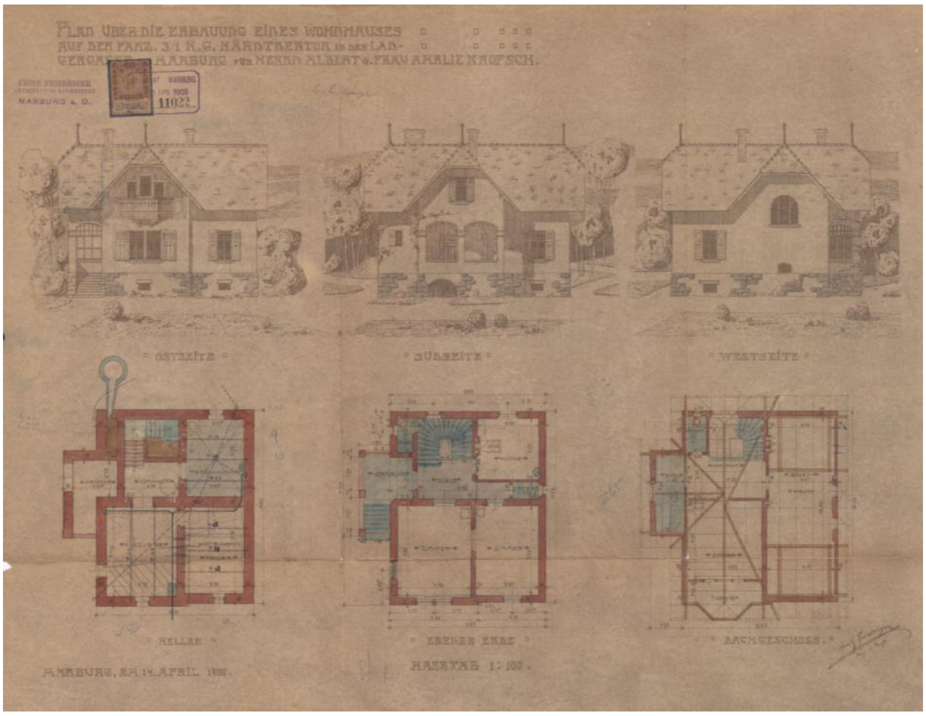

Figure 5. Design planes from building Kajuhova 13 from 1909 (vir: Pokrajinski Arhiv Maribor SI_PAM_0011-026-0015-MA/251_003.jpg).

The past research work, in which we analyzed literature, construction legislation and plans of existing historic buildings, namely residential buildings of ground floor + floor for the period 1857-1948, led us to the realization that individual elements of the building can be described with parameters. At the same time, we construct relational databases on the basis of which we can produce a predictive model of the same elements for random objects. The relevance of the results was checked on random buildings of the same purpose and floor level from the same period, [5].

In this issue we described several buildings with the use of knowledge moddelling langue as follows:

(A) research of the archived plans (Figures 3,4 and 5),

(B) identification of building's basic structural elements (Figure 6),

© description with RDF triples (Figure 9).

The first (A) and second (B) phase include very hard work which lasted a lot of time.

In the end of phase C) we concluded, the many common characteristics have been found in the different buildings in different places.

EXPERIMENTS

When taxonomy was made, the started with ontology development.

Figure 6 is shows decomposition of building and the workflow to transfer knowledge to ending users

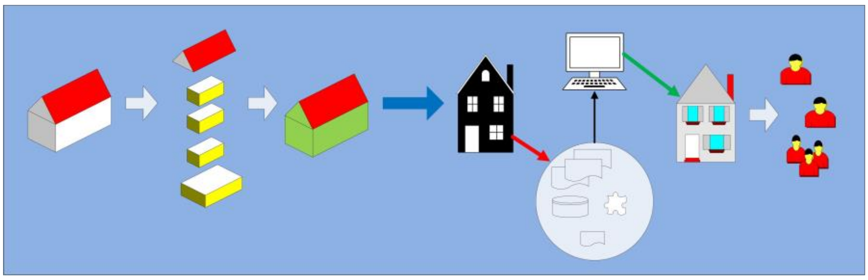

Figure 6. Decomposition of building and workflow of the algorithm based on knowledge modeling langue

Software tool Protege was used for development of ontologies. Ontology contains information about location, ownership, thickness of the main loadbearing walls, material of main walls, levels of floors and thickness of walls in each floor and the characteristics of buildings material. SPARQL language was used to query the ontology.
Moreover, by building ontologies of "building" and "material" that can be developed independently, we have met the knowledge management conditions by searching for both ontologies, [6].

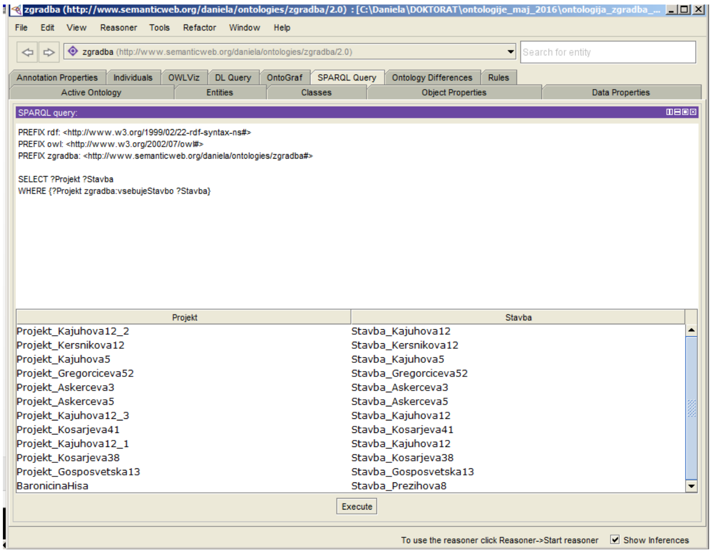

Figure 7. Ontology with instances from different Buildings (from Figures 3-5)

Baroness´ Hause reconstruction project (Figure 8) was used for validation of the approach. The ontology uses concept “zgradba” (in slovene http://www.semanticweb.org/daniela/ontologies/zgradba#) for „building“. The following SPARQL example displays existing knoowledge related to the Baroness´ Hause (Prežihova street 8).

Figure 8. Baroness´ Hause before reconstruction (photo by: Daniela Dvornik Perhavec, 2015)

In the SPARQL following commands were used:
PREFIX zgradba denotes the used namespace,
SELECT DISTINCT: displays only distinct results (without duplicates),

WHERE: contains results to specific set.
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX zgradba: <http://www.semanticweb.org/daniela/ontologies/zgradba#>
SELECT DISTINCT *
WHERE { zgradba:Stavba_Prezihova8 ?p ?o.
MINUS { zgradba:Stavba_Prezihova8 rdf:type ?o. }
}

RESULTS AND DISCUSSION

With the results (Figure 9) we can support the reconstruction project [7].

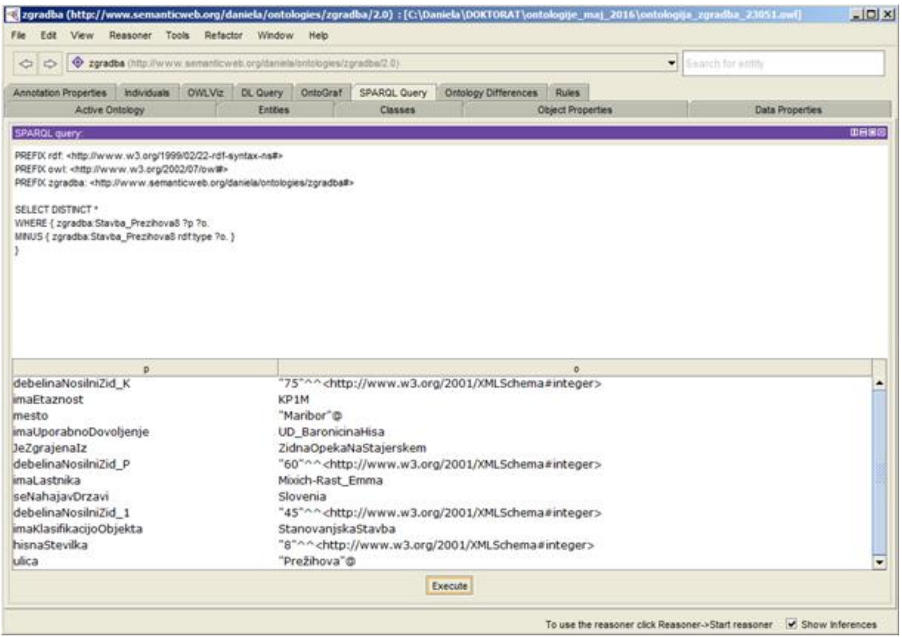

Figure 9. Results of the SPARQL query

A designer can use the knowledge-based system to obtain information about buildings, which decrease the number of physical inspections on-site (Figure 10). With this knowledge can supporting also other users, which need information about building.

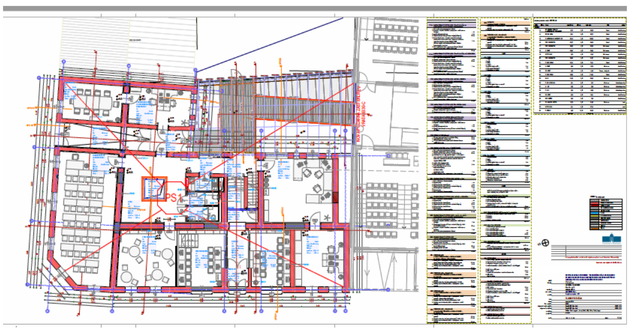

Figure 10. Baroness´ Hause new design plan to first floor (by Styria Architecture d.o.o.)

Figure 11. Baroness´ Hause after reconstruction (photo by: Bogdan Dugonik, 2016)

CONCLUSION

The model offers brooder interdisciplinary integration of different areas of expertise, i.e. location, arts, sustainability, energy efficiency, etc, [8, 9].

In the interdisciplinary field of historical building or cultural heritage buildings, we want to introduce machine learning, which through data mining in databases and with the help of knowledge bases (ontologies) contribute to more efficient information management, including in the management of buildings and other construction objects. For example, we are looking for data on the built material, where we define the material or manufacture year of brick, we follow the paths of the architect or building master or the occurrence of an artistic and historical building element. The use of system theories gives a broader insight into the field of historical buildings. With the development of ontologies, we create an environment for the joint use of knowledge, [10], which in the context of science is a new look at the historical building or cultural heritage object. This approach will provide new and innovative guidelines in the management and maintenance of historical buildings, thus contributing to the development of technical, social and humanistic fields. By complementing and linking the ontologies, we will endeavor to obtain a sufficiently good basis not only for conservation or restoration activity but also for multi-parameter modeling, for example, the link between energy consumption and the rehabilitation of buildings, forecasts of investments for maintenance needs, art historical and architectural valuation, valuation of real estate, and more. This will create new knowledge that will contribute to science and an interdisciplinary approach.

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THE ROLE OF HTML5 SVG GRAPHICS IN RESPONSIVE WEB DESIGN, SEARCH ENGINE OPTIMIZATION AND WEB GAME DEVELOPMENT EDUCATION – CASE STUDY

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Abstract: This work represents a case study of responsive web design and search engine optimization education on study programs in the field of IT in the Higher Technical School of Professional Studies in Novi Sad, Serbia. The role of SVG graphics in responsive web design is discussed in detail, as well as the impact of this graphics format on search engine optimization. Herein, curriculums of subjects dealing with SVG graphics and responsive web design are given. This paper contains examples of students' projects including SVG graphics on websites.
Key words: HTML 5, SVG, Responsive web design, Search engine optimization

INTRODUCTION

The World Wide Web plays a very important role in promoting business in all fields of industry. One can hardly imagine a successful company without a web site. According to [1], among many other benefits of digital marketing when compared to the traditional way, digital marketing is cost efficient, there is an ability of interaction with the audience, an ability of global (international) promotion, etc. But now there is a new trend - the use of mobile phones for surfing around the internet increases year by year. At [2] one can find the fact that mobile internet traffic as share of total global online traffic in 2018 is 51,2%. Specifically, this number is much higher in Asia - even 65.18%, see Fig. 1. This means that people use mobile phones for reaching websites more often than desktop devices. On [3] we can find many other interesting facts about the increasing number of mobile ecommerce accounts, mobile share of digital numbers, smartphone conversion rates, etc. On the other hand, the same source claims also an increasing number of internet users that would not recommend business with poorly designed website on mobile devices. Hence the need of responsive web design.

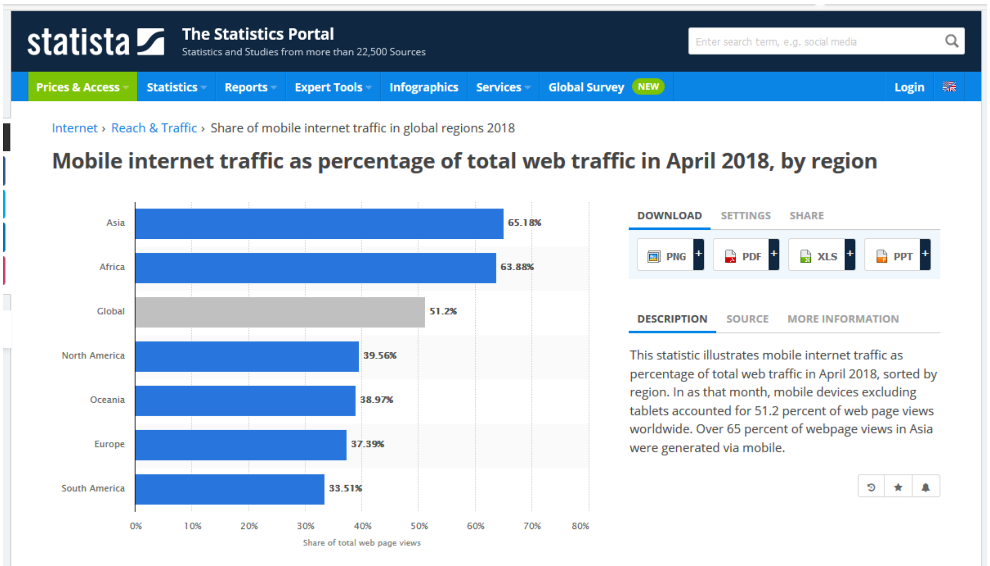


Figure 1. Mobile internet traffic as percentage of total web traffic in 2018, [2]

According to [4], responsive web design is "an approach whereby a designer creates a web page that responds to or resizes itself depending on the type of device it is being seen through."

Figure 2. Responsive web design**,** [4]

There are many problems that can occur on traditional, not responsive web sites. Lunching such websites on small mobile device screens can be rather complicated. For example, images with large dimensions can break the layout forcing the visitor to use the quite uncomfortable horizontal scroll. If such images are heavy, things are much more complicated, since this can cause a slow loading of the page. Technically, responsive web design is a mix of flexible grids and layouts, as well as the use of CSS3 media queries which enable us to use different styles for different screen resolutions, [6].
Publishing a web site at the WWW is not enough to increase a company's business. If users cannot easily find it using a search engine like Google, the whole project is just a waste of time and money. So a set of steps called SEO (Search Engine Optimization) is needed to be performed in order to reach a high rank at Google, [7]. Those steps include on-page (keyword optimization, meta tags optimization, title optimization, including alt texts for images, content and link optimization) and off-page steps (social media marketing and link building), [8].
In the next section we will discuss the impact of using SVG graphics on responsive web design. In addition, we will mention other benefits of using SVG graphics on web sites, such as a positive impact on search engine optimization. The third section is devoted to our case study of using SVG images in responsive web design education in The Higher Technical Education School of Professional Studies.

SVG GRAPHGICS IN MODERN WEB DESGIN

SVG graphics

SVG – Scalable vector graphics is an XML based markup language used to describe two-dimensional vector graphics. It is an open standard developed by the World Wide Web consortium since 1999. SVG images are defined as XML text files, so they can be searched, indexed, scripted and compressed. Since they are in XML format, they can be created and edited in any text editor or drawing software, [9], [10]. If an SVG is created in a text editor, then we simple use as shown in Fig.3.

Figure 3. Creating SVGs in text editor by writing code, [11]

On the other hand, there are many graphic programs which may be used for creating icons, web banners, and other graphics which support exporting the final version into a SVG format which can then easily be included in the web page (Adobe Illustrator, Photoshop, etc.). But for the purpose of education, free tools are preferred. A list of Top 15 free SVG graphics tools is given at [12]. Let us mention thee of them: *Raw* – supports online creating SVG graphics, as well as animations, *Inkscape* – vector graphics editor good for logos and other illustrations, *Method draw* – a free web tool for editing SVGs.

SVG and responsive web design

For illustrated icons on web sites, the source [13] recommend the use of SVGs instead of JPG file format. The reason is very simple: SVGs are vector graphics (a combination of lines created using mathematics) so they can easy be resized, whereas JPGs are raster graphics (they use pixels -small squares of color) and resizing can cause a loss of the image quality.

SVG and SEO optimization

According to [14]-[16], there is a positive impact on SEO when using SVGs on a web site. Let us list some of the benefits. First of all, SVGs are code, so such files are mainly of small size, (even at graphic with large dimensions). This means that pages using SVGs load faster, wich is a well known to have positive impact on SEO. The same holds for animations. Namely, animations created as vector graphics are also of significant lower size than those create in gif format. That's why it's efficient to use tools for SVG animations, like SVG gator, [17].

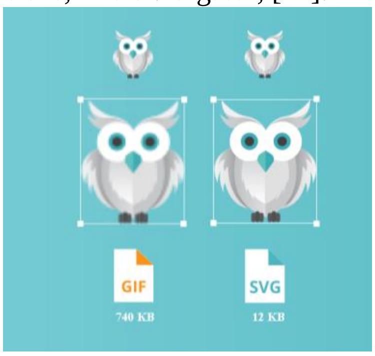


Figure 4. Comparison between gif an SVG animations, [17]

The source [15] claims that the best practice is to have a separate SVG file called in by using an <img src="file.svg" alt="youralttaghere">. This is because SVGs don't have an alt attribut, and are using the title attribut insted. On the other hand, the content of the alt attribut is more respected by google bots than the content of the tite attribut. At Fig. 5 we can see an example of a SVG logo at the https://eipix.com/ website.

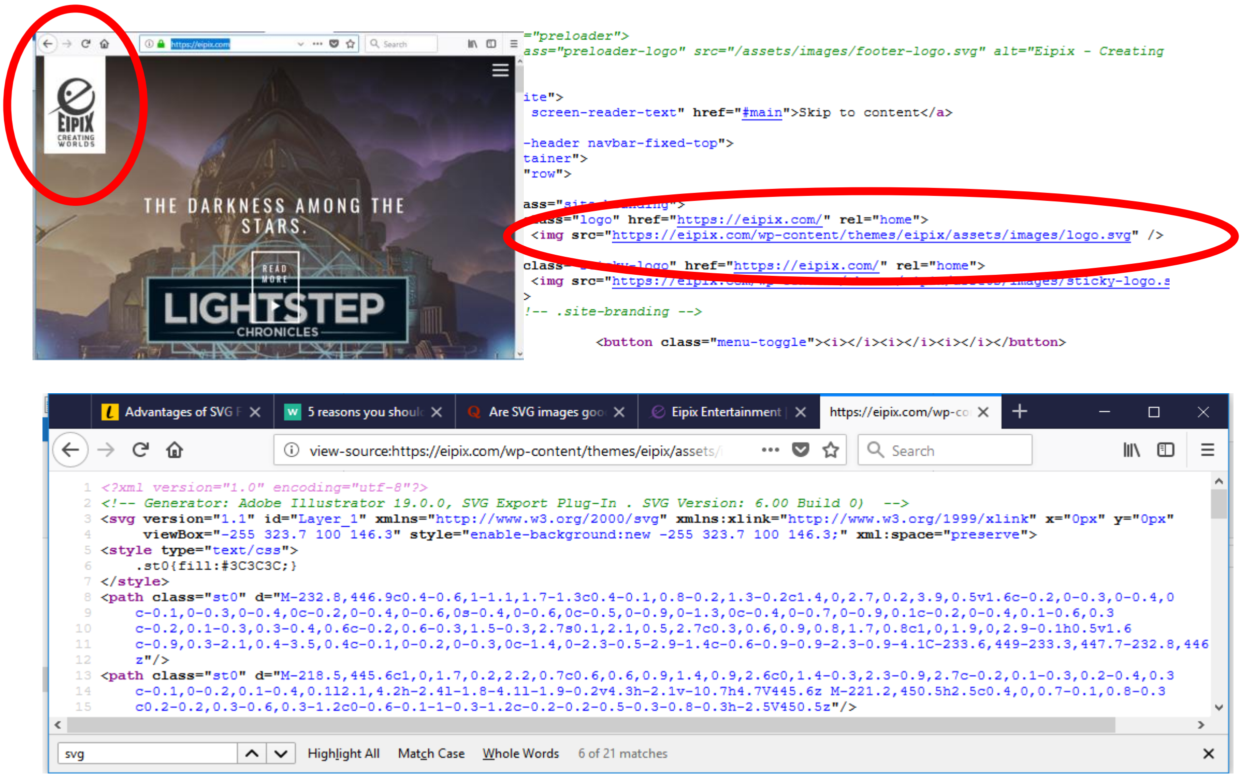


Figure 5. An example of a SVG graphic on a website

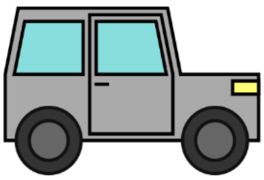
In addition, SVG images are easier are easier for search engines to navigate through since they are in XML format.

SVG and web game development

According to [18] - [20], web games are the future of computer games. In other words, games created in HTML 5 using JavaScript have many advantages in comparison with classical computer games: Cross platform support, Accessibility, Global promotion, Easy update, Technology Stacks an there is no need of download software and installation on the users' device. SVG together with canvas are a building block of these web games, [21].

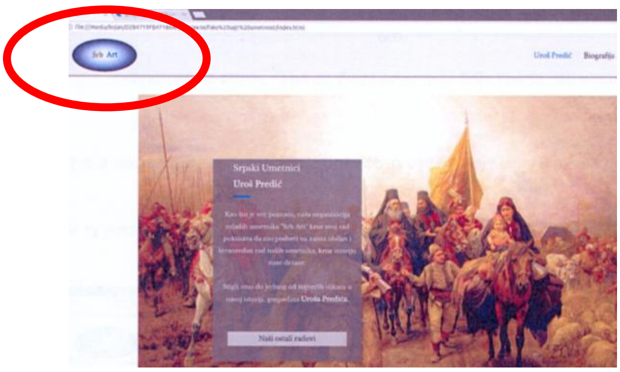
SVG GRAPHIS IN WEB DESIGN EDUCATION

Responsive web design was first introduced in 2010 in the online magazine *A list Apart*, [22] but was performed in practice since 2011. In the Higher Technical Education School of Professional Studies, there are two study programs in the field of web development: Web design and Information Technologies. Topics on responsive web design are included in subjects *Introduction to web design* (Grid System, Twitter Bootstrap) and Internet Tools and languages (CSS3 media queries) since 2013, [23]. Topics on HTML 5 and SVG graphics are included in subjects *Practicum* since 2014 *Introduction to internet technologies* since 2016. At Fig. 6 and 7 we can see students' works on websites including SVG graphics. On these two subjects students learn to create SVGs by HTML 5 coding.



```
<svg width="410" height="270">
    <polygon points="30,10 260,10 280,110 400,110 400,210 10,210 10,110" style="fill:#AAAAAA;stroke:#000000;stroke-width:5;" />
    <polygon points="40,30 130,30 130,110 24,110" style="fill:#88DDDD;stroke:#000000;stroke-width:5;" />
    <polygon points="150,30 242,30 258,110 150,110" style="fill:#88DDDD;stroke:#000000;stroke-width:5;" />
    <polygon points="140,20 250,20 268,110 268,200 140,200" style="fill:none;stroke:#000000;stroke-width:5;" />
    <polygon points="148,125 170,125" style="fill:none;stroke:#000000;stroke-width:5;" />
    <polygon points="400,120 400,140 360,140 360,120" style="fill:#ffff77;stroke:#000000;stroke-width:5;" />
    <circle cx="77" cy="210" r="50" style="fill:#333333;stroke:#111111;stroke-width:5;" />
    <circle cx="77" cy="210" r="30" style="fill:#666666;stroke:#111111;stroke-width:5;" />
    <circle cx="333" cy="210" r="50" style="fill:#333333;stroke:#111111;stroke-width:5;" />
    <circle cx="333" cy="210" r="30" style="fill:#666666;stroke:#111111;stroke-width:5;" />
    Sorry, your browser does not support inline SVG.
</svg>
```

Figure 6. Students' work including coded HTML 5 SVG graphics




```
<svg id="svgelem">
<radialGradient id="gradient" cx="50%" cy="50%" r="50%" fx="50%" fy="50%">
<stop offset="25%" style="stop-color:rgb(0, 97, 255); stop-opacity:0"/>
<stop offset="100%" style="stop-color:rgb(0,0,0); stop-opacity:1"/>
</radialGradient>
<ellipse cx="100" cy="50" rx="80" ry="40" style="fill:url(#gradient)" />
<text x="70" y="55" font-size="20" fill="black" float="center" class="srbart">Srb</text>
<text x="105" y="55" font-size="20" fill="#0061ff" float="center" font-weight="bold" class="srbart">Art</text>
</svg>
```

Figure 7. Students' work including coded HTML 5 SVG graphics

As a support for responsive design and SEO, topics concerning SVGs are newly included in the subjects *Computer graphics* and *Computer animations.* The main idea was that students learn to create SVGs by graphic tools and to include them on websites later. Below we can see a list of topics of the two aforementioned subjects.

Main topics of the Computer graphics and Computer animation subjects.

1. Primary components of graphics processing; Application of computer graphics: Classification of graphic applications, Conceptual frame for interactive graphic
2. Graphic systems: What does the connection between computers and graphic applications allow? Diagrams and graphs: Projecting using a computer; Virtual reality; Data Visualization
3. Graphic software hierarchy: Simple graphic libraryes;
4. Visualization tools, Modeling tools, Rendering tools, Animation tools, Simulation tools, Virtual reality tools, Web3d tools, Format conversion tools

5. Geometric transformations: 2D computer graphics; Orthogonal projections, 3D graphics
6. Vector and raster graphics
7. Graphic file formats
8. Graphic communication; Color theory
9. Graphic hardware: Input devices, Pointing input devices; Output devices
10. Types of modeling: Wire model, Volume presentation, Procedural models
11. Computer animation: Types of lightning – light sources, Types of reflection, Shading techniques, Hidden surfaces techniques, Camera placement
12. Graphic formats: Configuration of the image file, Image compression, Color reduction methods, Most used graphic formats.

Computer graphics exercises are divided into two parts and are representing two seven week courses, in which students are taught how to work in programs CorelDraw and Indesign.
Animation exercises include working in 3D Max and last for 14 weeks.
SVGs are a part of the theoretical topic *File formats and Format conversion tools.* In addition, students learn how to export their final illustrations and animations to SVG formats in all of the aforementioned graphic programs.
As a result of all these efforts, our graduated students use SVG graphics and animations when they create their web sites. In addition, they are able to scale those graphics using CSS3 media queries in order to fit screens of various devices. Also, they use CSS to animate them. Below we can see an animation given on the homepage of a website created for the purpose of a student's final work, **Error! Reference source not found.**. The animation consists of SVG graphics and an appropriately created CSS animation. It lasts 1 second and it repeats itself back and forth infinite number of times. With keyframes we ordered that element will scroll from initial size to size that is 1.3 times bigger than initial, Fig 3. The image used for the animation was created in a graphic program and exported to SVG. The obtained code can is given in Fig. 9. At Fig. 10 we can see the CSS 3 code of the animation.

Figure 8. Animation football sneaker

```
<section class="svg_element">
		<svg width="410px" height="270px" viewBox="0 0 480.043 480.043">
				<path d="M432.7,341.222c-4-0.1-8-0.1-12.4-0.1c-6.5,0-12.199,0.1-17.8,0.4l5.7,31.299c0.2,1.301,1.4,2.201,2.7,2.201h27.7   c1.3,0,2.399-0.9,2.699-2.201l6.5-31.6c-1.699,0-3.3,0-5,0C439.601,341.321,436.3,341.321,432.7,341.222z" fill="#fff"/>
				<path d="M334.3,373.321c0.2,1.301,1.4,2.201,2.7,2.201h27.7c1.3,0,2.4-0.9,2.7-2.201l6.2-30.6c-12.301,0.5-27.601,1-44.5,1.5   L334.3,373.321z" fill="#fff"/>
				<path d="M119.4,377.622c0.2,1.3,1.4,2.199,2.7,2.199h27.7c1.3,0,2.4-0.899,2.7-2.199l5.8-28.5c-17.5,0.4-32.6,0.699-43.9,0.9   L119.4,377.622z" fill="#fff"/>
				<path d="M49.8,343.722l6.2,33.9c0.2,1.3,1.4,2.199,2.7,2.199h27.7c1.3,0,2.4-0.899,2.7-2.199l5.7-27.7   c-14.8-0.7-30.2-3.601-44.4-8.3C49.9,342.321,49.7,343.022,49.8,343.722z" fill="#fff"/>
				<path d="M437.7,145.422c-10.7,0-9.7,32.4-32.5,40.7c-11,4-21.6,5.6-30.9,5.6c-16.6,0-29.3-4.9-34-9.5   c-7.399-7.2,59.801-29.9,45.4-49.4l-22-29.5c-1.5-2-3.8-3.1-6.1-3.1c-1.5,0-3,0.5-4.4,1.5l-73.8,54.2c0,0-28.2,0-33.1,16.5   c0,0-0.801-0.1-2.201-0.1c-6.1,0-22.699,1.3-27.199,15.2c0,0-69.9,13.8-111.6,36.2c-41.6,22.301-105.3,21-105.3,56.5   s56.4,59.2,101.1,59.2c44.7,0,269-6.8,300.4-8.601c6.7-0.399,13-0.5,18.9-0.5c8.399,0,15.899,0.201,22.5,0.201   c23.8,0,36.1-3,36.5-30.301c0.6-40.199,5.5-102.4-25.101-141.3C446.4,149.222,441.3,145.422,437.7,145.422z M292.2,302.222h-37   c-0.7,0-1.3-0.3-1.8-0.699l-80.3-73.5c-1.6-1.5-0.9-4.1,1.1-4.6l28-7.5c0.9-0.2,1.9,0,2.5,0.6l89.399,81   C295.9,299.122,294.7,302.222,292.2,302.222z M366.9,302.122l-39-0.5c-0.7,0-1.3-0.301-1.8-0.7l-99.601-90.3   c-1.6-1.5-1-4.1,1.1-4.7l27.9-7.5c0.9-0.2,1.801,0,2.5,0.6l110.8,98.299C370.601,299.022,369.4,302.122,366.9,302.122z" fill="#9c3901"/>
		</svg>
</section>
```

Figure 9. HTML 5 code of the SVG

main .svg_element {
margin: auto;
margin-top: 8%;
margin-bottom: 11%;
width: 22%;
animation-name: anim1;
animation-duration: 1s;
animation-iteration-count: infinite;
animation-direction: alternate;
}
	@keyframes anim1 {
	from { transform: scale(1) }
	to { transform: scale(1.3) }
	}

Figure 10. CSS 3 code of the animation

CONCLUSION

Responsive web design and search engine optimization are an important part of web development, so it is an imperative for any undergraduate study program in this area to include subjects dealing with these topics. Since SVG graphics plays an important role in responsive design and SEO, it is clear that topics on SVGs have to be included in the curriculum, too. Herein, we have presented a good practice on teaching topics concerning SVGs in the Higher Technical Education School in Novi Sad on study programs in the field of IT.

The aim of our institution is to accredit a master study program in the field of IT. One or two subjects would be devoted on web game modeling and development. The knowledge of SVG graphics would be significant for those subjects.

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AN EXAMPLE OF IMPLEMENTATION CRM IN THE BANKING SECTOR

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Abstract: In this work, we have presented basic characteristics, goals, strategies, elements and an example of a CRM (Customer Relationship Management) application in banking sector. Many businesses such as banking industry realize the importance of CRM and its potential to help them acquire new customers retain existing ones and maximize their lifetime value. CRM is a business strategy designed to reduce costs and increase profitability by increasing client loyalty. This paper provides an example of a implemented CRM application for banking industry. The CRM process includes creating a data base with the data necessary for interaction between a bank and a client. Also, CRM application has been implemented for the purpose of the paper. In this work we presented the advantages and disadvantages of the CRM application as well as the possible solutions of existing problems in this field of study.
Key Words: CRM, application, banking systems.

INTRODUCTION

CRM (Customer Relationship Management) is a strategy for business systems that have prioritized retention of the existing large customer base due to the strong development of products or services on the market and strong competition. There are many CRM definitions in the author's works [4], [7], [13], [19]. CRM is a broader business strategy designed to reduce costs and increase profitability by increasing customer loyalty [14], [15], [25]. CRM represents an advanced framework that combines customer satisfaction management, marketing strategy and IT in the banking industry [2], [5], [9], [10]. CRM collects information from all sources within the banking sector to provide a unique image and satisfaction of each client in real time [10]. CRM proved successful in practice in more research [6], [21], [25]. CRM applications are widely used in various areas, of which the banking sector particularly stands out [1], [22], [23]. Loyalty and acquisition of new customers can be improved by using data mining techniques in CRM applications. Data mining techniques are used for dynamic, real-time monitoring and forecasting of client behavior and the timely adoption of the decisions [8], [12], [18]. The reasons for the introduction CRM by the authors [2], [16] are: IT development, current users of services require a personalized relationship with the bank, it is more cost-effective to keep an existing customer with additional services than to invest in gaining new, improved availability of information, integration of communication channels in and outside the bank reducing hierarchical business.
In practice, there are four problems that can arise in the application of CRM [24]. The first problem is that building and maintaining a customer database requires large investments in computer hardware, database, software, in analytical programs, in communications, and well-trained employees are needed. It is difficult to collect the good data, and in particular take advantage of all the opportunities for interacting the banking sector with individual customers. Another problem is the difficulty that everyone in the banking sector is customer-oriented and use the available information. It is much easier for employees to stick to traditional marketing transactions than to apply marketing relationships with customers. Effective marketing on databases requires employee guidance and training. The next problem is that all customers do

not want to establish a relationship with the banking system, and many customers do not like to find out that the banking system has collected information about them. This is especially true for banks because clients are still skeptical and have no confidence in the banking sector. Marketers need to take into account the customer's views regarding privacy and security. According to research by authors [3], [11], [17], [20], the advantages of introducing CRM are: understanding the value of a particular client in the entire life cycle, consistently structured and complete customer data, recognition of the client as an individual, integral processing of clients through all communication channels, greater emphasis on keeping clients by programs of increasing loyalty, planning of product cross-marketing strategy, measuring the effects of marketing actions and sales activities, optimization, automation and supervision of marketing, sales and service processes and rationalization business by saving time and money.
A well-designed CRM has the following characteristics in accordance with research by the author [16], [24]: customer-based services, direct contact with the user at any time from anywhere, user services to solve client problems; functions that include automation of sales promotion, automated monitoring of client activities and coordination of sales activities, marketing, call centers and suppliers; IT tracing and customer acquisition skills, currently obtaining customer data, and applying data warehousing to aggregate transactional data and linking to CRM applications; the flexibility of managing unpredictable movements and requirements for good forecasting models that integrate past sales data with sales plans. The introduction of CRM requires the involvement of all employees within the banking sector, as well as the reengineering of all existing business processes with the aim of adapting to the CRM concept [2], [14], [15].

MATERIAL AND METHODS

An example of a CRM application in the banking sector

Due to the different areas covered by the application of CRM applications, the first step towards its successful impetement is the creation of a strategic CRM plan that clearly and unambiguously needs to achieve the goals of the banking system. Modern banking has imposed a need for continuous improvement of relations with the client, quick response to its needs and requirements. Dynamic development of IT leads to new forms of communication with the client, as well as the way of its understanding and understanding of its needs and behavior. The expected benefits of implementing the CRM application in the banking sector are: increasing sales, retaining profitable users, acquiring new users, improving customer satisfaction, customer loyalty, improving customer service quality, lowering operating costs, increasing overall profitability and profitability per user, increasing cross sales and up selling the index, increasing the number of products per user, and so on.

CRM application database

The Data warehouse is the core of any decision support system of the CRM process. The data is imported into the database from the internal and external data sources. In the paper, the database represents an operational data source, as shown in Fig. 1. This database has a star scheme form, which is also the simplest form of a database. Fig. 1 shows four tables, where the Fact table is transactional and primary (with identification fields Date, Store, Product, Units_Sold), while the other three tables are multi-dimensional and are associated with a transit central table. Other tables are Date (fields Id, Date, Day, DayofWeek, Month, MonthName, Quarter, QuarterName, Year), Store (with fields Id, StoreNumber, StateProvince, Country) and Product (Id, EANCode, ProductName, Brand, ProductCategory).

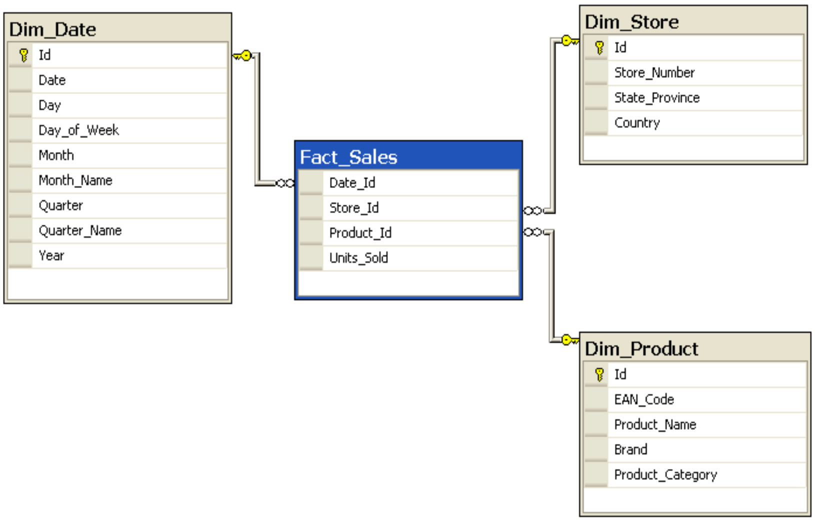

Figure 1. CRM application database

One Fact table, along with associated dimension tables, is a subject area. Within the CRM application, five subject areas have been defined. They are formed by groups of products that can be identified in the banking sector: current accounts, loans, deposits, payment cards and others (services, e-banking, overdraft, product and service offers, etc.). Selecting the appropriate clients in the target groups is done by creating queries according to the following criteria: consumer demographic attributes, consumer transactions completed, data-relativ filters, event triggers. The list of filters for client selection are shown in Fig.2.

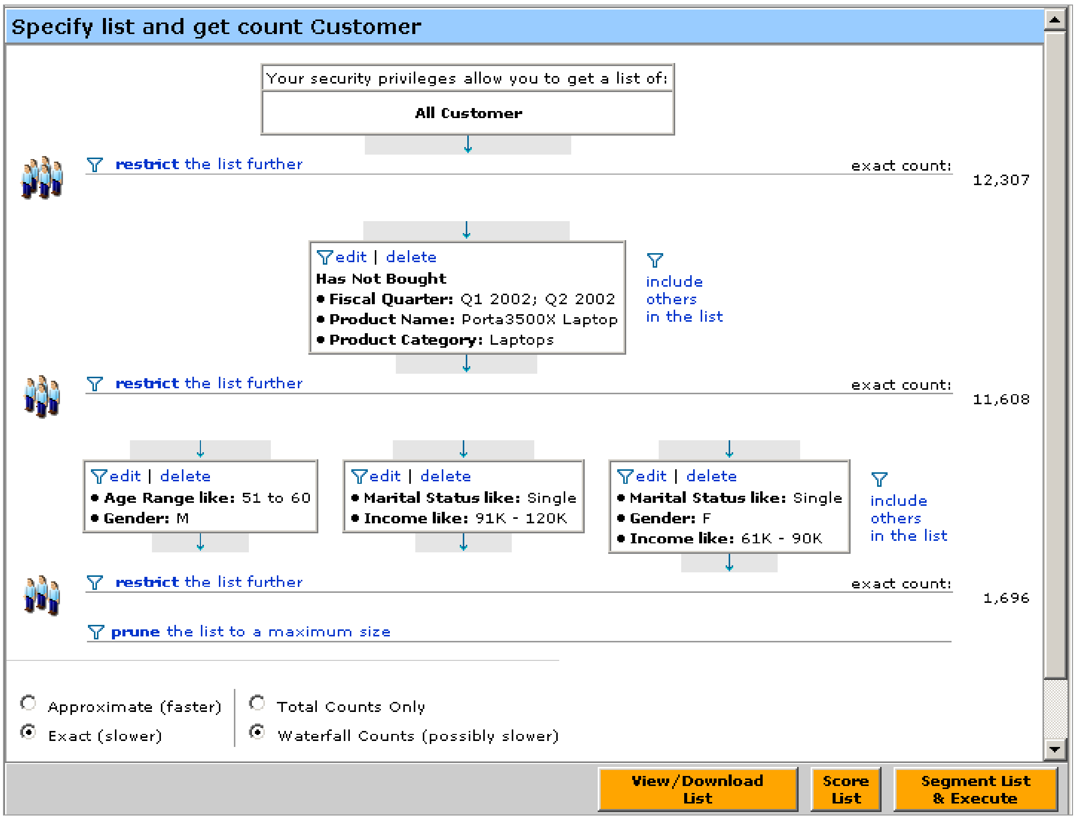

Figure 2. The list of filters for client selection

CRM application capabilities and chances sections

The current client/potential client can self-interest for a product via one of the communication channels (branches, call center, customer service). The channel through which the contact is created manually creates the section Possibility. The possibilities can be created by: sales persons, branch managers, agents and supervisors, as well as employees in the customer care department. If the bank implements a campaign, each client from the target group will also be shown in the CRM scquisition section. Section option is automatically created for clients who have been selected for a specific banking campaign. The overview of client options section is shown in Fig.3. The Chances section implies greater likelihood that a customer will buy a product or service. This section can be created by: improving the existing possibilities in the chance, by independently creating the chance if a client/potential client is inquiring about some of the products of the bank and showing a higher level of interest that will sound the sales person as a chance to sell, a higher level of interest of the client/the potential client for the offer of the bank estimates the sales person, only the sales person and the manager of the branch can create a chance. The overview of client chances section is shown in Fig.4.

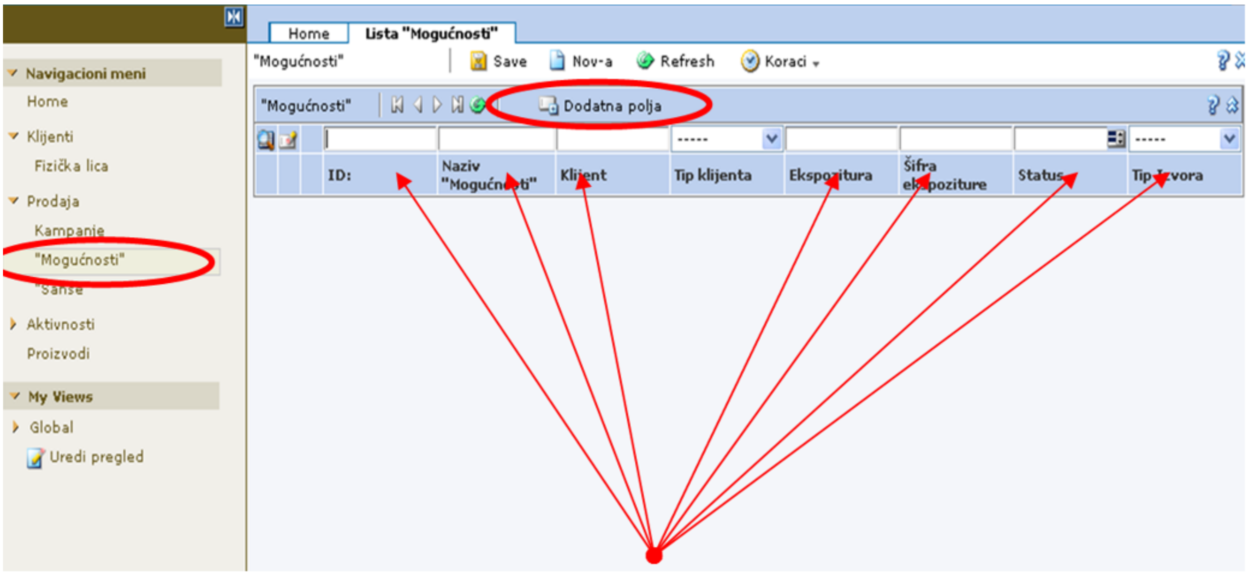

Figure 3. The review of client options section in the CRM application

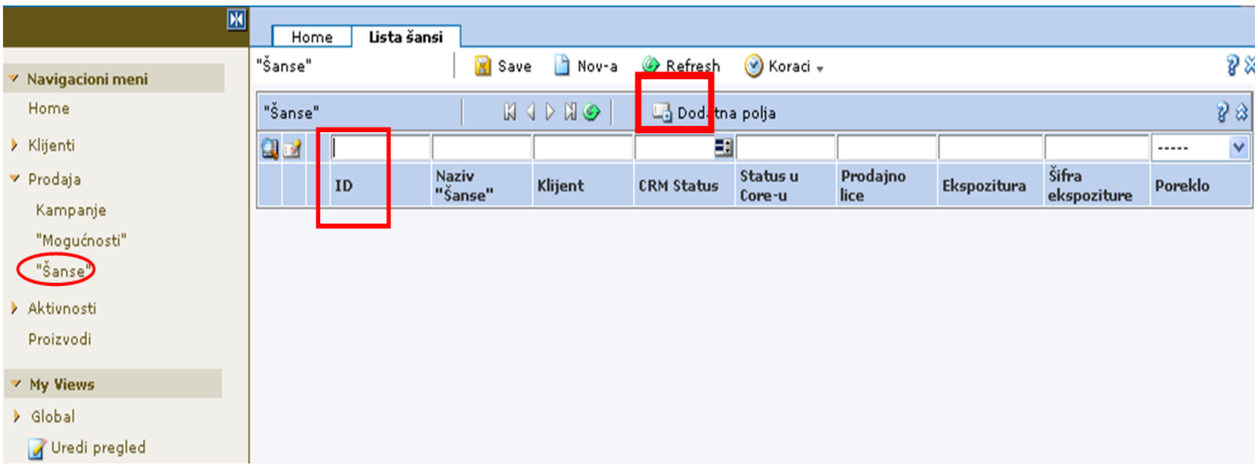

Figure 4. The review of client chances section in the CRM application

RESULTS AND DISCUSSION

Realization of CRM application in the banking sector leads to the adjustment of business strategies, organizational structure and culture in banking sector, information on users and IT with the goal of meeting their needs in all contact with clients and achieving optimal financial results. CRM creates business practices and processes that increase business success, identifies value parameters, and offers tools for developing a business culture geared towards providing maximum value to customers with minimal costs for the bank. The basis of each CRM solution offered to the bank is a unique view of the client. This means that all customer information is in one place and their collection and upgrading is done in a unique, organized way. For the successful introduction of the CRM system, a vision is needed that will cover the entire business of the bank and must begin at the highest organizational level. CRM strategy determines how the bank builds profitable relationships with its clients and acquires their trust. The goals of the CRM strategy must be measurable and standardized according to the CRM criteria, with an emphasis on meeting customer needs, thus providing satisfied and faithful bank clients.

CONCLUSION

Created CRM application and good business process and strategy provide that the data can be fully utilized, precise, organized and updated in real time. CRM applications can help predict customer behavior. The use of CRM applications in the banking sector implies employee training. The challenge for future research can be how to measure the profit generated by applying CRM applications in banking system. In order to maintain itself in a competitive market, the bank must constantly and in real time update information on clients needs, desire and affinities.

Acknowledgments

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ENTREPRENEURSHIP AND ENTREPRENEURIAL PROFILES

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Abstract: The theories on enterprise and entrepreneurship define the enterprise and entrepreneurship as immanent phenomena, as two inseparable entities of one body. In that, entrepreneurship implies the directing of resources in the area of their optimal use, while entrepreneur implies the person who acts, who gives concrete forms to jobs, who anticipates risk, create new forms of jobs, expands employment, and enables better and more efficient organization of enterprises capable of meeting all the challenges put in front of it. The role of entrepreneurship is universal. It includes almost all aspects of human life. Every society uses entrepreneurs' experience in management, support and success encouragement, resource activation, motivation and risk awarding, business efficiency, stability and growth, taking responsibility and business risk. Entrepreneurs see their chances where others see confusion and chaos. Key players enabling such changes are free entrepreneurs, young entrepreneurial managers, persistent innovators, and creators of a new business world.
Key words: entrepreneurship, entrepreneur, profiles of entrepreneurs

INTRODUCTION

Many people search for activities that will make them financially independent. The reasons for creating one's own business are numerous. Such reasons depend on personalities. Not everyone is capable of running a business or grasps what is necessary to run a certain project. This suggests that there is a great number of those who may become entrepreneurs, who have entrepreneurial characteristics and who could express their potential in an effective way. Entrepreneurship has been in focus during the previous years, due to the significant benefits realized by small and medium-sized enterprises in the overall development of national economies of developed countries. Entrepreneurship is a multidimensional phenomenon which is involved in many disciplines. The entrepreneurship theories come from various schools, with different opinions, and many authors identify various different factors that lead to entrepreneurial ventures[7].

The key word that circulates around the economy development in numerous countries is education. The emphasis of entrepreneurship and entrepreneurial education is on starting a business and the growth of entrepreneurial activities, and especially on the occurrence of business problems. Enabling the young through the education, i.e. the introduction of entrepreneurship in the curricula within the present educational system-starting from the lowest educational level-creates more possibilities for a continuous increase in awareness and expands the horizons to future entrepreneurs.

Over recent decades, the change of economic structure on the global level has been characterized by a redistribution of those employed in the economic sector, where an overflow of labour force from the primary and secondary sector to the tertiary sector has occurred. The valorisation of real (hidden) potentials and productive employment have been greatly conditioned by the affirmation of entrepreneurial behaviour, starting from family, small and medium-sized enterprises and progressing to a higher (aggregate) level. A multitude of factors affect the processes of intensifying the development of entrepreneurship (including, among others, market, financial, urban, communal, legal, and human factors), which are the ambience in which the entrepreneurship is affirmed as an efficient way of running and developing a business, and also the improvement of quality of life and work in certain environments[10].

Small and medium-sized enterprises are one of the key sectors of the economy development in European countries. They are significant initiators of innovations, employment and social and local integration in Europe. In the European Union, there are about 23 million micro-, small- and medium-sized enterprises, comprising 99% of all registered business subjects. The enterprises employ close to 75-million people and constitute the basis of the economic growth strategy[8,9].

The business of small- and medium-sized enterprises, i.e. the entrepreneurs, is burdened by numerous problems, but vary based on the phase of life cycle of an enterprise. At the start of the business,

entrepreneurs are often adequately not prepared to launch their business and do not perceive all problems they will encounter. On the other hand, there is an evident lack of readiness of banks to finance the “start-up” activities of future entrepreneurs. In the phase of growth and development, small enterprises are burdened with other additional problems. As the first, management is burdened by achieving efficiencies to overcome a lack of information about the possibilities of growth and development, as well the challenges of market recognition and evaluations of their business’ chances and risks. As the second, the transition from the entrepreneurial to the management phase of an enterprise causes a crisis in the form of lack of management skills, which is manifested in the lack of, or inadequate, business plans, intuitive models of business decisions making, inadequate controlling methods, lack of education, or criteria and plans, in general. As the third, even successful small enterprises face a crisis due to the needs of further growth, and that requires greater technical and administrative knowledge related to export business, international marketing and financial operations, professional knowledge on modern production and quality systems. As the fourth, with the growth of an enterprise and the increase of the technical-technological level of the business, there occurs a lack of professional labour force, modern production equipment, adequate business premises/objects and/or a suitable location. As the fifth, they must meet the challenge of financing growth through self-financing, credits for working capital and long-term investments, often with unfavourable conditions from perspectives of interest rates and mortgages.
The process of quick technological changes, which characterizes the modern economy, is mostly the result of new entrepreneurial ideas[12]. Because of that, entrepreneurship becomes an opportunity for the countries in transition, because entrepreneurs can contribute to a greater degree of utilization of available resources and faster economic growth, by which it is possible to gain parity with developed countries[6]. As was shown by [5], young entrepreneurs are confrinted by limitations to a greater extent, above all as regards access to finances and the creditability of the young, and at the same time such limitations decrease the chances for the young people to build their own business by themselves.
The development of small- and medium-sized enterprises is not realized only through the entrepreneurial practice and economic policy measures, but through system efforts to achieve direct, structural changes in the sphere of education. On the basis of the research up to now[3], an increasing number of young people will link their professional development with the sector of small and medium-sized enterprises in the future. Many learned lessons and experiences[4], extracted from successful projects, confirm that entrepreneurs should have the following potentials and abilities: a sharp perspicacity for new market chances and consumers’ needs; general and personal management skills, good communication with potential investors/financers, partners, employees; analytical dexterity, enthusiasm, self-confidence and innovativeness.

DEFINING ENTREPRENEURSHIP

In theory and practice, we often meet with the dilemma of making distinctions between the functions of an entrepreneur and a manager. The difference exists, certainly, but the distinctions depends on the amount of entrepreneurship actually used in particular enterprises, i.e. on the way that an enterprise is run. In every case, it is impossible to imagine the business of an enterprise outside the normal chain (ownership-market-entrepreneurship-management). So, it is impossible to imagine the function of a manager without entrepreneurship, and, at the same time, it is impossible to imagine an entrepreneur who does not use at least some of managerial methods.
The history of entrepreneurship dates back to the Middle Ages, and entrepreneurship came into full bloom with the development of capitalism, which unites the preferences for personal wealth and the wish for profit maximization.
Over time, entrepreneurship and entrepreneurial activities attained a professional and civilized character. The notions of entrepreneur and entrepreneurship were used for the first time by Richard Cantillon, an English economist at the end of the 17th and the beginning of the 18th century, and, until today, an entrepreneur is considered to be an initiator and organizer of jobs, an innovator, a vigorous business man who operates under conditions of, at least, moderate risk and under its own property liability. From this statement, it can be concluded what is the strength of the entrepreneurship spirit and why that spirit is what forms the heart of the spirit of a market and the economic system in

general. Zombart thought that the spirit, form-order and substance were the three key formative elements of every economic system.
Entrepreneurship is often defined even more broadly[5], and it is related to the type of behaviour, and not only the running of a business, or self-employment. For example, the International Labour Organisation (ILO) defines entrepreneurship as the way of thinking and reasoning. That is much more than the bare running of a business. That is a process in which individuals become aware of the options for self-employment and career building, development of ideas, taking and management of risks, learning the process of taking initiative in the development and owning of a business[11].
The theorists in the area of entrepreneurship are obsessed with defining the word "entrepreneur." Their priorities are maybe backwards. The entrepreneurship theory, as stated by[1], can solve the problem with a definition, and it becomes irrelevant.
Thus, for example, a famous theorist[2] pointed out the nine primary factors of entrepreneurship. Due to the fact that all the notions (in English) start with "f", the concept has been known in literature as the 9F concept of successful entrepreneurship:

- Founders: significance of first-class founders, wise and respected;
- Focused: directing towards selected market segments (so called niches);
- Fast: fast decision making and fast application of the decisions;
- Flexible: fast adaptation to change;
- Forever-innovating: permanent quest for the new;
- Flat: permanent struggle to decrease all costs;
- Friendship: to be a friend with all stakeholders;
- Fun: it is fun to cooperate with an entrepreneurial enterprise.

It is clearly understandable that it is not easy to provide all the named factors simultaneously, as the assumptions of successful entrepreneurship, but it is undoubtedly necessary to strive to create a greater number of them, thus providing successful conditions for a good start of a business venture. Although it has been believed that a good start is what the entire entrepreneurial process depends on, a weak start will not disturb a true entrepreneur and make him/her quit. On the contrary, there is a not so small number of those, who draw additional inspiration and new energy, so that they persist and end up as winners. So, for a success, a synergy of the personal characteristics of the entrepreneur and businessenvironmental conditions is necessary.
Although it is not disputable that, for the manifestation of entrepreneurial behaviour, besides the personal features of an entrepreneur, being an individual and the holder of personality, it is extremely important that there are adequate socioeconomic, legal and cultural ambients in which personal features of potential entrepreneurs can be realized and developed. At first, it is necessary to check if and to what extent there are participants who have psychological and other potentials to become entrepreneurs in the given environment. The characteristics of potential entrepreneurs are the following ones[8,9]:

1. Taking the risk. An entrepreneur is a person who takes risks, i.e. someone who deals with a new business run outside pre-existing organizations.
2. Independence. An entrepreneur is an independent person who does not like to work for others, but who rather works on his/her own.
3. Internal centre of control. Those who believe that they themselves have a great influence on what happens to them are denoted as people who have an internal centre of control.
4. Live though excitement. Although some people strive for a calm life, some other are oriented towards excitement and action. Entrepreneurs fit into the second category, because they like the excitement brought by the new and different.
5. Self-initiative. Entrepreneurs start things when they decide to do so, using their own ideas and energy as the rationale.
6. Self-confidence. Entrepreneurs have great self-confidence, i.e. significant belief that the new product, service, idea or approach they propose brings benefits. This self-confidence is necessary because others often do not support their new ideas.
7. Adaptability. Entrepreneurs are adaptable. Markets and systems change. Business must change together with them.
8. Pertinacity. Entrepreneurs are pertinacious. They are the people who do not quit in spite of obstacles.

9. Ambiguity. Entrepreneurs must tolerate the dilemma of choice placed in front of them. For some persons, some situations are difficult to be resolve, dangerous and psychologically problematic. That is not the case when an entrepreneur is in question, because the uncertainty affects them less, so they are even able to use it.
10. Identification patterns. Entrepreneurs are capable of solving disputes by using identification patterns. They are able to see how everything fits together, perceiving in one glance the entire "wood," while others choose to fight with "trees".
11. Little need for assistance. This is closely related to self-confidence. Entrepreneurs are more than self-confident. They feel little need for assistance from other people.
12. "The right thing". The phrase presumes a psychological perspective in entrepreneurship. It is necessary to possess certain features, i.e. the characteristics of someone who wants to be an entrepreneur.

Which of these characteristics-they can also be called the entrepreneurial values-will be accepted, rejected or ignored in the environment in which an entrepreneur operates, depends on numerous circumstances, and above all on accepted social norms, as well as on economic, political, and, increasingly, on international conditions. Politically and economically stable societies are more tolerant towards the stated values, because they are widely accepted and make up a part of the social and entrepreneurial climate, culture and moral.

Besides the analysed personality characteristics of an entrepreneur and the structure of knowledge he/she must possess, it is necessary to say something on the specific skills he/she needs to perform such a complex and multi-layered activity as entrepreneurship.

Above all, it is necessary to remember that his/her entire work is reduced to the realization of an idea to achieve a positive result and that is always together with other people, never alone. An entrepreneur needs skills so that he/she converts the ideas into reality. The conversion of ideas into reality requires two types of skills from an entrepreneur: management ability in the purpose of organizing physical and financial resources and human resources management skills because of the necessary support of others. Every entrepreneur, regardless of his/her abilities and education, has to rely on associates, and that is why teamwork skills and abilities are so essential for him/her. It is also very important that an entrepreneur possesses the following skills[8,9]:

- strategic ability, i.e. the ability to perceive a job as a whole, holistically, but also the ability to look ahead, prospectively;
- ability to plan as an initial step every action and ad a basis of perceiving the future, but also the ability to predict the future;
- marketing ability, by which the needs, demands and interests of clients as the key stakeholders are perceived, because of which, generally, an entrepreneurial venture has been initiated;
- financial abilities, because the management of money as working capital is the condition that ensures the continuity of a business and the flow of money, and the ability to evaluate the required investments and accompanying risks;
- ability for project management, which implies project organization and providing project resources at the right time and at the right place;
- ability for time management, since time is a resource that cannot be refunded, implying a strict hierarchy of priorities in performing the tasks.

Besides the named abilities and skills of an entrepreneur, it is useful to indicate the necessity of possessing the abilities which qualify him/her as a successful communicator within an enterprise's environment. Above all, in this regard, we think of [8,9]:

- management skills, needed to stimulate the people to work and perform the tasks important for the success of an entrepreneurial venture, their directing, support and assistance in realization of the tasks, organization of work processes, selection of staff and rational use of their abilities, administration and control of all work processes and achieved business results;
- motivation ability, by which the commitment to an entrepreneurial idea, jobs and tasks in its realization are achieved; it is also important that an entrepreneur equally motivates himself/herself, and also the people he administers in the business process;

- ability for the distribution or assignment of jobs and tasks, assuming knowledge about the abilities the people possess and the means of their engagement and of greater development of their abilities for a more efficient execution of jobs;
- communication abilities, i.e. the need for oral and spoken expression of ideas and informing of people about them with the aim to affect the actions of people by means of information and communication;
- negotiation abilities are not bargaining abilities, but the creation of a situation of general understanding and recognition of possible outcome for all the sides in a negotiation process;
- operational ability, as a response to the changes in a dynamic organization system and as a condition for a successful and efficient business by taking adequate measures and actions;
- creativity, as the ability for logical thinking and inference, which produces the ideas and practical solution to problems by successful use of markets, technical aspects, staff, scientific details, other information and other potentials;
- ability for critical observation of statuses and relationships because nothing should be taken "for granted," but every bit of business information and phenomenon must be critically discussed, its positive and negative effects perceived, and only after that satisfactory decisions should be made:
- analytical ability enables a complex organizational system, composed of numerous elements and subsystems, to be perceived, arranged and functionally harmonised with numerous internal and external factors by entrepreneurs.

ENTREPRENEURIAL PROFILES

The current globalization process convinces use every day that the so-called global entrepreneurial revolution is in progress in which the main participants become the economies of China and India (not so significant until recently), and of many other Asian countries, as well as of Russia and Brazil. The abundant talent for creation of almost incredible business ideas, a flood of the most diverse production and service programs and projects, unbeatable talent for innovation, and especially for imitation, great inner markets and aggressive orientation towards exports are all sufficient reason to reassess the up-to-now trajectories of entrepreneurship based on the Western paradigm of selfish individualism and quick enrichment. In the context of such global transition processes, the profile of an entrepreneur as a key agent of change, who confronts great challenges, should be redefined, i.e. redesigned. At the beginning of the 1970s, the so called third technological (microelectronic) revolution started in the West, which really rocked the world of labour thoroughly, especially that of industrial production, and it contributed to sophistication and systematization of many spheres of human life. In the 1990s, completely new opportunities, the so-called e-business and net entrepreneurship, were launched along with revolutionary breakthroughs in trade, banking, the stock-exchange business etc. But, relatively quickly, the fast-growing business (dot.com) experienced a deadlock, and, at the turn to this century, even a collapse, with dramatic consequences. It is recovering at the moment and will probably gain new strength, but a logical question occurs on the real perspectives of new businesses, their reach, limits and likely prospects. In that light, new roles, tasks and, especially, the profile of modern and future entrepreneurs are being studied. Essentially, the roles and tasks of entrepreneurs will remain more-or-less the same, including the fact that the way to realization of the roles and tasks will experience many changes. It is apparent even now that the main change is reflected in the change of the entrepreneurs' focus from financial, material, and, especially, technical-technological resources, to human and intellectual resources as the key components of every entrepreneurial process. Some important characteristics of a modern entrepreneur then are[8,9]:

- ❖ A modern entrepreneur is not a rigid boss, slave driver who is awe-inspiring, but is also a leader and trainer who commands respect, because he/she knows how and wants to encourage, motivate and develop the creative energy of the members of his/her team in the realization of common goals.
- ❖ A modern entrepreneur is dominantly oriented towards the stimulation of creativity and innovativeness. He/she does not wait for changes to react, but generates or at least anticipates

them, i.e. predicts and prepares himself/herself for upcoming changes. He/she is not afraid of change, because they are seen as a challenge and a chance for new success.

- A modern entrepreneur raises the morale and works on the improvement of business ethics in his/her environment. He/she is aware of the long-term importance of a business' reputation, and business ethics can contribute to that in many ways.
- Because of the strengthening of his/her own abilities, as well as the abilities of the associates, a modern entrepreneur becomes aware of the importance of constant renewal of knowledge and skills necessary for following, predicting and generating changes.
- The ability for effective communication becomes an imperative for success for modern entrepreneurs. This fact must be recognised in all educational curricula for entrepreneurship, and, above all, in business schools.
- A modern entrepreneur is greatly oriented towards the global business stage. Because of that, he/she must be familiar with international relations, relations among countries and people, various cultures and economies and must be capable of developing the goals and strategies of his/her enterprise in the wider context of international business and fiercer competition.
- Modern entrepreneurship becomes more and more based on high technology, especially information technology. Due to that, a modern entrepreneur has to know the key trends (megatrends) of production and control technologies and to take them into account as the key factors for gaining a competitive advantage.
- Modern entrepreneurship is based on legally regulation and the procedures that are internationally standardised and harmonised to a great extent. Because of that, a modern entrepreneur must know the logic of complexity in the field of legislation and respect the legality of competent local and international institutions and accepted conventions, treaties, agreements etc.

In brief, modern entrepreneurs are a personification of numerous human qualities and features, and because of that they can be classified into these three groups[8,9]:

- Entrepreneurs–technicians, when there is a wish to point out their emphasized technical orientation, which, above all, considers them as innovators in the creation of new products or processes. In that, they see the creation of organization as the instrument for realization of their defined goals, and not as the final goal.
- Entrepreneurs–creators of organisation, to whom the creation of organisation is the most important goal, as a opposed to entrepreneurs–technicians. The most important thing for them is to realize the development of organisation by means of the growth and development of business, which is measured by the increase of profit and the number of employees. They are aware that it is possible, through good cooperation with people, by organising them into teams within which they exert their influence and power.
- Entrepreneurs–job constructors, who are the "cause" of the processes of contracting, negotiating and making new arrangements, because they like initiating jobs. They do not tolerate a total dedication to one organisation over a long period of time and are always ready to start a new entrepreneurial venture because they enjoy the creation of a new business and always have a "backup option."

Although the territory of the Balkans is incorporated into the processes of European integration and global processes, there are still numerous specificities of doing business there, especially in so-called transitional countries. Such specificities are reflected, above all, in the long-term isolation and enslavement of some nations, in the major influence of tradition, in the mixture of cultures, religions (exchanges, of Eastern and Western Christianity and Islam), etc. They have a manifold origin and are not only resident, but are also formed in modern conditions that are marked by numerous crossed interests of a wide circle of (international) participants at the "geostrategic route" of Europe and which, in most cases, to not have legitimacy (justification) for their actions. Having all that in mind, it is also possible to speak about a specific type of a so-called Balkan entrepreneur. However, in doing that, the significant differences between particular Balkan countries and societies must be taken into account, because some of them have always been capitalistic, while others are in the process of transition to capitalism, and some are formally integrated into European integrations, so that it gets more and more difficult to talk about a unique profile, although the differences in relation to the Western European profile are still very visible. It also have to be pointed out that there are many entrepreneurs who, in their features and behaviour, do not differ in any way from the best European entrepreneurs and managers. Unfortunately, they are still not a majority. In brief, we can state a few important flaws of Balkan entrepreneurs, which should be removed as soon as possible[8,9]:

1. The lack of vision and clear perspective on what to do in a turbulent business environment;
2. Wrong or completely neglected following of the flow of money in most enterprises;
3. Insufficient knowledge and understanding of the structure of costs;
4. Nonexistence of the practice of making business plans for an enterprise;
5. Underdevelopment of a marketing approach to entrepreneurship;
6. There are no traditions, skills and techniques for rapidly making important decisions;
7. There is very strong distrust towards all forms of business cooperation, especially with foreigners;
8. Ethical standards of entrepreneurship and personal fairness are not on such a high level;
9. The age structure of entrepreneurs is unfavourable, i.e. there are very few young entrepreneurs in the Balkans in ages up to 30; most of them are up to 50 or older;
10. Mental inertness and aversion to further education;
11. Persistent orientation to waiting for external help (there is a strong inclination by some Balkan entrepreneurs towards waiting for someone (i.e. the state or an international organization, e.g. the European Union funds, to determine finally “our development priorities”, with every entrepreneur hoping that exactly his/her enterprise will be included in the priorities, which would solve all problems automatically);
12. The lack of understanding and slow acceptance of the ecological criteria of business.

CONCLUSION

The definition of entrepreneurship has evolved over time. The earlier understanding of entrepreneurship is not similar to the current one and will acquire yet other attributes in the future. Basically, there is a consensus in some aspects of definition, such as: creativity, innovativeness, independence, and affinity for risk. Entrepreneurship does not come to the fore outside a market ambience. Entrepreneurship and its creative components are related for the idea of market verification, i.e. the commercialization of a result in the market. The main characteristic of entrepreneurship is the creation of something new in a production or service program, depending on influences from the environment.

The characteristics and profiles of entrepreneurs presented in the paper do not characterize, to the same degree, all those who consider themselves entrepreneurs. These characteristics comprise what could be called the typical entrepreneurial profile. Due to the fact that every person has her/his own special personal features, they make an entrepreneur unique. Of course, the number of features varies and is more expressed in some entrepreneurs then in some other.

If the entrepreneurial profile of a person is similar to the profile of entrepreneurs, in general, these persons can be expected to exhibit entrepreneurial behaviour and to be more strongly motived to start their own businesses. If certain conditions and events are favourable, the individuals with adequate entrepreneurial characteristics apply their resources and compensate for their weakness to exploit a sufficiently favourable situation. None of the discussed characteristics and profiles of entrepreneurs gives an integral interpretation of the key factors for success of an entrepreneur, but they integrally enable the understanding and explanation of the reasons for success of entrepreneurial enterprises and, of course, entrepreneurs as owners of such enterprises. Success is the result of the personal characteristics of an entrepreneur and the ability to learn from experience and to adapt to influences from the environment. The personal characteristics of an entrepreneur are the most important in the start-up stage of a new business. The ability to learn from experience becomes more important after the running of an enterprise, and the growth and development of the enterprise depend on the gained experience, knowledge and ability to adapt to influences from the environment. Entrepreneurial intentions depend on the way in which an entrepreneur experiences the feasibility of the imagined idea and his/her affinity for action. The spark to action often depends on the availability of resources. Before starting a business, an entrepreneur usually has a form of a business plan. That is the entrepreneur’s personal concept, vision and expectation about the way in which the business activity will develop. From that point of view, a business plan is desirable and relevant. An entrepreneur may

plan only the project, i.e. to design a business plan, but he/she usually depends on some assistance in the form of training, advice or consulting. His/her decision to take action in a certain moment may depend on whether he/she feels relevant and efficient.
The future of entrepreneurship is promising. The support to entrepreneurship, i.e. to entrepreneurs, is growing. There is even a global process that unifies, to a certain degree, the relationship of the state to entrepreneurship and the development of small- and medium-sized enterprises pursuant to that. It is apparent even now that the main change is reflected in the change of the entrepreneurs' focus from financial, material, and, especially, technical–technological resources to human and intellectual resources as the key components of every entrepreneurial process.

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Session 6.

Health and Environmental protection

BEST PRACTICES IN ENVIRONMENTAL PROTECTION THROUGH EDUCATION AND INFORMATION ACTIVITIES: THE GRACILIS SHOWCASE

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Abstract: This work is a showcase where education and awareness processes are combined through student's project. We show how the problem (about greening) was addressed, what the tools for solving the problem were, which results we achieved and how we managed them. This project involved three partners, coming from academia, industry and non-governmental institution and gave benefits to all three involved parties and students as the main participants in the project.
Key words: sustainability, greening, climate changes, public awareness, good practice example

INTRODUCTION

Knowledge and use of greening as one of the most modern approaches to solving pollution and global climate change are still poorly investigated in Slovenia. This was also shown by the study, which was carried out at Environmental Protection College (EPC) within the project GRACiLIs - GReen Answers CLImate change (www.gracilis.si) and a thesis work [3]. The Complementarium Institute (CMP), a non-governmental organization (which co-operated as a second partner in the national project co-financed by the “Creative path to knowledge programme”; first partner was from industry – Matrica, s.p.), recognized the need for a wider local community involvement in awareness-raising activities regarding greening of urban areas.
The project coincided well with the diploma thesis [3] where greening in a local microclimate was investigated. During the project study process students were looking at possible green solutions and learn how to expand and share the gained knowledge on greening.
After Industrial Revolution, due to urbanization and industrialization of human civilization, more population moved to urban areas and urban spaces [3]. The urban population around the world has risen dramatically: from 13 % in 1900 to up to 54 % in 2014. By 2050, 66 % of the world's population are projected to be urban residents, according to the World Population Prospects, United Nations (2014) reports. Growing population forced developers to construct more buildings and therefore, more green areas were destroyed and converted to build environment [1]. Rise of constructed areas without enough vegetation has changed the flow of energy and material through urban ecosystem which causes many environmental problems. First urbanization – cities tend to be hotter as the surrounding (countryside) areas and create what is known as an urban heat island. Second, urbanization affects hydrology; cities shed more water as run off to their streams and rivers. Third, cities are net producers of carbon dioxide and have lower amounts of stored carbon. Fourth, cities are widely regarded as having lower biodiversity [4]. All these four facts affect the ecological balance of urban environment and should be carefully addressed not just locally, but on a national scale.
Within this paper we will present the showcase of Gracilis project, how it was built, what were research needs and in the end the results of it.

MATERIAL AND METHODS

This section describes how we built our project collaboration, partners as mentors on one side and students on the other, but together we made a team.
The thesis work included survey, where 112 respondents gave valuable answers in connection to greening. We used Excel for statistical evaluation.

Within the first project activity (A1): we established the way of communication, defined the tools we will use and we set the dates of our exact activities. As our first meeting was virtual, we picked the first possible opportunity to meet in person combining it with a public event. All other activities (A2-A5) are presented in Figure 1.

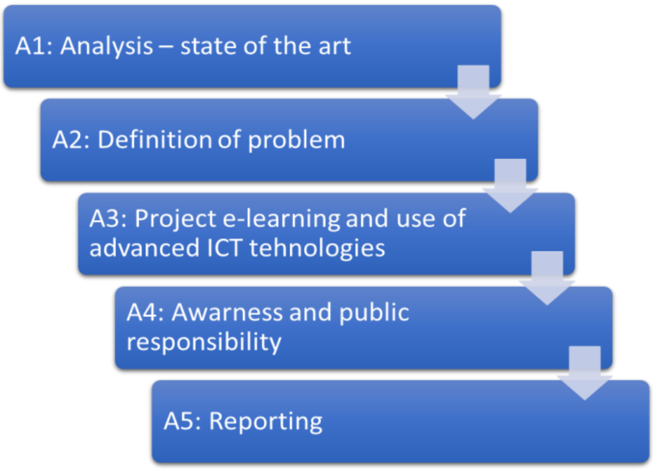

Figure 1. The action plan in the project Gracilis.

RESULTS AND DISCUSSION

The project communication was one of the most important activities of the group. It enabled collaboration among all the project participants, sharing and saving the established documents and lead to efficient informational flow. Due to all listed facts we had to find a platform with features which would be easily applied to different devices (mobiles, computers, tablets) and could be used for free. We chose G-suite of Google which gained enormously on quality in the past few years, so it is now optimized and reliable service. The Figure 2 shows what all is possible when using G-suite.

Figure 2. A Google platform- G suite with various possibilities.

All this requires only internet link and an active Google account – usually Gmail. In our project we used:
Google Docs: for all work with documents and easy sharing with all participants.
Google Gmail: email which is widely used also on general level.
Google Scholar: enables looking for scientific and professional papers.
Google Groups: enables a formation of joined email-s (projekt_convert@googlegroups.com in our case).
Google Drive: cloud file storage, sharing and backup service enabling saving and sharing of documents inside the group participants.

These are just a few of possible Google services, which are still quite unrecognized among public. As our project was oriented also in the sense of educating about novel approaches, we presented those possibilities whenever we had an event. We found these tools very useable as they enabled us higher productivity and efficiency in the group work. We chose Google and not Microsoft or Dropbox as they are mainly focused on business users and are licensed -payable.
Another service we used for conference calls was *Skype* – also here we made a group and we used it on the upfront determined dates – at least once a month, preferably twice. It was all a part of project management learning and students were fast in adopting and using it.

Figure 3. An internet (home) page of the project Gracilis.

Within the project also a *web page* was developed. This solution was a logical consequence of collective project idea. www.gracilis.si presents our current work, studies already developed, blog section, members of the team presentation, gallery and events calendar. This tool enabled constant information service, where on the other hand social media served different purpose, but we used them too.
Social media can encourage participation, conversation and community all of which can help spread key messages, influence decision making, as well as promote behavior change. It helps to reach people when, where, and how it is convenient for them, which improves the availability of content and might influence satisfaction and trust in messages delivered [2] It is also one of the key tools in building awareness and credibility, but most certainly not the only one. Social media content should be: relevant, useful, and interesting; easy to understand and share; friendly, conversational, and engaging; action-oriented. Your target audience can receive multiple messages from multiple sources every day [2]. Therefore, we need to make our messages relevant, useful and interesting so our audience will interact and will be engaged. This engagement is a key with social media. Within Gracilis we used Facebook, Twitter, Instagram and LinkedIn profiles to share our messages. The name of all listed channels was in connection to the project title: GRACiLIs - GReen Answers CLImate change, as we followed the tip of personalizing our account to our brand. Students were involved in publishing for one week in one media and then they switched; e.g. from tweeting to Facebook etc., so they all developed skills in social media (advertising) communication. Writing using social media can be a demanding task. One way to cope is to tweet, post, and text about web content you have already created. During process of project duration, we tried to follow this as much as possible; it was a hard task, but definitely the most efficient solution. On Figure 4 we show all possible social media solution and their main characteristics.

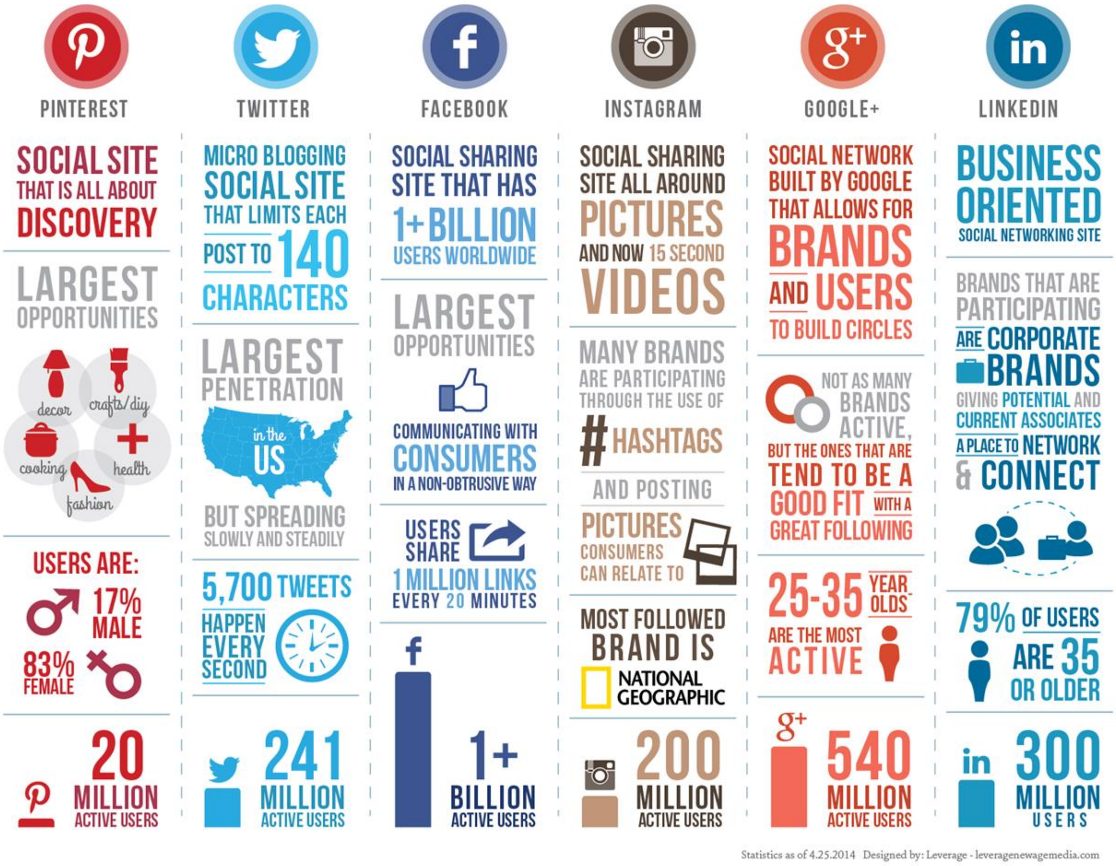

Figure 4. Social media and their characteristics. Source: Leverage, 2014.

The important result is also a survey about awareness on greening among general population (112) participants in Slovenia [3]. Majority answer regarding familiarity with the term "green roof" was positive in 63 %, as we can see below in Figure 5.

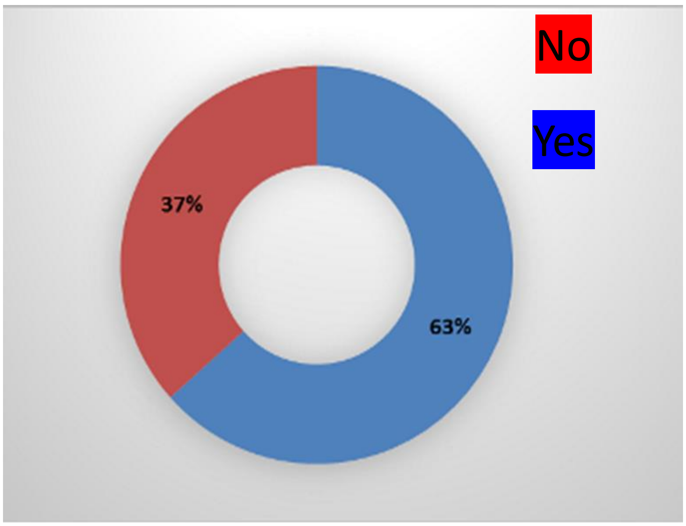

Figure 5. Knowing of the term "green roof" among general public. [3]

The next question was also about people's opinion whether green roofs are present in Slovenia, where 70 % answered positively as shown on Figure 6.

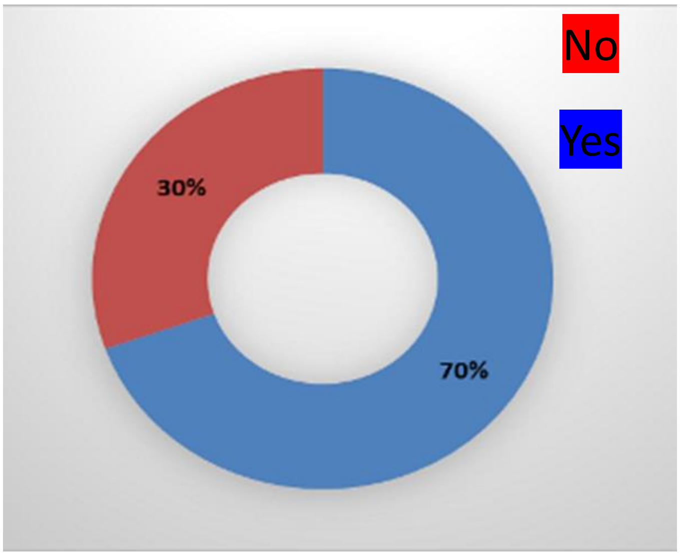

Figure 6. Presence of the green roof in Slovenia – public opinion. [3]

Figure 7 presents the most interesting answers saying that 59 %participants saw green roof abroad.

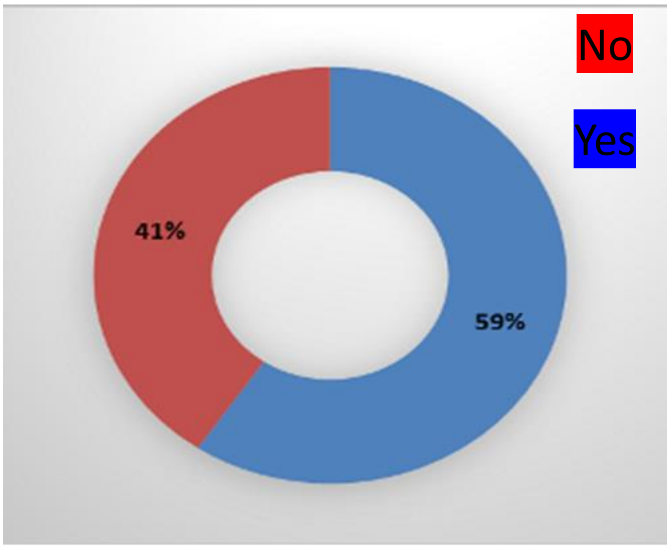

Figure 7. Presents answers about where people saw green roof (in Slovenia or abroad). [3]

The survey in general showed low awareness of the interviewed population, as more than 60 % it's not aware of the positive contribution greening (e.g. green roofs) can have on the (local) climate [3]. However, few of participants have seen them green building abroad and 94 % claimed they would support green building. Based on these, regular awareness raising events, publishing and communication we have a lot of room for improvement [3].

CONCLUSION

The aim of GRACILIS project was exactly prevention or better, raising awareness on the greening issue. Building a strong project model with many different project partners enabled very diverse approach to the problem on one hand and on the other enabled us fast and efficient adaptation to all challenges. During the project duration we managed to establish an extra helpful connection to the enterprise Knauf, Urbanscape Green Solutions department, where we used (also) their products to build, or even invent ours such as a green cubicle, green curtain which was completely independent contribution of students. Our important activity was also public event performing – in three months we had five events, and all are were very well recognized. Events always had "standard protocol": introduction of members, problem, solution, discussion – important for students to gain project

learning skills. We find the importance between balanced exchange with best practices in environmental protection through education and information activities (such as GRACILIS showcase), an important upgrade of theoretical grounds towards practical experience.
Such projects open many new questions, but are an important basics for more complex, conceptual approaches to study causes for climate changes – at least some of them. With such support and green thinking, we are a step closer to low carbon society of the future.

ACKNOWLEDGEMENTS

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ATTITUDES TOWARDS ENERGY CONSUMPTION: EMPLOYEE PERSPECTIVE

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Abstract: For companies engaged in agricultural activities, energy consumption represents a significant part of the total costs, with the dominant usage of electrical energy. Considering a raising awareness regarding the usage of alternative energy sources such as energy from agricultural activities (biogas, biodiesel ...), this study focuses on the attitudes of the employees towards energy consumption in companies in this line of business. Since The Republic of Serbia is an official candidate to enter the European Union, we have performed an analysis considering the EU standards. The questions examined the attitudes toward other sources of energy, including energy from agricultural production and renewable energy as a supplement and replacement for electrical energy. The conducted study involved 150 respondents (employees) with their opinions on the importance of various activities in agricultural production for energy consumption in the enterprise. This paper demonstrates the relationship between a company (employees) with a higher energy cost and a level of awareness of different sources of energy.

INTRODUCTION

The survey "Renewable Energy Sources" was conducted on a sample of 150 respondents. The survey consisted of questions about personal data and opinion on efficient consumption and renewable energy sources (1. Competitiveness and consumer energy, 2. Energy sources). Each of the questions asked consisted of a response with a scale of 5 offered responses: A - insignificant, B - less significant, C - medium, D - very significant, E - extremely important.
We will consider the criterion question:

Electricity consumption has a significant share in the total cost of the company.

The answer to this criterion question shows us how the respondent looks at the consumption of electricity within the work he deals with. Since this is the criterion question, it means that the entire sample is divided into 5 groups depending on their answers to it:
A - Insignificant (0 respondents), B - less significant (5 subjects), C - intermediate (37 subjects), D - very significant (72 respondents) and E - extremely significant (36 subjects).
Based on the distribution of the answers to the criterion question, we see that the group A is minimal, we will not use it in the future because there are no respondents, while the results of group B are less significantly taken with the reserve because the group has a small number of respondents, so we can not consider the result as relevant. So our focus will be on the difference in attitudes between groups: C - medium significant (37 subjects), D - very significant (72 respondents) and E - extremely significant (36 respondents).

METHODOLOGY

Our goal is to determine whether there are differences and on which questions differences exist between the 4 groups mentioned. That is, among the respondents who consider that electricity consumption has a significant share in the total costs of the company. We will test hypotheses:

H1 – Groups defined by criteria question (CQ) have different opinion (answer) on the question *"The level of agricultural production is satisfactory."*

H2 - Groups defined by criteria question have different opinion (answer) on the question *"The use of chemicals is sufficiently controlled"*.

H3 - Groups defined by criteria question have different opinion (answer) on the question *"Energy from agricultural production (biogas, biodiesel, energy crops ...) will be used more and more.) "*.

H4 - Groups defined by criteria question have different opinion (answer) on the question *"Within the agricultural sector, the relationship between food production and the production of crops used in energy production is balanced. (food for energy)"*.

H5 - Groups defined by criteria question have different opinion (answer) on the question *"The use of wood biomass and biofuel processing is on the rise and is properly regulated."*.

In this study, MANOVA and ANOVA analysis will be performed. The analysis was done with R-project. First, the MANOVA analysis was done where we tested whether there was a difference on all groups. If there is the difference as a result of MANOVA, later ANOVA analysis was conducted to test between which groups differences exists.

RESULTS

First test was done on the first question in relation to the criterion question:

1. The level of agricultural production is satisfactory.
0. Electricity consumption has a significant share in the total cost of the company. (criterion question, CQ)

MANOVA results are shown in the table bellow

Table 1. MANOVA

	Df	**Sum Sq**	**Mean Sq**	**F value**	**Pr (>F)**
data1$p3	3	10.13	3.376	2.583	0.0557 .
Residuals	146	190.86	1.307		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The test shows that is statistically significant difference, between some groups, so hypothesis H1 is proven

Next analysis, ANOVA, was performed on following questions:

1 The level of agricultural production is satisfactory.

0 Electricity consumption has a significant share in the total cost of the company. (criterion question, CQ)

There was a significant difference between the groups (D - very significant) - (C - medium significant) with p = 0.044131

In other case there is no statistically significant difference.

Second test was done on the third question in relation to the criterion question

2 The use of chemicals is sufficiently controlled.

0 Electricity consumption has a significant share in the total cost of the company. (Criterion question, CQ)

Table 2. ANOVA

Groups defined by criteria question	Diff	lwr	Upr	p adj
(C - intermediate)- (B - less significant)	-0.65946	-2.07528	0.756362	0.621198
(D - very significant) - (B - less significant)	-0.04722	-1.42147	1.327022	0.999744
(E - extremely significant) - (B - less significant)	-0.08889	-1.50705	1.329272	0.998455
(D - very significant) - (C - medium significant)	0.612237	0.01118	1.213295	0.044131
(E - extremely significant) - (C - intermediate)	0.570571	-0.12506	1.266202	0.147984
(E - extremely significant) - (D - very significant)	-0.04167	-0.64821	0.56488	0.997971

Table 3. ANOVA

	Df	Sum Sq	Mean Sq	F value	Pr (>F)
data1$p3	3	7.09	2.362	2.025	0.113
Residuals	146	170.27	1.166		

The test MANOVA shows that is no statistically significant difference (p = 0.113), but in test ANOVA we have there is significant difference between groups.

Table 4. ANOVA

Groups defined by criteria question	Diff	lwr	upr	p adj
(C - intermediate)- (B - less significant)	-0.53514	-1.87241	0.80214	0.726255
(D - very significant) - (B - less significant)	-0.01111	-1.30912	1.286894	0.999996
(E - extremely significant) - (B - less significant)	-0.09444	-1.43393	1.24504	0.997807
(D - very significant) - (C - medium significant)	0.524024	-0.04369	1.091736	0.081775
(E - extremely significant) - (C - intermediate)	0.440691	-0.21635	1.09773	0.305309
(E - extremely significant) - (D - very significant)	-0.08333	-0.65623	0.489564	0.981529

There was a significant difference between the groups (D - very significant) - (C - medium significant) with p = 0.081775. Because p <0.1 and p>0.05, we consider it to be a conclusion with an increased risk of conclusion, so hypothesis H2 is proven. When<1 and >0.5, it is considered as a higher risk conclusion.
In other case there is no statistically significant difference.
Third test was done on the third question in relation to the criterion question

3. Energy from agricultural production (biogas, biodiesel, energy crops ...) will be used more and more.)
0. Electricity consumption has a significant share in the total cost of the company. (criterion question, CQ)

Table 5. MANOVA

	Df	Sum Sq	Mean Sq	F value	Pr (>F)
data1$p3	3	2.92	0.9717	0.961	0.413
Residuals	146	147.62	1.0111		

There is no statistically significant difference, so hypothesis H3 is not proven.

Table 6. ANOVA

Groups defined by criteria question	Diff	lwr	upr	p adj
(C - intermediate)- (B - less significant)	-0.22162	-1.46678	1.023541	0.967054
(D - very significant) - (B - less significant)	-0.01667	-1.22526	1.19193	0.999983
(E - extremely significant) - (B - less significant)	0.177778	-1.06944	1.424998	0.982582
(D - very significant) - (C - medium significant)	0.204955	-0.32365	0.733563	0.745203
(E - extremely significant) - (C - intermediate)	0.399399	-0.21238	1.011181	0.329154
(E - extremely significant) - (D - very significant)	0.194444	-0.33899	0.72788	0.779337

There is no statistically significant difference.
Fourth test was done on the third question in relation to the criterion question

4. Within the agricultural sector, the relationship between food production and the production of crops used in energy production is balanced. (food for energy).
0. Electricity consumption has a significant share in the total cost of the company. (criterion question, CQ)

Table 7. MANOVA

	Df	Sum Sq	Mean Sq	F value	Pr (>F)
data1$p3	3	6.58	2.1936	2.331	0.0767
Residuals	146	137.42	0.9412		

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

There is a statistically significant difference but on level 0.1. In the next table analyze ANOVA will show is there some difference or not.

Table 8. ANOVA

Groups defined by criteria question	Diff	lwr	upr	p adj
(C - intermediate)- (B - less significant)	0.075676	-1.12568	1.277027	0.998432
(D - very significant) - (B - less significant)	0.511111	-0.65496	1.677183	0.66597
(E - extremely significant) - (B - less significant)	0.566667	-0.63667	1.770003	0.612754
(D - very significant) - (C - medium significant)	0.435435	-0.07457	0.945444	0.122951
(E - extremely significant) - (C - intermediate)	0.490991	-0.09927	1.081247	0.138925
(E - extremely significant) - (D - very significant)	0.055556	-0.45911	0.570222	0.992265

ANOVA shows there is no statistically significant difference, with level 0.1, that means that we reject the hypothesis H4.
Fifth test was done on the third question in relation to the criterion question

5 The use of wood biomass and biofuel processing is on the rise and is properly regulated.
0 Electricity consumption has a significant share in the total cost of the company. (criterion question, CQ)

Table 9. MANOVA

	Df	Sum Sq	Mean Sq	F value	Pr (>F)
data1$p3	3	2.33	0.7756	0.855	0.466
Residuals	146	132.37	0.9066		

There is no statistically significant difference, so hypothesis H3 is not proven.

Table 10. ANOVA

Groups defined by criteria question	Diff	lwr	upr	p adj
(C - intermediate)- (B - less significant)	0.4	-0.77906	1.579059	0.814366
(D - very significant) - (B - less significant)	0.594444	-0.54999	1.738879	0.532815
(E - extremely significant) - (B - less significant)	0.455556	-0.72545	1.636563	0.748196
(D - very significant) - (C - medium significant)	0.194444	-0.3061	0.694989	0.744088
(E - extremely significant) - (C - intermediate)	0.055556	-0.52375	0.634859	0.994542
(E - extremely significant) - (D - very significant)	-0.13889	-0.64401	0.366227	0.891172

There is no statistically significant difference, with level 0.1, that means that we reject the hypothesis H5.

DISCUSSION

Based of results we can tell that groups "D - very significant" and "C - medium significant" defined on question "Electricity consumption has a significant share in the total cost of the company" (criterion question, CQ) have different **opinion on question** *"*The level of agricultural production is satisfactory.*" and "*The use of chemicals is sufficiently controlled*".*
Reason is given by the fact that they do not feel pressure with high costs of electric energy, and so their interests for the other source of energy are small.
Respondents from the companies where costs for electric energy are intermediate didn't show any interest in the other sources of energy besides electrical energy.
On the other hand, respondents from companies with high electric energy costs, have shown more interest for the renewable sources of energy.

CONCLUSION

1. For hypothesis H3, H4 and H5 results indicated that there is no significant differences between criteria groups with analyses MANOVA and ANOVA.
2. For hypothesis H1 we get different results with MANOVA and ANOVA analysis.
3. For hypothesis H2 we get there is significant differences on level of significance 0.1.
For H1
This means that the group of respondents who think that electricity consumption has significant share in the total cost of the company (answer E on the CQ), have different opinion (answer) on question "**The level of agricultural production is satisfactory**" there is difference between the group (D - very significant) - (C - medium significant).
And on the other side respondents who think that electricity consumption has insignificant share in the total cost of the company (answer C on the CQ), there is difference between the group (D - very significant) and (C - medium significant) on question "**The use of chemicals is sufficiently controlled**".

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GREENING AS A PERSPECTIVE SOLUTION FOR URBAN MICROCLIMATE MITIGATION – A PILOT STUDY

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Abstract: At the Environmental Protection College (EPC), in cooperation with the Institute Complementarium (CMP), we designed a flat green roof pilot model with extensive greening. Based on annual monitoring of different physical and chemical parameters, we evaluated the effectiveness of two different substrates and assessed the relevance and application of extensive greening principle in the urban environment – in the city of Velenje. The areas which are ecologically burdened due to their rich natural resources (forests, water bodies, coal…) and dense population, the implementation of green areas provide variety of environmental benefits. Moreover, constant socio-economic pressures and the needs make us to plan thoroughly and prudently our future activities and developmental potentials of urban areas.
Key words: greening, pilot models, urban microclimate

INTRODUCTION

Green roofs originate from the earliest times of human history, mostly as natural human shelters. They were known by the ancient Greeks and Romans and were the most widespread in Scandinavia and Iceland at the time of the Vikings [1]. In the cities green roofs are becoming very popular again, since the ecological and environmental benefits of their technologies can improve the urban microclimate and thereby return the possibility of sustainable life to the citizens. Beside roofs we can build green walls, facades even whole infrastructures.
Buildings are important part of our natural environment. Therefore, it is crucial to combine architecture with nature to achieve sustainable urban development [2]. Any construction activity in the environment leads to the reduction of vegetation and humidity, ventilation changes, lack of oxygen and large temperature fluctuations. Based on their characteristics, cities are the most vulnerable areas and in the same time the most important greening environment.
Urban green spaces fulfill a range of different roles, such as aesthetic, sociological and psychological and have economic and environmental purposes. They counteract the urban heat island effect, thereby reducing the energy costs of cooling buildings. Urban greenery minimizes air, water, and noise pollution, and may offset greenhouse gas emissions through CO_2 absorption. They help to distribute rainwater - attenuate a storm water runoff and therefore act as a measure for flood mitigation. Other ecological benefits include raising and preservation of biodiversity, a new habitat creation for certain animal species and the ability to conserve nature [2, 3, 4, 5].
Green areas are also social spaces and areas for recreation and cultural purposes. Health benefits are associated with access to public open space in urban environments that offer an opportunity for health-promoting activities, such as physical activity or rest and relaxation. In this way, they have a direct relationship with the quality of life of urban citizens [5]. For example, parks, playgrounds and other vegetated areas have been associated with better perceived general health, reduced stress levels, reduced depression and provide many advantages, related to human health, like sport and recreation [6].
Based on the fact that over half of the world's population now lives in urban areas, and this proportion is expected to increase to two-thirds by 2050 [6], it is important to evaluate every possibility to increase the quality of life. Therefore, we decided to implement a pilot project, which emphasize all benefits of greening principles and increases the level of awareness and social responsibility of the citizens.

MATERIAL AND METHODS

With the long-term experiment we evaluated the greening potential in the city of Velenje, Slovenia maybe also as a demonstration project on the flat roof of Environmental Protection College (EPC) in the future.

Two flat bottom models were constructed on EPC by undergraduate student. Three different low and slowly growing adaptable plants (Murale white stonecrop (*Sedum album "Murale"*), houseleek (*Sempurirum tectorum*) and blue-green sedge (*Carex flacca*)) were seeded into each model using two different commercial substrates (named A and B), separately (Figure 1). Models were placed outside, on the open balcony of the EPC. Greening process was monitored and evaluated during all four seasons using different physical and chemical parameters (air in substrate pH, air in substrate humidity, total organic matter of substrates). Photodocumentation and picture analysis using Image software were used for more representative assessment of the greening effectiveness. Additionally, some awareness campaigns were organized during the pilot experiments for students and general public.

RESULTS AND DISCUSSION

All plants were successfully adapted to selected urban microclimate during first months of extensive green roof simulation experiment. Their growth was equal in both models using different substrates (Figure 2A, 2B). After 6 months, adaptation and growth of individual plants were changed; the blue blue-green sedge was completely dried, the houseleek grew successfully, while the Murale white stonecrop adapted to the urban microclimate even more, as it has grown along the entire area of both models. Based on the results, we can confirm that the sedums are more suitable plants for extensive green roofs in the local microclimate.

Figure 1. Three different plants (Murale white stonecrop (*Sedum album "Murale"*), houseleek (*Sempurirum tectorum*) and blue-green sedge (*Carex flacca*)) were tested

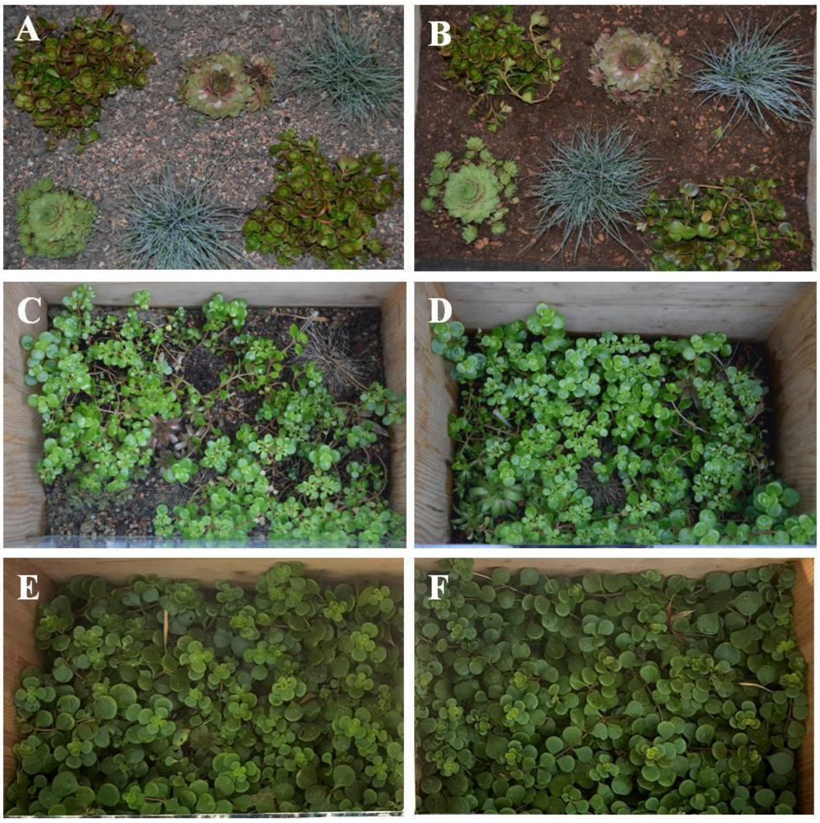

Figure 2. Adaptation of seeded plants to urban microclimate at the beginning (A, B), after 8 months (C, D) and 12 months (E, F) of the pilot experiment

The results of annual measurements of physical and chemical parameters and photo documentation of adaptation process of pilots showed that the selected environment is suitable for the installation of extensive flat roofs. The microclimate is favorable with an average annual temperature of 18.6 ºC and an average relative air humidity of 26.2 %. Temperature varied between T_{min} -0.5 ºC and T_{max} 31 ºC, and no extreme weather event that would jeopardize the existence of pilot models was observed. The substrate temperatures were stable and varied proportionally to the air temperature and were on average 4.3 °C lower and almost the same in both substrates (Figure 3, dashed line trends).

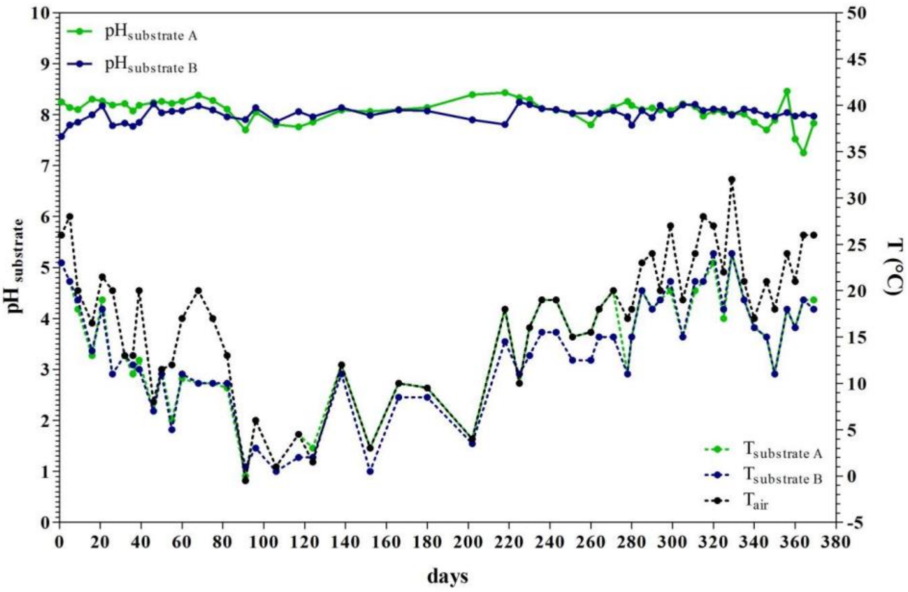

Figure 3. Adaptation of substrate to urban microclimate - annual measurements of air and substrate temperature and substrate pH

Organic compounds present a small part of the soil, which is very variable and important for quality of the soil. Since the organic matter can affect the physical and chemical properties of the substrate, the total organic carbon (TOC - total organic carbon) was monitored throughout the pilot study with the aim to determine the suitability and compatibility of our substrates regarding seeded plants. Measurements showed low levels of organic carbon in both substrates (<0.5%), which ranks the substrate into a very low-level grade, in which Slovenia has 9.4% of their surface (summarized by Slovenian Environment Agency). TOC values in the substrate B are in average higher for 16 % than the TOC of substrate A trough the entire experiment, indicating better growing conditions in consequently greening potential in the substrate B (Tables 2 and 3). With the line to TOC measurements, the substrate areas of the pilot model B were also more filled with plants compared to the pilot model A over the entire observation period, indicating that the substrate B in is more successful the selected environment.

Table 1. Average season values of parameters for substrate A

Season	Air Temperature (°C)	Substrate Temperature (°C)	pH	Relative humidity (%)	TOC (%)
autumn	16.7 ± 6.5	12.2 ± 5.1	8.20 ± 0.13	32.8 ± 14	0.29 ± 0.17
winter	6.1 ± 4.0	4.5 ± 4.2	7.98 ± 0.15	33.3 ± 1.4	0.35 ± 0.02
spring	15.5 ± 4.9	12.8 ± 3.6	8.16 ± 0.20	34.8 ± 6.5	0.30 ± 0.03
summer	23.9 ± 4.9	18.2 ± 4.0	7.98 ± 0.29	31.4 ± 5.5	0.41 ± 0.08
AVERAGE	**18.6 ± 7.7**	**14.1 ± 6.1**	**8.08 ± 0.24**	**32.2 ± 9.5**	**0.35 ± 0.09**

Table 2. Average season values of parameters for substrate B

Season	Air Temperature (°C)	Substrate Temperature (°C)	pH	Relative humidity (%)	TOC (%)
autumn	16.7 ± 6.5	12.5 ± 5.0	7.94 ± 0.20	31.3 ± 15.1	0.43 ± 0.18
winter	6.1 ± 4.0	4.1 ± 4.2	8.04 ± 0.10	36.8 ± 3.7	0.48 ± 0.02
spring	15.5 ± 4.9	12.5 ± 3.4	8.05 ± 0.13	37.1 ± 9.9	0.33 ± 0.05
summer	23.9 ± 4.9	18.3 ± 4.1	8.04 ± 0.09	34.1 ± 6.1	0.46 ± 0.11
AVERAGE	**18.6 ± 7.7**	**14.2 ± 6.1**	**8.01 ± 0.15**	**33.4 ± 10.6**	**0.42 ± 0.13**

Both substrates were slightly basic before planting, i.e. 8.21 for substrate A and 7.86 for substrate B. Average pH value of substrate A during the experiment was 8,08 and of B 8,01, what is 1,6 % lower and 1,8 % higher than the initial value, respectively (Tables 2 and 3). Additionally, during the experiment pH value varied for 24, 0 % and 14,9 %, respectively (Figure 2, full line trends; Tables 2 and 3). Interesting trend was observed after analyzing and comparing different seasons. In the pilot model with the substrate A pH value changed up and down throughout 4 seasons; whereas in the model with the substrate B, pH increased during the autumn and then stayed almost constant through the rest of the experiment. Based on pH measurements, substrate A is more sensitive to temperature changes and weather conditions (Figure 4).

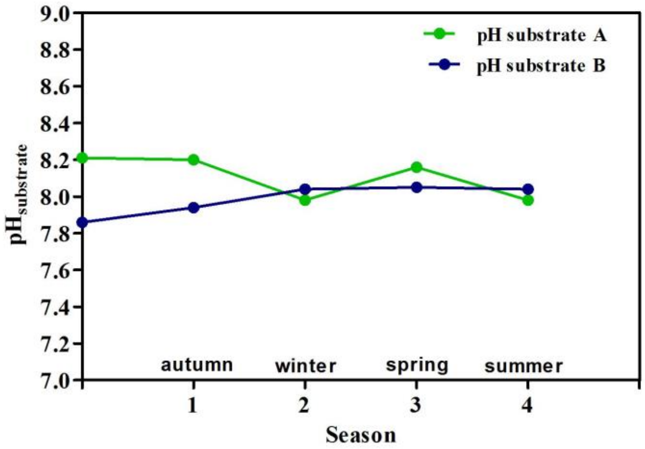

Figure 4. Average pH values of substrates through 4 seasons

CONCLUSION

Green roofs should be considered as an important part of urban and local planning. Therefore it is necessary to develop and establish guidelines to ensure its optimal ecological role in the local natural and social environment.

The implementation of our model in selected urban environment was successful. Moreover, with awareness campaigns we emphasized the importance of the extensive greening principle in the urban environment, also from the perspective of finding a sustainable environmental solution, which ultimately mitigates the urban heat island effects and contributes to reduction of global warming effects. Since, the advantages of green roofs would certainly obtain a higher quality of living space and presents one of the important steps regarding better environment in highly industrial city of Velenje, our green solutions will be performed and presented also to the citizens using various campaigns and research projects.

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NATURAL GAS - AN ENERGY AND ENVIRONMENTAL SAVIOR DURING THE 21ST CENTURY

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Abstract: Climate change is inevitable. Contributing to this change are (i) natural effects, which include the Earth in an interglacial period and (ii) various other effects such as anthropogenic effects, which include the release of non-indigenous gases into the atmosphere. However, the exact contribution of each effect to global climate change is not known with any degree of certainty. Natural gas has been proposed as a savior for the environment insofar as it released less carbon dioxide during combustion that crude oil or coal. This paper examines the properties of natural gas and how this fuel might affect the environment.
Key words: climate change, natural gas, anthropogenic activity

INTRODUCTION

The most general definition of climate change is a change in the statistical properties of the climate system when considered over long periods of time, regardless of cause. Accordingly, fluctuations over periods shorter than a few decades, such as El Niño, do not represent climate change. The term sometimes is used to refer to climate change caused by human activity, as opposed to changes in climate that may have resulted as part of Earth's natural processes. In this sense, especially in the context of environmental policy, the term climate change has unfortunately and incorrectly been associated with anthropogenic (human activities) global warming as the causative factor. Within scientific journals, global warming refers to an increase in the surface temperature of the Earth while climate change is amore all-inclusive term that includes global.
The issue of global climate change is often associated with the use of fossil fuels as sources of energy. Of most concern is the increase in emissions of carbon dioxide (CO2) due to emissions from fossil fuel combustion:

$$C_{fossil\ fuel} + O_2 \rightarrow CO_2 \quad (1)$$

Natural gas produces carbon dioxide when it is burned for energy but the combustion of natural gas produces considerably less carbon dioxide per unit of usable energy than combustion of other fossil fuels such as coal or crude oil, and their respective products. However, carbon dioxide emissions are not the main cause of observed atmospheric warming and there are several other causes that contribute to the global warming phenomenon [1]. The focus solely on carbon dioxide as the is due to. Human activity produces vastly more carbon dioxide than all other greenhouse gases put together. However, this does not mean it is responsible for most of the earth's warming. Many other greenhouse gases trap heat far more powerful than carbon dioxide [2].
Thus, the focus of this paper is the properties of natural gas and how this fuel might affect the environment.

NATURAL GAS

Natural gas, which includes shale gas, gas from tight formations, and coalbed methane (Speight, 2018), is predominantly methane, occurs in underground reservoirs separately or in association with crude oil [3,4,5]. The principal types of hydrocarbons produced from natural gas are methane (CH4) and varying amounts of higher molecular weight hydrocarbons from ethane (CH3CH3) to octane [CH3(CH2)6CH3]. Generally the higher molecular weight liquid hydrocarbons from pentane to octane and collective referred to as gas condensate.

While natural gas is predominantly a mixture of combustible hydrocarbons (Table 1), many natural gases also contain nitrogen (N2) as well as carbon dioxide (CO2) and hydrogen sulfide (H2S). Trace quantities of helium and other sulfur and nitrogen compounds may also be present. However. raw natural gas varies greatly in composition and the constituents can be several of a group of saturated hydrocarbons from methane to higher molecular weight hydrocarbons, especially natural gas that has been associated with crude oil in the reservoir, and non-hydrocarbon constituents (Table 1). The treatment required to prepare natural gas for distribution as an industrial or household fuel is specified in terms of the use and environmental regulations. Briefly, natural gas contains hydrocarbons and non-hydrocarbon gases. Hydrocarbon gases are methane (CH4), ethane (C2H6), propane (C3H8), butanes (C4H10), pentanes (C5H12), hexane (C6H14), heptane (C7H16), and sometimes trace amounts of octane (C8H18), and higher molecular weight hydrocarbons. Some aromatics [BTX – benzene (C6H6), toluene (C6H5CH3), and the xylene isomers (o-, m-, and p-CH3C6H4CH3)] can also be present, raising safety issues due to their toxicity. The non-hydrocarbon gas portion of the natural gas contains nitrogen (N2), carbon dioxide (CO2), helium (He), hydrogen sulfide (H2S), water vapor (H2O), and other sulfur compounds (such as carbonyl sulfide (COS) and mercaptans (e.g., methyl mercaptan, CH3SH) and trace amounts of other gases. In addition, the composition of a gas stream gas from a source or at a location can also vary over time which can cause difficulties in resolving the data from the application of standard test methods [6,7].

Table 1. Composition of Natural Gas from a Petroleum Well

Category	**Component**	**Amount**
Paraffins	Methane (CH_4)	70-98
	Ethane (C_2H_6)	1-10
	Propane (C_3H_8)	Trace-5
	Butane (C_4H_{10})	Trace-2
	Pentane (C_5H_{12})	Trace-l
	Hexane (C_6H_{14})	Trace-0.5
	Heptane and higher molecular weight (C_{7+})	Trace
Cycloparaffins	Cyclohexane (C_6H_{12})	Trace
Aromatics	Benzene (C_6H_6) + other aromatics	Trace
Non-hydrocarbons	Nitrogen (N_2)	Trace-15
	Carbon dioxide (CO_2)	Trace-1
	Hydrogen sulfide (H_2S)	Trace-1
	Helium (He)	Trace-5
	Other sulfur and nitrogen compounds	Trace
	Water (H_2O)	Trace-5

However, prior to use, natural gas must be processed to remove the non-methane constituents [3,5,8]. Gas processing (also called gas cleaning or gas refining) consists of separating all of the various hydrocarbons and fluids from the pure natural gas [3,5,8,9,10,11,12,13,14]. While often assumed to be hydrocarbons in nature, there are also components of the gaseous products that must be removed prior to release of the gases to the atmosphere or prior to use of the gas in another part of the refinery, i.e., as a fuel gas or as a process feedstock.

Gas processing involves the use of several different types of processes to remove contaminants from gas streams but there is always overlap between the various processing concepts. In addition, the terminology used for gas processing can often be confusing and/or misleading because of the overlap [10]. Gas processing is necessary to ensure that the natural gas prepared for transportation (usually by pipeline) and for sales must be as clean and pure as the specifications dictate. Thus, natural gas, as it is used by consumers, is much different from the natural gas that is brought from underground formations up to the wellhead.

OTHER SOURCES OF METHANE

Natural sources

The main natural sources of methane are wetlands, termites and oceans. Wetlands are by far the largest source with methane being produced from the anaerobic decomposition of organic matter covered by water. Because this process involves the action of bacteria, the rate of methane production is strongly temperature dependent. Maximum methane production is experienced at temperatures between 37 and 45ºC (100 and 112oF) and so future increases in global temperature may enhance methane production from wetlands, thereby reinforcing the greenhouse effect.
Methane is also produced by the digestive processes of termites, resulting in approximately 5% of world methane emissions. This value is unlikely to change as termite populations are not expanding despite greater availability of biomass due to deforestation.22 Methane emissions from termites should be treated as a significant, but background, source that is likely to remain constant.
Oceans contribute approximately 2% to global methane emissions. The methane is produced by methanogenic bacteria within sinking particles in surface waters. The production of methane from oceans is spatially dependent, with much methane arising from methanogenesis in marine sediments, particularly in nutrient rich areas such as estuaries. There is also an anthropogenic component to ocean emissions, with bacterial populations being increased by high nutrient levels from agricultural fertilizer run-off and waste treatment effluents.

Anthropogenic sources

The key anthropogenic sources of methane include fossil fuels, agriculture, landfill and the burning of biomass. Methane emissions arising from the fossil fuel industry form the largest anthropogenic source of methane. The main sources of fossil fuel-related methane emissions are the release of natural gas from coal mining and leakage from gas processing and distribution pipes [15,16,17]. Pockets of methane that have been trapped between layers of coal during its formation and methane within the coal itself are released once the coal is mined. Agricultural practices also result in significant methane emissions, the two major sectors being rice production and the rearing of livestock [18,19]. Thus, the relative lifecycle carbon intensity of a range of potential natural gas sources must be more fully understood, particularly methane leakage.
Methane is produced as part of the natural digestive processes of ruminant animals such as cattle, sheep and goats. Food is broken down by bacteria in the rumen, aiding digestion, since stomach enzymes are insufficient to break down plant polymers. However, the action of these bacteria yields methane, carbon dioxide and ammonia as gaseous by-products. With an increasing global population, coupled with higher living standards, livestock numbers are increasing world-wide.
Landfill sites also provide an anaerobic environment where methanogenic bacteria break down waste organic materials. Somewhere between 40 and 60% of landfill gas is methane, depending on the composition of the waste. The remainder is mainly carbon dioxide with other trace gases. The amount of methane emitted to the atmosphere from a landfill site is strongly dependent on the design and operation of the site. Unchecked, the landfill gas will simply permeate through the waste or along cracks in the compacted waste or bedrock. Modern landfill sites use impermeable liners and a capping layer to control the movement of the gas, which may then be collected. However, even the best caps are only 85% efficient25 with the remaining 15% of methane escaping through the cap.26 This is offset by breakdown of up to 90% of the methane in the capping layer by methanotrophic bacteria.
The burning of biomass releases substantial quantities of methane into the atmosphere each year. Biomass burning results mainly in the production of carbon dioxide, but if fires smolder and combustion is incomplete, methane and other volatile organic compounds are released. The extent of methane emissions is dependent on the completeness of combustion and the carbon content of the fuel used.

Methane hydrates

Although currently neither a source nor a sink, methane hydrates are by far the largest store of methane on the planet and account for 53% of all fossil fuels on earth.28 They are a crystalline solid mixture of water and methane (essentially methane trapped in ice) and are found in ocean floor sediments and arctic permafrost.

The methane in ocean sediment hydrates is trapped by the high pressure deep in the ocean but is released above a depth of 400m as the pressure drops. The energy industry is keen to take advantage of this and mine these deposits.29 Methane contained in arctic tundra, trapped within the frozen solid structure of the hydrate, is a more serious issue. Should temperatures rise, the methane hydrate will melt, releasing methane gas to the atmosphere. There is concern that, if rising global temperatures due to anthropogenic climate change cause the arctic permafrost to melt, massive quantities of methane would be released into the atmosphere, causing a catastrophic run-away greenhouse effect beyond even the upper 5.8ºC estimate postulated by the IPCC. Such a process is believed to have occurred in the Paleocene-Eocene Thermal Maximum, which occurred approximately 55 million years ago, when global temperatures increased by 5 º C (9oF) average and which lasted for 150,000 years.

GASES IN THE ATMOSPHERE

The atmosphere (excluding moisture) consists of nitrogen (78%) and oxygen (21%) as well other gases, including greenhouse gases such as carbon dioxide, are collectively classified as trace gases due to their low concentrations. There is the belief that human activity is altering the composition of the atmosphere by increasing the concentration of greenhouse gases. Greenhouse gases occur naturally in the atmosphere and their presence results in what atmospheric scientists call the greenhouse effect. It is important to remember that the greenhouse effect is what keeps the earth warm enough to be habitable. The current concern is directed at an enhanced greenhouse effect, one that would put more heat-absorbing gases into the atmosphere, thereby increasing global temperatures.

The recent attention given to the greenhouse effect and global warming is based on the recorded increases in concentrations of some of the greenhouse gases due to human activity. Of particular interest are water vapor, carbon dioxide (CO_2), methane (CH_4), nitrogen oxides – such as nitrous oxide (N_2O) nitric oxide (NO), and nitrogen dioxide (NO_2), and ozone (O_3) – and all of these gases occur naturally and/or are also produced by anthropogenic activity [20].

Carbon dioxide (CO_2) is considered the most important human-influenced greenhouse gas. Scientific measurements reveal an unmistakable global increase in the amount of carbon dioxide, which arises primarily from the burning of fossil fuels (motorized vehicles, electric power plants, and homes heated with gas or oil) and the burning and clearing of forested land for agricultural purposes. But is carbon dioxide the real culprit for global climate change?

Methane (CH_4) is the major constituent of natural gas and it is also a product of natural biologic processes, but its output can also arise from anthropogenic activity. This gas is emitted from the decay of organic matter in waterlogged soils (for example, wetlands and rice paddies) and from the digestive tracts of grazing animals (for example, ruminants). The additions from human activities include (i) emissions from livestock, (ii) emissions from landfills, and (iii) leakage from natural gas during production and transportation [21,22].

Methane, the principal constituent of natural gas, is a much more effective greenhouse gas than carbon dioxide and has adverse effects on the atmosphere [23]. The infrared absorption of a methane molecule is almost 30 times that of a carbon dioxide molecule. However, the effective lifetime of methane in the atmosphere is much shorter. Nevertheless, an increase in the concentration in the atmosphere could result in a major change in the effects on the climate. Moreover, substitution of natural gas for crude oil and coal can be an important interim strategy to moderate carbon dioxide emissions while better non-fossil sources are developed and deployed.

The emissions of methane during the lifecycle of natural gas may be much higher than conventional estimates and the total greenhouse gas emissions may, as a result, be close to, or even higher than, those from the lifecycle of coal – particularly in the case of shale gas [24]. Clearly, there is a need for research to quantify much more reliably the methane emissions associated with natural gas. This can

result in in findings that are unfavorable to the use of natural gas and there is need for serious quantification of any derived data.
It is therefore important to reduce global emissions to such a level that they are outweighed by methane sinks, so that the concentration of methane in the atmosphere decreases and its subsequent warming effect is reduced.

CONCLUSIONS

Natural gas has been promoted as a fuel that will allow society to continue to use fossil energy over the coming decades while emitting fewer greenhouse gases than from using other fossil fuels such as coal and crude oil. It is a fact that less carbon dioxide is emitted per unit of energy released during combustion when burning natural gas is compared to coal or crude oil, natural gas is composed largely of methane which is an extremely potent greenhouse gas. In fact, methane is responsible for nearly as much global warming as all other non- carbon dioxide greenhouse gases put together. Methane is twenty-one times more powerful a greenhouse gas than carbon dioxide.
The current information for global climate change points to global warming/climate change being influenced by the sum of all effects with no one effect (such the anthropogenic effect) being the major contributor from a multi-component group of effects, one of which is methane emissions. However, sound policies must be in place to make certain that natural gas is used to replace coal and minimize methane emissions.

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EXPERIMENTAL AND MODELING APPROACH IN TERMS OF BIOGAS PRODUCTION BY ANAEROBIC FERMENTATION OF DIFFERENT SUBSTRATES

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Abstract: Biogas production based on anaerobic digestion process has become nowadays a promising alternative for natural gas, mainly in power plants. Biogas is produced in pilot plants by using generally organic wastes that are able to be submitted to anaerobic fermentation, process that generates methane, carbon dioxide and other residual gases.
The present the study shows that a mix of cow manure, cow whey and digestate is suitable for anaerobic digestion, in a pilot plant, using thermophilic operation conditions. The influence of the substrate on methane production was studied and it was concluded that the increase in cow whey content increases the efficiency of the process. The kinetic study of methane production was performed using a modified Gompertz model, revealing different evolution patterns of digestion processes due to substrate properties. The correlation coefficients displayed a good adequacy of the kinetic model.
Key words:biogas, mathematical modeling, small scale test rig, Gompertz model

INTRODUCTION

In terms of continuous demand for "green" technologies able to supply sustainable resources for household and industry use, biogas produced from biomass has the potential of a suitable alternative for natural gas [1-3]. Another environmental advantage would be that the technology of producing biogas is based on renewable feedstock consisted of vegetable and/or animal wastes which can be turned into a valuable resource [4].
Anaerobic digestion is the process of turning organic matter into biogas (methane and other volatiles) in the absence of oxygen using a consortium of microorganisms which are naturally living in this media [5]. Biogas is a biofuel which is consisted of: methane (> 50%), carbon dioxide (< 40%) and other minor volatiles like ammonia, hydrogen sulfide, hydrogen, nitrogen [6].
Mathematical modeling has become an important tool for the operation and optimization of the process of anaerobic fermentation responsible for biogas production [7]. Nonetheless, as anaerobic digestion is a complex process following several reaction paths, an accurate mathematical model is difficult to build up [8]. The mathematical models have to consider several biochemical reaction steps involved in biogas production: disintegration, hydrolysis, acidogenesis, acetogenesis and methanogenesis [9] and also physic-chemical process like heat/mass transfer are being parameterized. The rate limiting step is the hydrolysis step, corresponding to the chemical reaction of breaking big molecules of proteins and carbohydrates into smaller amino-acids and monosaccharide available for the next reaction steps [10]. These molecules will then be transformed into organic acids (propionic, butyric, valeric, etc acids) during acid fermentation process. The final step is the methanogenesis corresponding to the formation of methane by biochemical transformation of organic acids [11]. The process can be operated in mesophilic (33-37ºC) or thermophilic conditions (50-57ºC), using continuous or semi-continuous stirred tank reactors with a semi-continuous injection of substrate and media withdrawn periodically [12]. Several parameters should be monitored during operation of a anaerobic process: pH, substrate/innoculum ratio, total solid content, chemical oxygen demand, quantity and composition of the obtained biogas, hydraulic retention time, etc [13]. Basic kinetic

models are used for the characterization of the process, generally first order kinetic model or Cone model is used to calculate the hydrolysis rate and the amount of biogas. Also, modified Gompertz model estimates the lag-phase duration [13, 14].
Our group has focused on the production of biogas based on anaerobic digestion process using natural raw materials like manure, cereal residues, etc, first on laboratory scale and then, scaling up to pilot plant. The obtained results were fitted against Gompertz kinetic model.

MATERIAL AND METHODS

Substrates

The following raw materials have been studied in order to determine their potential in the anaerobic digestion process: cow manure, cow whey and digestate from another process. These were mixed in different proportion as follows: > 50% digestate, >20% cow manure, 5% cow whey (DBZ5), >50% digestate, >20% cow manure, 10% cow whey (DBZ10).

Description of the Pilot Plant

Six laboratory scale anaerobic reactors with a total volume of 2L were used in this study.
In this purpose, it was used again the thermostatic bath and batches of 0.8 L inside plastic vessels of 1L total volume together with batches of 1.5 L inside of plastic vessels with a total volume of 2 L. The work principle of the small scale testing rig is presented below (Fig.1).

Figure 1. Schematic experimental setup

The components of the small scale installation are:
1 – thermostatic bath with 6 places for heating up the used materials for the anaerobic fermentation process (the temperature is controlled with the help of the thermocouple and can be checked with the help of a thermometer inserted into the bath);
2 – plastic bottles with a total volume of 2 L, filled up to about 1.5 L with the materials used for determinations;
3 – the corks of the plastic bottles were modified in order to allow both sampling for pH checking, homogenization by means of plastic syringes, and gas transfer from the bottles into the gas bags. Also, because of the light sensibility of the anaerobic bacteria, the bottles were covered with aluminum foil;

4 – hose orifice for syringe insertion, used for sampling and homogenization;
5 – connection (small diameter hose) between the plastic bottle and the gas bag for biogas storage;
6 – gas bag for biogas storage.

The fermentation process was observed for 45 days in order to measure the pH, the biogas yield and its composition in terms of CH_4 and CO_2 concentration. The temperature was kept constant in a range between 36 and 37 °C. In order to correct the pH values during the process, it was used a solution of NH3, 10% concentration.

For measuring the methane and carbon dioxide concentration of biogas a DELTA 1600 S IV gas analyzer was used.

Mathematical Model

The mathematical model used to calculate and compare the methane production during anaerobic digestion of different substrates was the modified Gompertz model:

$$M = M_p * \exp(-\exp\left(R_m * \exp(1)/M_p * (\lambda - t) + 1\right)) \quad (1)$$

where: M is the cumulative equivalent methane yield at time t, (m^3), MP is the methane production potential, (m^3), Rm is the maximum methane production rate (m^3/day), λ is the period of lag phase (days), t is the time (days) and e is the exp(1)=2.7183.

The parameters of the model were calculated by non-linear unconstrained optimization method, using the Nelder-Mead algorithm which minimizes a scalar-valued nonlinear function of n real variables using only function values [15].

The software used to determine those parameters was Matlab R2008b (version 7.7.0.741). The adequacy of model was first graphically evaluated and then the Pearson correlation coefficient (r) and the root mean square deviation (RMSD) were calculated.

RESULTS AND DISCUSSION

The general properties of the substrates used are presented in table 1. The physico-chemical analyses were made according to standard methods [16-21].

Table 1.

Material Property	DBZ5	DBZ10
Hygroscopic moisture content, %	13	14.3
Ash content (dry basis), %	25	25.1
Mean calorific value (dry basis), %	14.2	14
Carbon content, %	29.5	29
Sulphur content, %	0.5	0.6
Volatile content (dry basis), %	43	48.5

The cumulative biogas production during anaerobic digestion is comparatively presented for both substrates in Figure 2.

From Figure 2 it can be noticed that the biogas production for both co-substrates started in the fifth day of digestion, but the quantity of biogas is significantly greater for DBZ10 (9.5 L) than for DBZ5 (7.6 L).

The methane content of biogas produced during anaerobic digestion of investigated substrates is presented in figure 3. Both substrates register almost the same pattern, the methane content being almost the same during the whole process.

The methane content of biogas increased rapidly and reaches a maximum of 63% for DBZ5 and 65% for DBZ10 in day 13. The methane concentration in the biogas produced from anaerobic digestion of DBZ10 was a little bit higher than DBZ5 substrate.

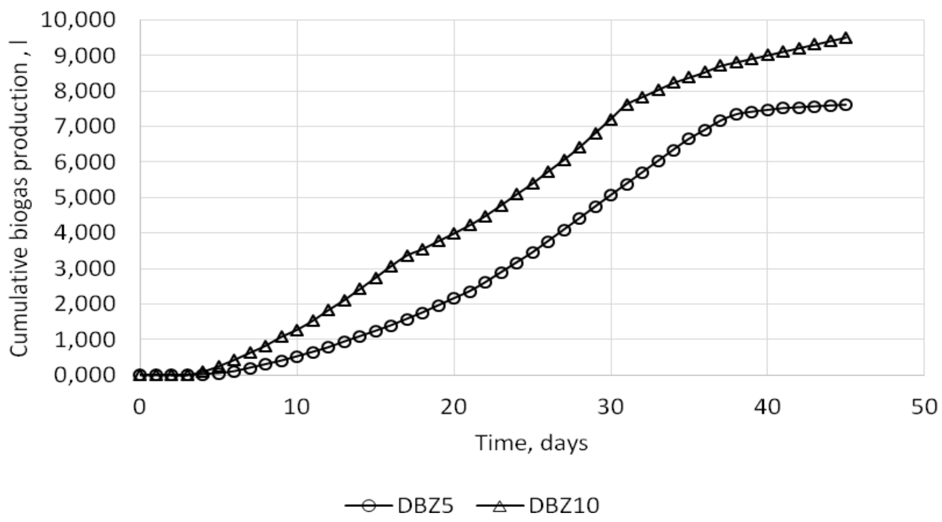

Figure 2. Cumulative biogas production during anaerobic digestion

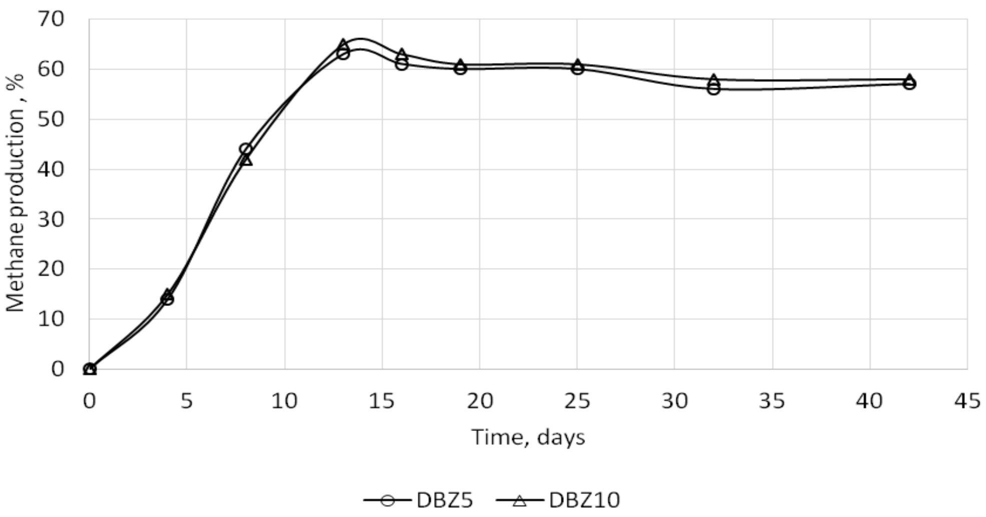

Figure 3. Methane content of biogas produced during anaerobic digestion

In order to calculate and compare the methane production during anaerobic digestion of investigated substrates, the modified Gompertz mathematical model was used.

The results of model against the experimental results are presented in Figure 4. The model parameters and the values of model performance are presented in Table 2.

Figure 4 and Table 2 clearly display that the highest methane production potential is exhibited by DBZ10. The maximum methane rate (Rm) is shown in the case of anaerobic digestion of the same substrate. The largest lag phase (λ) was observed for DBZ5, which suggests that the soluble degradable materials are not available and the initial microbiological composition of this sample is not adequate for anaerobic digestion. The use of a higher concentration of cow whey changed that situation and a shorter lag phase was exhibited by DBZ10. These model results are in agreement with the experimental data.

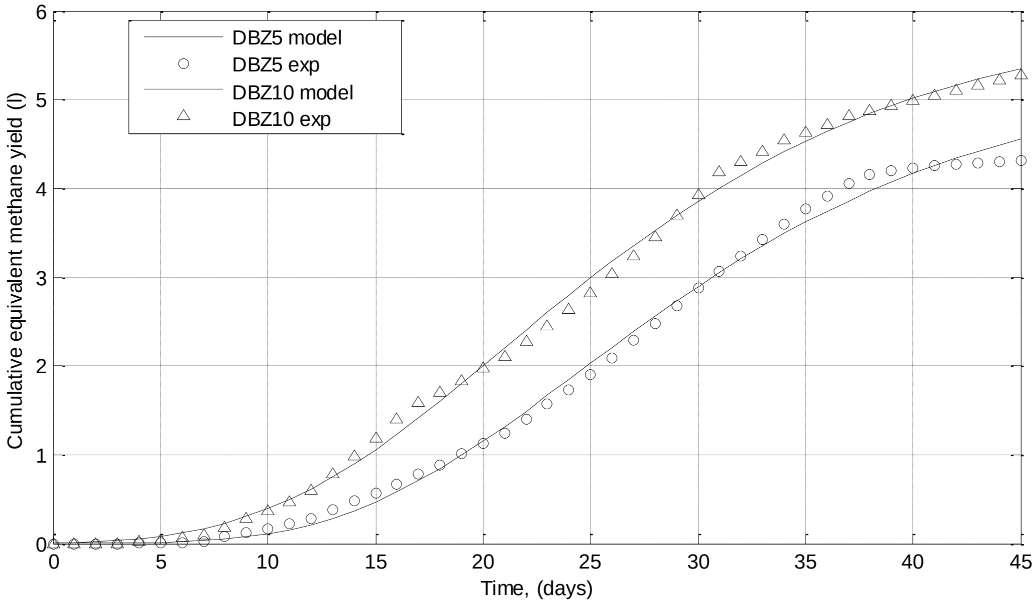

Figure 4. Experimental data (markers) and modified Gompertz models (solid lines) for methane production during anaerobic digestion of investigated substrates

Table 2. Parameters of modified Gompertz mathematical model and the values of model performances

Substrate used	Model parameters			r^a	RMSD[b]
	M_P (l)	R_m (l/days)	λ (days)		
DBZ5	5.2880	0.1806	13.7694	0.9983	0.0093
DBZ10	5.9868	0.2007	10.0387	0.9988	0.0086

[a] Pearson correlation coefficient; [b] the root mean square deviation

CONCLUSIONS

The results of the study showed that a mix of cow manure, cow whey and digestate is suitable for anaerobic digestion using the pilot scale set-up in thermophilic conditions. The increase in cow whey content increases the efficiency of the process. The most suitable for anaerobic digestion is DBZ10 substrate, which generated a higher quantity of biogas and methane.

The kinetic study of methane production revealed different evolution patterns of digestion processes due to substrate properties. The modified Gompertz model is suitable to describe the kinetic evolution of the anaerobic process of producing biogas from cow manure and cow whey.

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THERMOGRAVIMETRIC ANALYSIS OF BIOMASS AND SUB-BITUMINOUS COAL

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Abstract: Although, biomass has been utilized for energy purposes since ancient time, generating energy from biomass as a renewable energy source has become an imperative in recent years. In this paper thermogravimetric analysis of two materials, widely used for heating purposes, beech pellets and sub-bituminous coal, in a nitrogen atmosphere, at three different heating rates, was performed. TGA and DTG plots suggested that there are three different stages of weight loss during the pyrolysis of both samples: water and light volatiles pyrolysis, active pyrolysis and passive (high volatiles) pyrolysis. The temperature range of stages depended on the heating rate. The water and light volatile content were higher in the case of coal, while the weight loss in the zone of active pyrolysis was much higher for biomass sample than for the coal. Additionally, the pyrolytic residue was substantially greater in the case of coal sample as a consequence of high content of chemically bound carbon and mineral compounds. Obtained results can be used as input parameters for simulation studies as well as for design of different solid fuel thermochemical conversion (primarily gasification and combustion) units.
Keywords: thermogravimetric analysis, pyrolysis, biomass, beech pellets, coal.

INTRODUCTION

Global commitment to full transition to renewable energy is bigger than ever. The substantial impetus was Paris climate agreement from 2016. Now, a number of countries that are firmly committed to shifting to 100% renewable electricity constantly rise and in 2017 the figure climbed to 57 [1]. The rising trend is evident all around the world, even in developing countries. The average 10-year growth rate of combined renewables compared to final energy consumption is 2.3%, with modern renewables rate of 5.4%. Consequently, investments in renewable energy plants for power, fuels and heating are going up on yearly basis and according to REN 21[1] topped 280 billion of USD in 2017. If traditional biomass use is included, bioenergy is dominant renewable energy source providing nearly 13% of total global final energy demand [1]. In final energy consumption coal still dominates with 79.5%. Nevertheless, biomass can be regarded as almost perfect substitute for coal. It is carbon neutral, widely available and can be cultivated on the lands that are not suitable for food plants. The additional untapped potential is in short rotation plants which provide substantially greater yield than traditional wood species.

While different conversion routes of biomass and coal into final energy forms are available, thermochemical conversion still dominates. In process of feasibility assessment, research, scaling up and design of commercial thermochemical conversions plants, the proper characterization of fuel samples is indispensable. Thermogravimetric Analysis (TGA) represents reliable, sensitive and reproducible method for characterization of fuel samples. It is straightforward, rapid and low-cost analysis for obtaining pyrolysis and combustion profiles of fuels. TGA provides results concerning the various weight loss processes that can be a reflection of the physical and chemical structure of fuels, while additional information can be obtained by variation of TG variables, such as heating rate and purge gas type [2]. Fuel samples are exposed to a precisely defined heating programme while their mass loss, through very precise balance, is recorded. Experiments can be performed in an inert atmosphere (pyrolysis profile) or in an oxidative atmosphere (combustion profile). Usually, fuel samples are heated from ambient temperature to 900^0C. A significant amount of information, for thermochemical conversation, can be inferred from the data obtained through TGA analysis: elemental analysis, proximate analysis, heating value and other useful information affecting degradation kinetics of materials. The objective of this work was in performing thermogravimetric analysis of biomass and coal samples, since these two types of fuels dominates in energy usage [3].

MATERIAL AND METHODS

Sample preparation

The experiments were carried out with samples of sub-bituminous coal and commercially available beech pellets. In order to get representative samples, sampling of coal and pellets were performed according to [4] ASTM D6883 – 17 and [5] ISO 18135 standards respectively. Coal was sampled in form of lumps, cleaned from visible impurities, pulverized and sieved to dimensions of less than 5 µm. Primary sampled pellets had a diameter of 6 mm. They were also milled and pulverized to dimensions of less than 5 µm.

TGA experiments

Thermogravimetric analysis (TGA) was carried out using a Perkin-Elmer thermogravimetric analyzer TGA 4000 (Norwalk, CT). TGA 4000 is a top-loading instrument with a compact cylindrical ceramic furnace that ensures the large isothermal zone and provides the sample to be at the same temperature as the furnace. This configuration guarantees the reproducibility and repeatability of performed measurements. TGA is connected to the water cooling system (PolyScience chiller) that enables fast cooling of the furnace and conditioning during the TGA experiments. The calibration of the instrument, temperature, furnace, and weight calibration, was performed according to the manufacturer's recommendation. The temperature calibration was conducted by measuring Curie points of alumel, nickel, and iron.
Approximately 20 mg of sample was placed in the ceramic crucible. Samples were isothermally held at 30 °C for 5 min and then heated to the temperature of 900 °C. Three different heating rates were used: 10, 20 and 40 °C min^{-1}. For each material, and for each heating rate, at least three analysis were performed. Results presented in subsequent section correspond to the average values. As a system and sample purged gas nitrogen was used, at a constant purge flow rate of 20 mL min^{-1}. TGA analyzer was connected to the PolyScience chiller and the cooling temperature was set to 13 °C. After each experiment crucible was emptied, purged and heated again to 900 °C and subsequently cooled to ambient temperature in order to eliminate possible residues. The residual weight of the sample and the derivative of weight, with respect to time and temperature (differential thermogravimetry analysis, DTG), were recorded using Pyris software (software accompanying the instrument).

RESULTS AND DISCUSSION

In this paper thermogravimetric analysis (TGA) of two materials widely used for heating purposes, beech pellets and sub-bituminous coal, in a nitrogen atmosphere, at three different heating rates, was performed. Representative TGA plots, as well as corresponding derivative plots (DTG), are shown in Figs. 1 and 3. DTG curve highlighted that the pyrolysis of both samples occurred in three steps. The start and the end temperature of each step were determined by the intersection of tangents from the descending parts of the peak and the linear part of DTG curve as it was described by Kumar and his co-workers [6]. The temperature ranges of the steps depended on the heating rates (temperature scan rates). Tables 1 and 2 summarize the influence of heating rate on the temperature ranges of the steps and the weight losses during the pyrolysis, while the effects of heating rates on TGA plots are presented in Figs. 2 and 4.
As it has already been mentioned, the temperature ranges of stages depended on the heating rates. The start and end temperatures of each stage increase as the heating rate increases. This may be due to the heat transfer limitations because with an increase in heating rate longer time may be required for the purging gas to reach equilibrium with the temperature of the furnace or the sample [6]. However, as expected, the heating rate did not affect the total weight loss at any stage.

Thermogravimetric analysis (TGA) of beech pellets

Typical TGA and DTG plot of the of beech pellets in a nitrogen atmosphere are shown in Fig. 1. Based on their shapes one may conclude that there were three stages of weight loss during the pyrolysis of beech pellets. The first stage of weight loss that corresponds to the loss of water and light volatiles in the analyzed sample started at 30 °C. The end temperatures of this stage depended on the heating rate. At heating rates 10, 20 and 40 °C min^{-1} the end temperatures of the first stage were 110, 135 and 150 °C, respectively. Generally, low weight loss during this stage is due to the low moisture and light volatiles content in the sample.

Table 1. Dependence of weight loss on the heating rate during the pyrolysis of beech pellets

	10 °C min^{-1}		20 °C min^{-1}		40 °C min^{-1}	
	t (°C)	Wt (%)	t (°C)	Wt (%)	t (°C)	Wt (%)
Stage I	30	100	30	100	30	100
	110	93.67	135	90.84	150	91.92
Stage II	255	90.97	260	88.81	270	89.35
	395	29.35	410	29.54	420	29.02
Stage III	395	29.35	410	29.54	420	29.02
	900	14.99	900	17.82	900	18.35

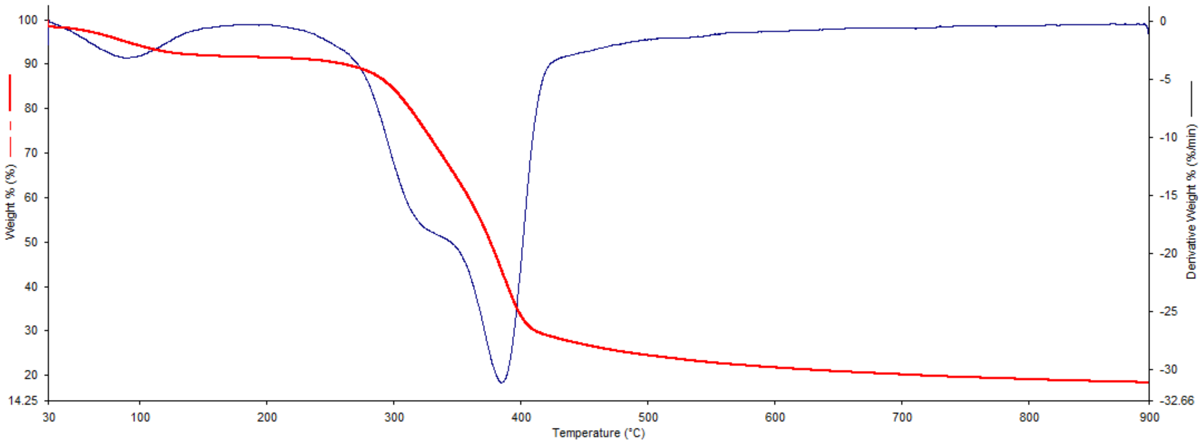

Figure 1. TGA (red line) and DTG plot (blue line) of beech pellets in a nitrogen atmosphere at the heating rate of 40 °C min^{-1}

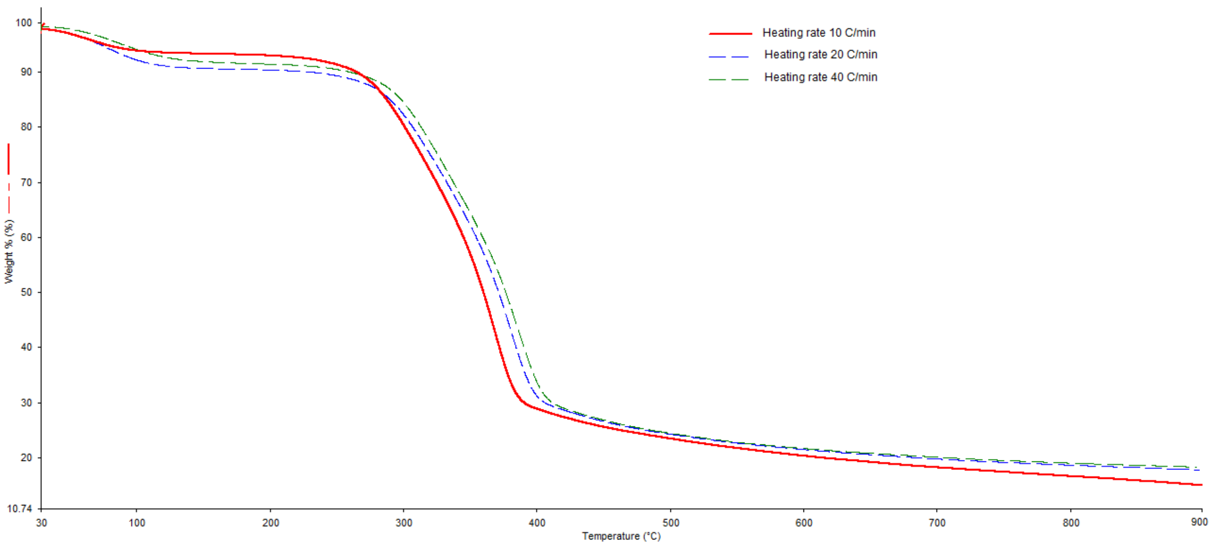

Figure 2. Effects of different heating rates on TGA plots of the pyrolysis of beech pellets

The second stage is the stage of the highest weight loss (*ca.* 60%) during the pyrolysis and it started at 250 – 270 °C and finished at 395 – 420 °C. This stage is characterized as the stage of active pyrolysis due to the high weight loss that probably corresponds to the major loss (decomposition) of cellulose and hemicellulose components and partial loss of the lignin component of the beech. This is in

accordance with the fact that during the TGA analyses of cellulose, hemicellulose, and lignin the loss of hemicellulose starts first and it is then overlapped with the loss of cellulose, while the loss of lignin is slow and occurs over a wide range of temperatures [7]. Between the first and the second stage, there was an insignificant weight loss (*ca*. 0.5%).
The continuous and slow weight loss, in the third stage, ranging from around 400 to 900 °C, may have been due to the thermal degradation of lignin or complex high-molecular-weight components of beech. This stage is designated as the passive pyrolysis zone. Generally, TGA plot of beech pellets was similar to the TGA plots of the other biomass samples, e.g. corn stover [6].
The residue, comprising of mineral constituents and chemically bound carbon, was in the range from 14.99 to 18.35 %. Such a low value was in accordance with the fact that the biomass belongs to a group of high volatile fuels.

Thermogravimetric analysis (TGA) of coal

Representative TGA and DTG plots of thermogravimetric analysis of coal in a nitrogen atmosphere are depicted in Fig. 3. As in the case of beech pellets, the pyrolysis processes of coal is also characterized by a three-stage thermal degradation. The temperatures limits of the stages were determined as described before and are given in Table 2. The temperature ranges of the stages depended on the heating rates (temperature scan rates) and the start and end temperatures of each stage increased with an increase in the heating rate.

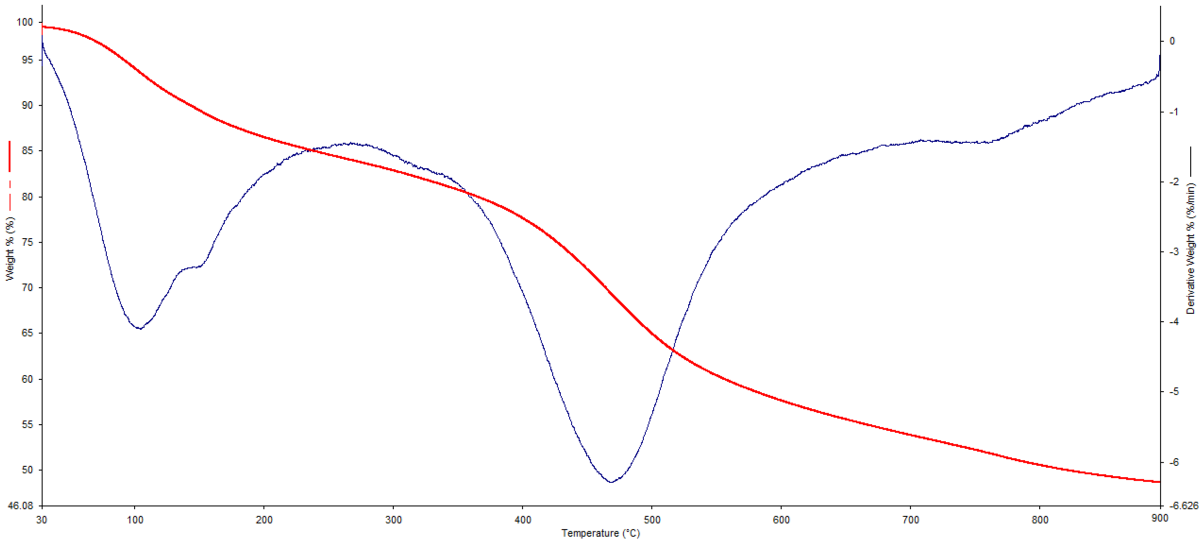

Figure 3. TGA (red line) and DTG plot (blue line) of sub-bituminous coal in a nitrogen atmosphere at the heating rate of 40 °C min^{-1}

The first stage of weight loss, corresponding to the loss of water and light volatiles in the analyzed sample, was in range from 30 to 160 – 200 °C. The end temperature of this stage was higher compared to the end temperature of the same stage in the case of beech pellets at the specific heating rate. Moreover, the weight loss during this stage was higher in the case of coal indicating higher water and light volatiles content in coal comparing to beech pellets.
The second stage of weight loss was in range from 335 – 355 to 565 – 590°C. As in the case of beech pellets, the weight loss during the second stage of coal pyrolysis was higher than the ones during the first and the third stage. However, the weight loss during the stage of active pyrolysis of coal was significantly lower compared to the one occurring during the same stage of pyrolysis of beech pellets (*ca*. 60%).

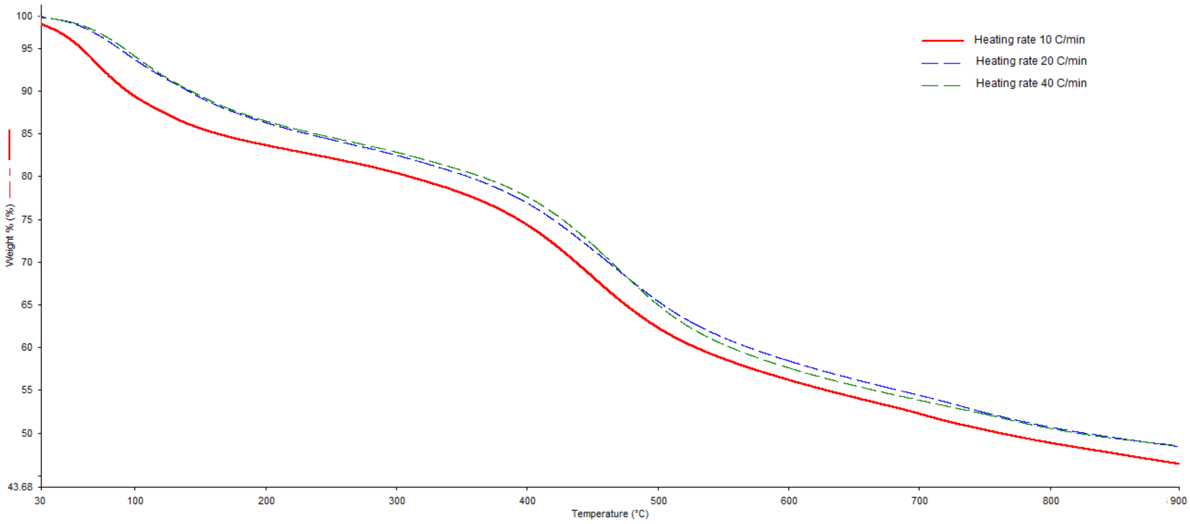

Figure 4. TGA and DTG plot of coal in a nitrogen atmosphere at the heating rate 10 °C min^{-1}

Table 2. Dependence of weight loss on the heating rate during the pyrolysis of brown coal

	10 °C min^{-1}		20 °C min^{-1}		40 °C min^{-1}	
	t (°C)	Wt (%)	t (°C)	Wt (%)	t (°C)	Wt (%)
Stage I	30	100	30	100	30	100
	160	85.14	180	87.32	200	86.53
Stage II	335	78.84	345	80.50	355	80.50
	565	57.85	590	58.93	590	58.10
Stage III	565	57.85	590	58.93	590	58.10
	900	46.37	900	48.52	900	48.65

This can be explained by the difference in the structural properties of the two analyzed materials. As it has been mentioned, beech pellets are built up from cellulose, hemicellulose, and lignin that are linked together by relatively weak ether bonds. On the other hand, relatively stable polycyclic aromatic hydrocarbons make the backbone of coal structure making the coal more resistant to thermal decomposition [8].

The third stage of the passive pyrolysis zone was ranged from 565 – 590 to 900 °C. The continuous and slow weight loss during this stage may have been due to the thermal degradation of lignin or complex high-molecular-weight components.

Generally, when comparing the weight losses of the stages, only the weight loss of the first stage was higher for coal than for beech pellets (Fig. 5). The weight loss of the second stage was significantly higher in the case of beech, while the weight loss during the third stage was comparable. The residual mass for coal was higher than for pellets due to its higher ash and fixed carbon content [8].

Moreover, the inflection points, the point of greatest rate of change on the weight loss curve, were determined and at the heating rates of 10, 20 and 40 °C min^{-1} they were 307.81, 314.53 and 318.80 °C for beech pellets and 376.71, 382.36 and 413.25 °C, respectively. Generally, the inflection point increased with an increase in the heating rate. The temperature at the peak of the DTG, indicating the temperature at which maximum weight loss occurs, was significantly lower for pellets then for coal, (for example, at the heating rate 20 °C min^{-1} the peak temperature for pellets was 381.95 °C and 471.17 °C for coal). This is due to differences in the fuel structures of coal and biomass. The peak in the DTG plot of beech pellets results from the thermal degradation of cellulose, while in the case of coal it is due to the release of volatile matter from sample. Furthermore, the decomposition of the coal sample in the active pyrolysis stage is slower as the coal has high carbon content [9].

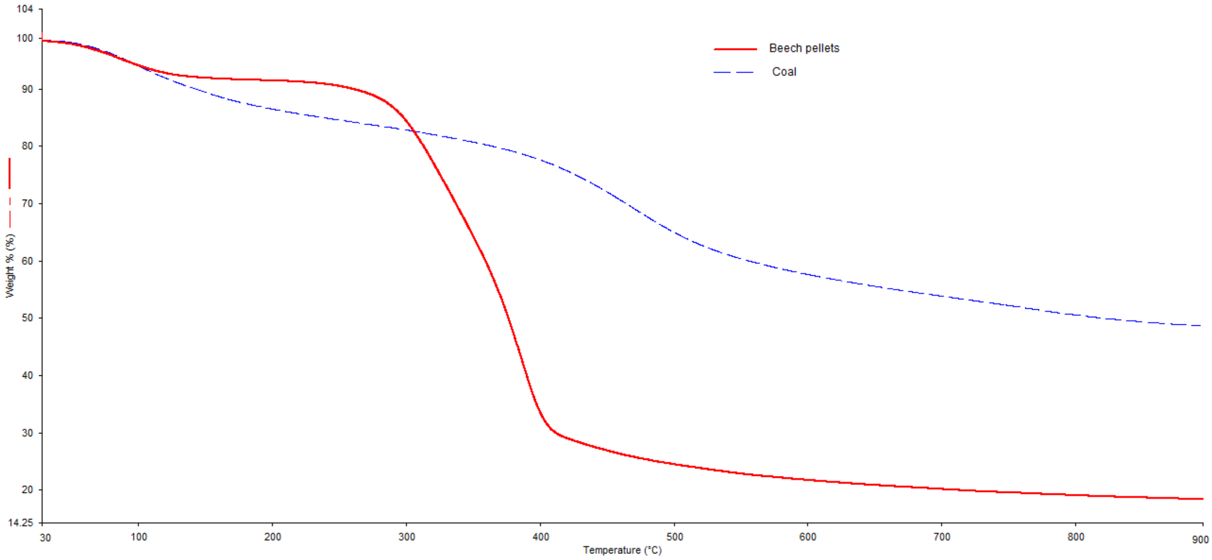

Figure 5. TGA plots of beech pellets and coal in a nitrogen atmosphere at the heating rate 40 °C min^{-1}

CONCLUSION

In this study, the pyrolysis characteristics of two typical solid fuels, beech pellets, and coal, have been examined through thermogravimetric analyses. Profiling was performed in an inert (nitrogen) atmosphere at three different heating rates 10, 20 and 40 °C min^{-1}. The results indicate that the thermal degradation processes of both samples are characterized by a three-stage reaction: water and light volatiles pyrolysis, active pyrolysis and passive (high volatiles) pyrolysis. The weight loss during the first stage (water and light volatiles) was higher in the case of coal sample due to higher moisture content. The low water content of pellets may be due to the technological process of pelleting during which biomass sample are substantially dried. As expected, the active pyrolysis was more pronounced for biomass sample than for coal. Additionally, the pyrolytic residue at 900 °C was substantially greater in the case of coal sample as a consequence of high content of chemically bound carbon and mineral compounds. Obtained results can be used as input parameters for designing and simulating different solid fuel thermochemical conversion processes.

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ASSESSMENT OF HEAVY METALS CONTENT IN URBAN SOILS USING KRIGING INTERPOLATION METHOD

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Abstract: Surface soil samples were taken from 121 locations in Novi Sad city area near the roads with different traffic density. The area under study was the size of (4 x 5) km^2. The pseudo-total concentration of metals (Cr, Ni, Pb, Zn) was determined using ICP-OES method. The mean values of the concentration of Cr, Ni, Pb, and Zn were 28.0, 28.7, 82.3 and 100.3 mg/kg, respectively. Interpolation method of ordinary kriging was used to obtain the contour maps of spatial distribution of these metals in the soil. The results of the statistical and spatial analysis indicate natural (geochemical) origin of chrome and nickel while the origin of lead and zinc is determined to be anthropogenic (motor vehicle emission).
Key words: kriging interpolation method, heavy metals, urban soil

INTRODUCTION

Rapid industrial growth and urban development of the society has, in addition to numerous advantages, also resulted in the intensified pollution of the environment. In comparison to rural areas, the soil in urban areas is more exposed to anthropogenic influences because of the higher density of population, the intensity of traffic, the proximity to industrial plants, etc. The contamination of soil by heavy metals leads to the disruption of natural geochemical cycles [1]. Due to the fact that they are not biodegradable and have complex activity in the soil as well as long biological half-lives of elimination from the body, heavy metals are classified as dangerous pollutants. Unlike organic pollutants, they do not undergo thermal or microbiological decomposition. Once they get into the soil, they stay there a long time and through absorption by plants they enter the food chain.
Geostatistical and multivariate methods, as well as GIS mapping, are often used to determine spatial distribution and behaviour of pollutants in the environment. Geostatistics is a branch of statistics which analyses and/or interprets spatially and temporally dependent variables. The use of geostatistics in spatial analyses and studies covers a wide range of applications, such as the use of interpolation models for developing various types of maps, sampling optimization, or spatial modeling and simulation [2].
Variogram is one of the key geostatistical tools. It is used for determining the behaviour of a selected variable in space, i.e., for defining the degree of spatial dependence [3]. When analysing data, the first phase involves calculating experimental variogram while in the second phase a suitable theoretical model is defined. A variogram is defined by the formula:

$$2\gamma(h) = \frac{1}{n}\sum_{i=1}^{n}[z(\boldsymbol{u}_i) - z(\boldsymbol{u}_i + h)]^2 \,. \quad (1)$$

Where:
n - number of data pairs at distance h (inside searching neighbourhood area)
$z(\boldsymbol{u}_i)$ - measured value at location i
$z(\boldsymbol{u}_i + h)$ - measured value at location $\boldsymbol{u}_i + h$.

When calculating an experimental variogram we first determine the distance between the points and then separate all pairs of points with the mutual distance h. The parameters of the theoretical model of a variogram are used to solve the kriging equation and it is therefore important that the theoretical and

experimental variogram match as much as possible. Variogram models can be different depending on the shape of the curve, with the spherical, exponential, Gaussian and linear model being most commonly used.
Kriging is one of the most commonly applied interpolation methods in environmental studies [4,5,6,7,8]. It is an advanced interpolation method for predicting the value of a regionalized variable located in space on a finite number of locations. In addition to the value of the variable in the known points, we need to know the distances between the known and the unknown points for which the prediction is made. The result of kriging is a cartographic representation of the spatial distribution of points. There are several methods of kriging which differ in relation to the shape of the matrix equation (simple kriging, ordinary kriging, universal kriging, indicator kriging, disjunctive kriging). All these methods determine the value of a variable in an unknown location [3]:

$$Z_k = \sum_{i=1}^{n} \lambda_i Z_i \ , \tag{2}$$

where:
- Z_k – estimated value based on n surrounding values
- λ_i – weight coefficient for kriging
- Z_i – known value at i-th location

In the next step we need to estimate the weight coefficients λ_i, as well as the values Z_k. To obtain this, we need to solve a system of kriging linear equations. A kriging algorithm studies the estimated values on the basis of the variogram which enters the kriging matrix. With ordinary kriging, the value of kriging variance is minimized by Lagrange factor so that:

$$\sum_{i=1}^{n} \lambda_i = 1 \, . \tag{3}$$

From a mathematical point of view, kriging is similar to regression analysis, since both methods are based on the spatial correlation of data. Kriging is frequently related to the abbreviation B.L.U.E. which stands for Best Linear Unbiased Estimator [9]. The estimator is linear because the equations contain a linear combination of the measured data. It is the best because it endeavours to minimize the difference variance between the real and estimated values. It is unbiased if there are no external influences on the variables and if the sum of all weight coefficients equals one.
This paper analyses the chrome, nickel, lead and zinc content in the soil in the Novi Sad urban area. The paper aims to develop geochemical maps for these metals and identify the areas (hotspots) which show the increased concentration of these metals.

MATERIAL AND METHODS

For the purpose of determining the distribution of heavy metals (Cr, Ni, Pb and Zn) 121 samples was taken from the soil on the territory of Novi Sad. Surface soil samples were taken from a depth of 0 – 10 cm in the close proximity of city roads. The investigated area was of the size 4 km by 5 km and was divided into 400 m x 400 m squares. From each square we took 12 – 15 subsamples from the area of 20 m^2 – 30 m^2 and the representative sample was obtained by mixing the appropriate subsamples. At each location, the exact spot where the samples were taken was determined by GPS (Global Position System) coordinates. The coordinates were determined using a GARMIN Eltrex Venture device. GIS mapping technique was used for determining the spatial distribution of Cr, Ni, Pb and Zn. The contour maps of the metal contents were obtained using the programs ArcView 9.3 [10] and Quantum GIS 1.7.0 (QGIS). The grid was formed based on (25 × 25) m^2 area using the appropriate input data.

RESULTS AND DISCUSSION

The obtained results were analyzed using descriptive statistics methods of Microsoft Office Excel 2003. The studied metals, sorted in descending order in relation to the mean values of their concentrations, form the following list: Zn, Pb, Ni, Cr. The highest mean value was obtained for Zn (100.3 mg/kg) followed by Pb (82.3 mg/kg). For Ni and Cr the mean values were 28.7 and 28.0 mg/kg, respectively.
One of the factors which can indicate the anthropogenic origin of heavy metals in the soil is the enrichment factor (EF) which shows how many times the concentration of a metal in a sample is higher than the background concentration. All the samples showed minimal enrichment values for Cr. Most samples showed minimal EF values for Ni and Zn and about a third of the samples showed moderate enrichment (values 2 - 5 times higher than the background concentration). The highest amount of pollution was found for Pb: with 25% of the samples the values were significantly higher (5 - 20 times) that the background concentration. An extremely high EF value (EF > 40) was registered in one sample.
The data on the metal concentration were used as input for developing the contour maps with the aim of studying the distribution of metals in the soil in the studied area. Advanced interpolation method of ordinary kriging was used for this purpose. The variogram is used to express the variance of property changes over the surface, based on the distance and direction separating two sampling locations. As a result of kriging, a cartographic display (graphical model) was obtained which illustrates the spatial distribution of data.
The resulting contour maps of levels of metals investigated in urban soils are illustrated in Figures 1 and 2. As seen from the maps in Figure 1, the spatial distribution of Cr and Ni are considerably different from the distribution of Pb and Zn (Figure 2). The shape of the distribution of Cr and Ni, as well as their rather low content in the soil, seem to indicate their natural origin. They most probably have an origin in the alluvial deposits made in the recent pedogenesis processes. According to the literature [11] parent material in alluvial areas, primarily in limestone terrain, determines the content of Cr and Ni. Other studies also confirm the presence of Cr and Ni in alluvial areas [12,13,14].

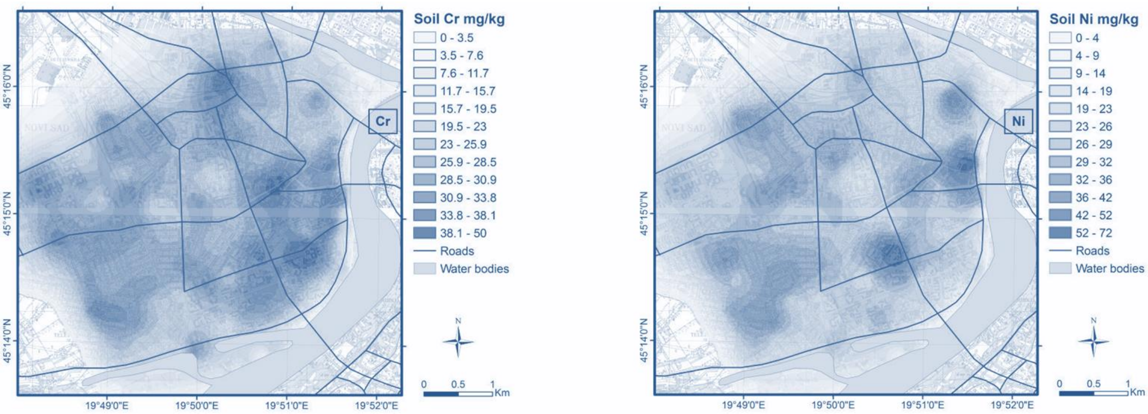

Figure 1. Spatial distribution of pseudo-total Cr and Ni content in urban soil of Novi Sad

In contrast to the distribution of Cr and Ni described above, the distribution for Pb and Zn is different in shape and, in addition, greater variations in the content of these two materials are also noticed. The locations near the roads with high traffic density show higher levels of these metals: the concentration of lead is usually in the interval of 200 to 320 mg/kg and that of zinc varies between 100 to 190 mg/kg. The map of Pb indicates a hotspot with a particularly high concentration (999 mg/kg) near a not particularly busy road. It was subsequently established that the source of the contamination can be traced to a lead battery manufacturing plant located a few dozen meters from the sample location. The results of the spatial analysis are in accordance with the results obtained by statistical analysis: the raised level of concentrations and variations of the levels of Pb and Zn in the Novi Sad city area indicate that these two metals originate from the same anthropogenic source which is traffic i.e., motor vehicles.

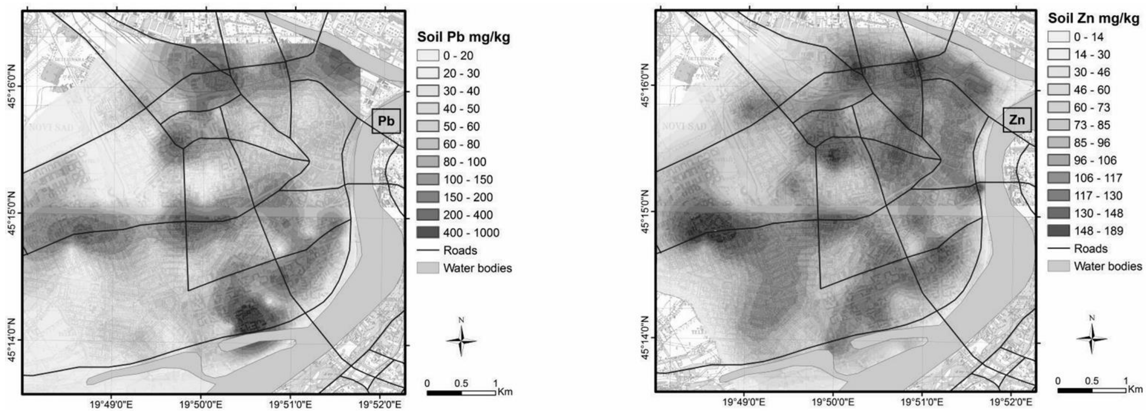

Figure 2. Spatial distribution of pseudo-total Pb and Zn content in urban soil of Novi Sad

CONCLUSION

On the basis of the obtained results the presence of Cr and Ni in the soil is linked to natural (geochemical) origin – most probably the alluvial deposits made in the recent pedogenesis processes whereas the presence of Pb and Zn is related to anthropogenic factors. The assumption that the main anthropogenic source of these metals is traffic is supported by their spatial distribution. Namely, the distribution maps clearly show the difference between these two pairs of metals, particularly in the vicinity of main roads, with considerably higher levels of Pb and Zn measured near the roads with higher traffic density.

ACKNOWLEDGEMENT

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HERBICIDAL IMPACTS ON SOIL BIOPROCESSES IN ALFALFA RHIZOSPHERE

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Abstract: Soil microbiotas regulate the bioprocesses in soil that are essential for plant growth, soil health and sustained productivity. Application of herbicides may not affect the overall size of the soil microbiotas but selectively can effect on specific microbial groups which may result in changing the balance of bioactivity and consequently nutrient availability, disease incidence and plant growth. In the current study, N_2-fixing soil microbial populations and their activities were determined in microcosms under the stress of 8 herbicides were applied at 3 doses based on the active ingredients and incubated for 10 weeks at 28°C. Results indicated that: Some of herbicides applied had negative impact on symbiotic N_2-fixation by legumes in rotation and application of a post-emergent herbicide caused significant changes in the microbial community and the activities of some hydrolytic enzymes in the rhizosphere. Impacts of glyphosate on rhizosphere microorganisms and activities were investigated. Information on the effects of herbicide application on useful soil microbiotas and their bioprocesses is necessary for the successful crop production. A particular practice may have the desired result in one situation but have little effect in another because biological communities respond to the interaction of multiple factors including food sources, physical habitat, moisture, and impacts of historical land use. Therefore, before a new product is applied to a field soil, it should be tested on a limited area and the results should be monitored in comparison to an untreated one.
Key words: herbicides, glyphosate, soil bioprocesses, alfalfa rhizosphere

INTRODUCTION

The goal of managing the soil biology is to improve biofunctions, e.g., forming and stabilizing soil structure, cycling nutrients, controlling pests and disease, and degrading or detoxifying contaminants. New climatic change and agricultural practice have led to an emerging pressure from weeds and phytopathogens, which complicate farming practice and have resulted in the increased use of agrochemicals worldwide. The term “Pollution” has many definitions, one being the presence of a substance in the environment whose chemical composition or quantity prevents the functioning of natural processes and produces undesirable environmental and health effects [1]. Pollution prevention is defined as the reduction of pollutants at the source. Moreover, the technological advancement has also given rise to new pollutants which are increasing at an alarming rate and are above the self-remediating ability of the environment. There is an urgent need to find technologies that would reduce these rates/pollution levels to risk-free status in quick and easy manner [2]. Soil microbiomes are very important for agroecosystem function and sustainability due to their contributions to nutrient cycling and to soil structure maintenance [3, 4]. Microbial properties like microbial diversity and biomass are useful for predicting changes in the soil functioning and for providing an integrated and relevant vision of soil quality. Little information is currently available for preventing the loss of microbial diversity and activity through the use of sustainable farming practices from the first cultivation year. Plants are able to select their own microbiome based on their specific root exudates or some other strategies such as root physical structure and mineral nutrients preference [5]. The exposure to pesticide has detrimental effects on health and might contribute to an increased risk of long-term diseases, including cancer and neurodegenerative diseases, reproductive and developmental disturbances, and emerging risks such as developmental neurotoxicity and immunotoxicological effects [6]. Microbial activity may increase in rhizospheres of glyphosate-treated plants through translocation and release from roots, where it is immediately metabolized resulting in stimulation of activity and changes in functional diversity of the heterotrophic microbial community [7], or by functions as described by Wardle [8]. Herbicide use is a vital component of modern agriculture; in particular under reduced till systems. With increased adoption of stubble retention and reduced till practices and the introduction of new herbicides, herbicide use will remain as an essential practice in the near future.

Application of herbicides may not affect the overall size of the microbial pool but selectively affect specific groups of microbiotas which may result in altering the balance of biological activity (soil biological health) and consequently nutrient availability, disease incidence and plant growth.
The primary function of herbicides is to protect agricultural crops from infestation with weeds and to prevent arable soil from being overgrown by plant cover indigenous to the ecosystem. The chemicals known as herbicides are mainly synthetic organic compounds with broad molecular configurations having as a common property the ability of selectivity killing or inhibiting the growth of plants. The effects of 2,4-D, a potent herbicide, on the rhizosphere associated N-ase, N_2-fixing bacteria and plant growth characters are little understood [9]. Glyphosate, a widely used broad spectrum, non-selective, post-emergence herbicide has been shown to reduce soil bacterial populations in field soils [10]. Bayoumi [11] studied the sensitivity of three strains of *Rhizobium leguminosarum* bv. *viceae* comparing with strains of *R. leguminosarum* bv. *phaseoli*, *R. leguminosarum* bv. *trifolii*, and *R. loti* to 8 herbicides. Among them, Paraquat was the most toxic one. Bayoumi et al. [12] reported that Acetochlor was the least inhibitor on tested *Rhizobium* strains. Bayoumi & Kecskés [13, 14, 15] in pot experiments established that microsymbionts were more sensitive to Trifluralin than macrosymbionts, whereas are sensitive to Paraquat, which reduced the size, number and dry weight of root-nodules, phytobiomass, height, and total N-content / plant. Eberbach & Douglas [16] found Paraquat and Trifluralin affected the nodulation potential of *Rhizobium*-legume. Quantitative and representative recovery of microorganisms from environmental samples is essential in understanding ecosystem function. Microbial communities play essential roles in the earth's ecology. A powerful concept in modern biology is that of the ecosystem. Soil enzymes are present in important cycles, such as C (invertase), N (urease and protease), and P (phosphatase) cycles. Soil enzyme activities are used as indices of microbial activity (Bergstrom et al., 1998) and react quickly to environment change. Hydrolytic enzymes activities (phosphatase, β-glucosidase), oxidoreductase activities (dehydrogenase) and indole acetic acid production, were used as measures of soil perturbation by Benitez et al. (2004). The hypothesis in this study is to estimate the effects of applied herbicides on (1) survival of symbiotic N_2-fixing bacteria before and after herbicide application and (2) activities of some soil enzymes.

MATERIAL AND METHODS

The soil sample used for the present study was collected from a non-cultivated field (without previous treatments) of the experimental station at Szent István University, Gödöllő, Hungary. The soil of the sampling area was sandy brown forest of general properties are given in Table 1. The first portion was stored at 4°C for enzymatic activities and microbiological analyses. The second portion was stored at cool room for plant-microbe interaction. Herbicides Sys 67 B 80%, Dikamin D 40%, Ro-Neet 6E 74%, Gliaka 20%,, Linuron 50%, Sys 67-ME 80%, Gramexone A 25%, and Treflan 26% were used in the *in vitro* while Glyphosate used *in vivo* experiments. The characterisations of the tested herbicides are mentioned in Table (2).

Table 1. Physical and chemical analysis of used soil

Different parameters	Value of contents
pH_{KCl}	5.33
pH_{H2O}	6.71
KA	24.6
Total Salt %	0.03
$CaCO_3$ %	0.01
Humus %	1.22
NH_4-N mg/kg	1.69
NO_3-N mg/kg	3.08
AL-K_2O mg/kg	107
AL-P_2O_5 mg/kg	106.1
Oxalate Fe mg/kg	789
Na mg/kg	36
Mg mg/kg	203
Zn mg/kg	6.9
Cu mg/kg	2.7
Mn mg/kg	36
SO_4 mg/kg	4.8

Table 2. Some characteristics of herbicides used in laboratory and greenhouse investigations

Group	Common name	Active substance	Field Recommended
Aliphatics	Gliaka	Glyphosate (20%)	1.2 l
Bipyridylims	Gramexone A	Paraquat (25%)	3.5 l
Carbamates	Sabet 72 EC	Cycloate (72%)	4.0 l
Dinitroanilines	Treflan	Trifluralin (26%)	3.5 l
Phenoxys	Dikamin D	2,4-D (40%)	2.4 l
	Sys 67 B	2,4-DB (80%)	2.0 kg
	Sys 67-ME 80	MCPA (80%)	2.0 kg
Substituted Ureas	Linuron 50	Linuron (50%)	2.0 kg

Eight herbicides were subjected to establish their side-effects on the growth rate of 8 *S. meliloti* strains in YMB medium using microfermentor technique [12, 15] at 5 concentrations of active ingredients (0.1, 1.0, 10.0 and 100 mgl^{-1}) of each herbicide. The experiment was designed to detect the interactions between the herbicides amendment and the biological N_2-fixation in brown forest soil as well as the potential activities of some soil enzymes in rhizosphere soil. The study was conducted in pot experiment predicated to low and high herbicide doses. The herbicide was applied to the soil before (post-emergence) and after (pre-emergence) plantation and plant inoculation in two separated sets of pots. Generally, the following experiments of predicating the impacts of herbicide on the plant-microbe interactions were carried out using one Hungarian cultivar of alfalfa, three new isolated strains of S. meliloti (GHF-162, GHF-281 and GHF-3153), one standard strain (GHR-94) and one herbicide Glyphosate at 3 concentrations (Table 3). Sterile plastic pots of 3 Kg capacity were used, filled with 2 kg sterile (steamed 100°C for 1 h on three consecutive days) brown forest soil. Seeds of *M. sativa* were surface-sterilized and germinated in the pots. The post-emergence or pre-emergence application of the Glyphosate was applied to 3 kg soil accordance with the fact that one hectare containing 3.6 x 10^6 kg soil, 10^4 m^2 (surface area), 0.25 m (depth) and 1.44 kg m^{-3} (soil density). The commercial formulation of the tested herbicides diluted with sterile distilled water to the appropriate concentration of each one according to its active ingredient (a.i.) on top of 25 cm of field soil.

Table 3. Herbicide treated doses

Active ingredient (a.i)	Rate (liter a.i/ha)	Relevance to field application rate
Glyphosate	0.60	½ Recommended
	1.20	Recommended
	2.40	2 x Recommended

Seeds were selected for healthy and uniformity without any injury, and surface sterilized with 70% ethanol followed by acidified 0.2% $HgCl_2$ for 5 minutes, and thoroughly washed in several changes of sterile distilled water. Seeds were then soaked for 8 h at room temperature in sterile distilled water (soaking water was changed every 2 h) and then seeds were germinated on sterile moisted filter paper in large Petri dish for 72 h in the dark at 28°C according to Franco & Vincent (1976). Seedling rhizosphere was inoculated with 10 ml of a suspension of biofertilizer *Sinorhizobium* inoculum (GHR-94, GHF-162, GHF-281, or GHF-3153) prepared as follows: each one of the five biofertilizers *S. meliloti* strains was grown in YMB for 48 h at 28°C, to give a final cell concentration 2.5 x 10^8 cell capacity ml^{-1}, using haemocytometer for calibration. Seedlings were watered with sterile tap water when required, and the plants grown under natural illumination (14 h) at around 28 ± 2°C.

At the end, plants were carefully uprooted, and washed several times in tap water for farther investigations. Data recorded / plant as follows: Height of plant shoot in cm, number of root nodules. Dry weight of plants biomass and nodules were determined after oven dried at 75°C to a constant weight and the values were expressed as g plant^{-1} and mg root nodules plant^{-1}. Total N-content (mg plant^{-1}) was measured using micro-Kjeldahl method as a criterion of N_2-fixation [17]. Therefore, all visible plant fragments were carefully removed from the soil sample prior to the enzyme assays. The potential activities of some enzymes in the alfalfa rhizospheres and soil bulk were measured under the stress at different concentrations of herbicides, and inoculated different biofertilizers strains of *S. meliloti*. The following enzymes were determined: Dehydrogenase activity: was determined according to García et al. [18]. Dehydrogenase activity is expressed as μg of INTF per gram dry soil. Protease activity on N-α-benzoyl-L-arginamide (Protease-BAA) was measured using the method of Nannipieri et al. [19]. Protease activity is expressed as μmol of NH_4^+-N released per gram dry soil per hour. Phosphatase activity was carried out using the method of Tabatabai & Bermner [20] and the phosphatase activity is expressed as μmol of PNP per gram dry soil and incubation time (hour). β-glucosidase activity is expressed as μmol of PNP per gram dry soil and incubation time (hours) after applying the method of Masciandaro et al. [21].

RESULTS AND DISCUSSION

Table 4 summarized the relative growth rates and the tolerance ability of the *S. meliloti* strains toward the potent effect of herbicides in compared with control growth of the strains in herbicide-free broth medium. These investigations showed that herbicide MCPA had no harmful influence on *S. meliloti* strains GHR-94, GHF-162, GHF-281, and GHF-3153. However, the other strains were tolerated the herbicide-amended YMB up to 10 mgl^{-1}. Herbicides Paraquat and Trifluralin were highly toxic to the all tested strains and their effect was rapid. The investigated strains can be grouped in three groups according to the effect of Paraquat, first group contained tolerant strains to 10 mgl^{-1} (GHR-94, GHF-162, GHF-281 and GHF-3153), the second group included the tolerant strains to 1 mgl^{-1} (GHF-1141 and GHF-353), the third group of strains tolerant 0.1 mgl^{-1} (GH-130 and GHF-2100). Herbicides Linuron, Cycloate and Glyphosate were toxic to all strains but at 100 mgl^{-1}. But their effects on the growth rate of strains were more gradual compare with the effect of Paraquat and Trifluralin. Herbicides 2,4-D, 2,4-DB, had stimulated effect on the growth of the strains GHR-94, GHF-162, GHF-281 and GHF-3153 throughout all investigated concentrations. These herbicides stimulated the growth rates of the all tested strains at different patterns at 1 mgl^{-1} and 10 mgl^{-1} but at 100 mgl^{-1}, strains GH-130, GHF-1141, GHF-2100, and GHF-353 were inhibited. The results indicated that the most tolerant strains of *S. meliloti* were GHR-94, GHF-162, GHF-281 and GHF-3153. Also, most of statistically significance values as regard between the relative growth rate of the different investigated strains and the low and high of herbicidal concentrations.

Table 4. Tolerance of the selected strains to concentrations of herbicides

Strain	Herbicides (mg/l)							
	Glyphosate	*Paraquat*	*Cycloate*	*Trifluralin*	*2,4-D*	*2,4-DB*	*MCPA*	*Linuron*
GHR-94	*100*	*10*	*100*	*10*	*> 100*	*> 100*	*> 100*	*100*
GH-130	*100*	*0.1*	*100*	*1*	*> 100*	*> 100*	*10*	*100*
GHF-162	*100*	*10*	*100*	*10*	*> 100*	*> 100*	*> 100*	*100*
GHF-1141	*100*	*1*	*100*	*1*	*> 100*	*> 100*	*10*	*100*
GHF-281	*100*	*10*	*100*	*10*	*> 100*	*> 100*	*> 100*	*100*
GHF-2100	*100*	*0.1*	*100*	*1*	*> 100*	*> 100*	*10*	*100*
GHF-353	*100*	*1*	*100*	*1*	*> 100*	*> 100*	*10*	*100*
GHF-3153	*100*	*10*	*100*	*10*	*> 100*	*> 100*	*> 100*	*100*

In addition, to determine the impacts of herbicide (Glyphosate) on the effectiveness (dry matter and total N content), „saprophytic competence” and competitiveness to evaluate the nodulation potential of the strains, in vivo experiment was conducted in a pot model under several factors. This investigation was done to show the influence of application of different factors such as herbicide applied in post- and pre-emergence of young alfalfa seedlings inoculated with the biofertilizer of *S. meliloti* strains (GHR-94, GHF-162, GHF-281 and GHF-3153). The results showed that reduction in nodulation was usually associated with reduced plant growth caused by herbicidal injury. The double of field recommended applied dose of herbicide in pre-emergence phase reduced the morphological characterization and plant dry weight of the plant as well as the symbiotic properties. These investigations show that herbicide Glyphosate had no harmful influence on the investigated *S. meliloti* strains if used as recommended. Generally, herbicide is presently used for establishment of alfalfa. The herbicide at three applied rates (0.5x, x and 2x, x = FRD) did not cause any visual phytotoxicity to the plant crop. Glyphosate had significantly improved the number and size of nodules especially those plants inoculated by the new isolated strains (GHF-162, GHF-281 and GHF-3153) compared with standard strains GHR-94. Figure (1) shows the impacts of soil treated Glyphosate on the nodule numbers formed by different strains of biofertilizer. In Figure 1, results indicated a significance differences between the controls plants grown in soil free from herbicide treatment and those plant grown in soil treated with herbicide at post-emergence at 0.5x dose applied to the soil. But when the herbicide was applied as pre-emergence, no statistical differences were recognized throughout all treatments.

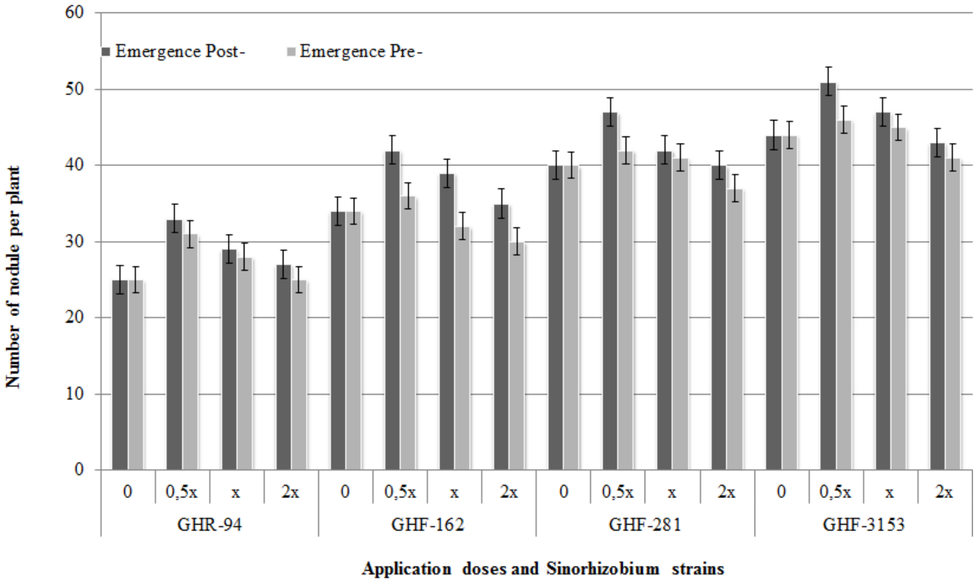

Figure 1. Impacts of post- and pre-emergence of Glyphosate on nodule number (number plant^{-1}) of alfalfa root inoculated by different biofertilizers

The nodule formation at post-emergence was more than at the pre-emergence condition. Only one case showed statistically difference between the plant inoculated by all biofertilizers and Glyphosate at 0.5x under post-emergence. The results indicated that the new isolated strains were more effective to modulate the plant than the standard strain (GHR-94) did. Here, the nodulation potential of the strains in decreasing order can be GHF-3153 > GHF-281 > GHF-162 > GHR 94. Figure 2 shows the relationship between the application of Glyphosate and the nodule dry weight, under the artificial inoculation by different biofertilizers. It was found that, the nodule dry weight in the case of post-emergence was more than those in the pre-emergence, and the results showed a statistically differences in the nodule dry weight on at the 0.5x level of herbicide applied dose. Similar results can be obtained based on the nodule dry weight in which the efficiency of the strain towards the effect of Glyphosate in decreasing order is GHF-3153 > GHF-281 > GHF-162 > GHR 94. The biofertilization of the plant with the new isolated strains of *S. meliloti* improved the plant height than the standard strain GHR-94. The effective strain was GHF-3153. Figure 3 explains the beneficial inoculation of the plant by the biofertilizer strains of *S. meliloti*. The plant dry weight is a fact of that the symbiosis take place and the process was efficient. This means that the biological N_2-fixation was happened, and the plant can accumulate the dry matter. The application of the herbicide Glyphosate at post-emergence to the soil significantly increased the plant dry matter compared with the control. But at pre-emergence application, the results were significant differences when the plant inoculated by GHF-162. The present study showed that there was no statistically a difference between the post- and pre-emergence application of herbicide in term of plant dry weight.

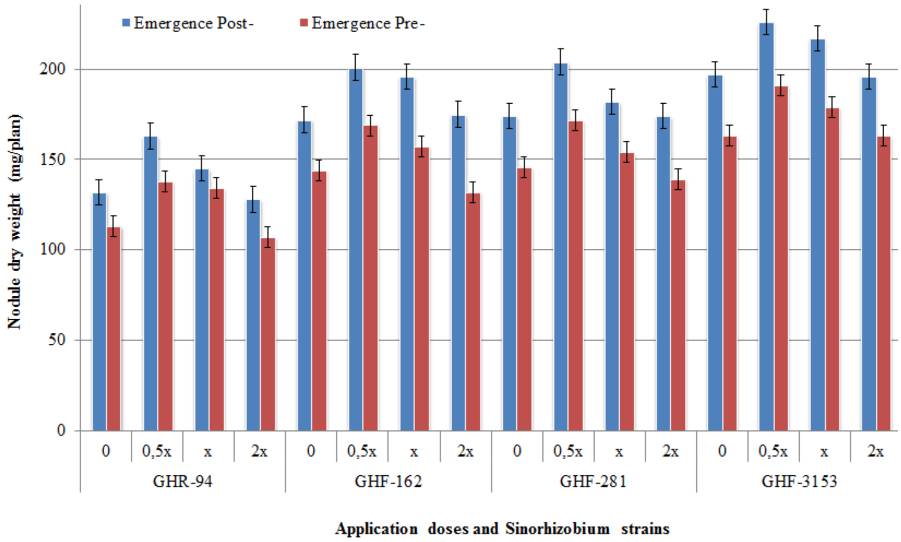

Figure 2. Impacts of post- and pre-emergence of Glyphosate on nodule dry weight (mg plant-1) of alfalfa root inoculated by different biofertilizers

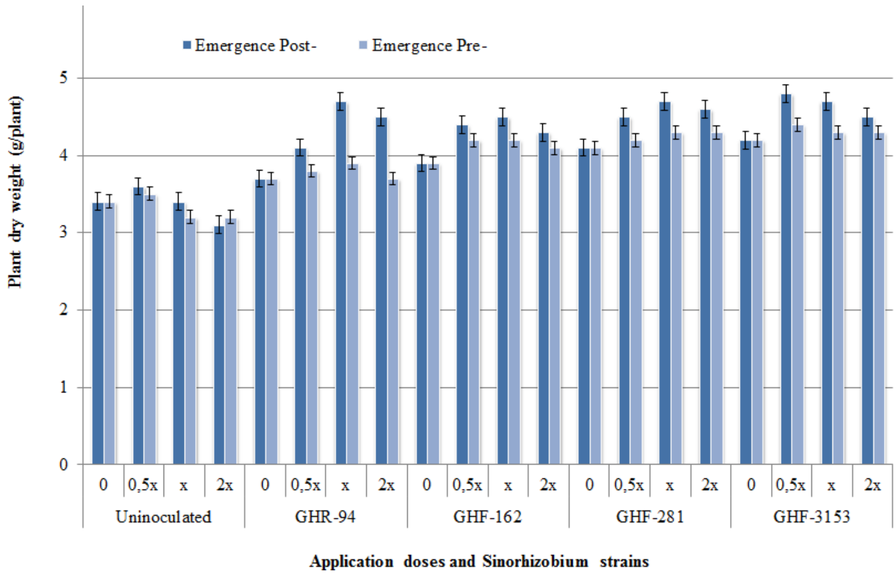

Figure 3. Impacts of post- and pre-emergence of Glyphosate on plant dry weight (g plant-1) of alfalfa root inoculated by different biofertilizers

The results indicated that GHF-3153 is the most effective strain. The concept of total N content per plant gives an idea about the N fixed by the association between the symbiotic partners as shown in Figure 4. It was found that the N accumulated in plant after inoculation with biofertilizers was increased compared with the control uninoculated plants. Also, it was indicated that the strain GHF-3153 is the most effective strain and economically can be industrially formulated as biofertilizer with high potent to increase the plant growth, plant dry matter and able to fix the atmospheric N more than the other investigated strains. It was found that the application of herbicide at the x and 2x of FRD increased significantly the amount of N accumulated in the plant; also the amount of N measured in plant grown at post-emergence application of herbicide was higher than the amount measured at pre-emergence. In pre-emergence, the application of double FRD was significantly increased the amount of N in the plants. The results directly demonstrated high amount of N content in the plant and indirectly showed the ability of the strains to multiply and survive in the soil. Alfalfa - *S. meliloti* strains in symbiotic relationship in the presence or absence of herbicide enhanced soil enzyme activities in the rhizosphere soil. In this study, soil treated with Glyphosate at 0.5 x had greater dehydrogenase, protease, phosphatase and β-glucosidase activities than soil treated with higher concentrations (Figures 5-8).

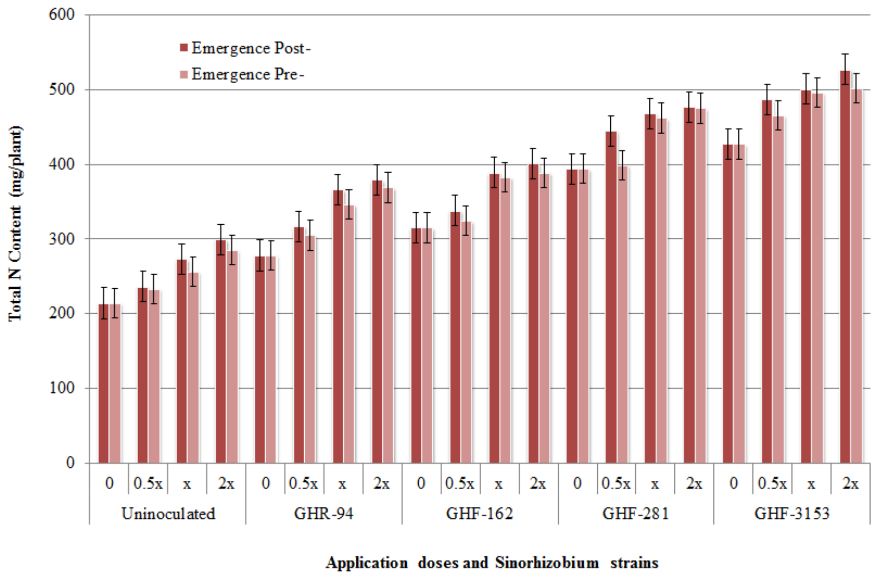

Figure 4. Impacts of post- and pre-emergence of Glyphosate on total N content (mg N plant^{-1})

Figure 5. indicates that the inoculation promoted the dehydrogenase activity and enhanced the enzyme activity at post-emergence over the activity at the pre-emergence. The results showed that application of Glyphosate at x and 2x of FRD were more statistically significant with the control. The inoculation of plants with GHF-3153 more effective to enhanced the activity of the enzyme. Figure 6. shows that the biofertilization of plants with *S. meliloti* strains promoted the protease activity and enhanced the enzyme activity at post-emergence over the activity at the pre-emergence. Similar mode of interactions between the symbionts and the application of herbicide were observed in case of determining the activity of protease. The results showed that application of Glyphosate at x and 2x of FRD were more statistically significant with the control and the inoculation of plants with GHF-3153 more effective to enhance the activity of the enzyme. Statistically, significant differences between the FRD of the herbicide at higher doses and the enzyme activity were found. Figure 7. illustrates that the *S. meliloti* strains promoted the phosphatase activity and increased the enzyme activity at post-emergence over the activity at the pre-emergence. Similar results were found as in the cases of dehydrogenase and protease that the effect of the plant inoculation with different strains of S. meliloti of interactions between the symbionts and the application of herbicide were observed in case of determining the activity of phosphatase. These results showed that application of Glyphosate at x and 2x of FRD were more statistically significant with the control and the inoculation of plants with GHF-3153 more effective to enhance the activity of the enzyme. Figure 8. shows that the activity of β-glucosidase activity in the rhizosphere of the alfalfa plants inoculated by different strains of *S. meliloti* was increased with the increasing the concentrations of the herbicide Glyphosate, especially at higher concentrations which show a statistically significant. The strain GHF-3153 proved to be ecological important for increasing the activities of the soil enzymes and reduce the toxicity of the herbicide.

New climatic change and agricultural practice have led to an emerging pressure from weeds and phytopathogens, which complicate farming practice and have resulted in the increased use of (new) agrochemicals worldwide. Herbicides can exert collateral effects on soil microbiotas and important functions such as N cycling, decomposition, hydrolytic enzyme activities, etc. Some of these compounds represent a source of N to microbial communities through mineralization. Soil microbiotas regulate a majority of processes in soil that are essential for plant growth, soil health and sustained productivity. A large, diverse and active soil microbiotas could provide soil conditions for sustainable crop production through (i) crop residue decomposition and improvement of nutrients, (ii) preventing aggressive phytopathogens taking hold and improve plants ability to withstand disease effects, (iii) reducing the loss of inorganic fertilizers through erosion and leaching by short-term immobilization (iv) stabilizing soil structure and (v) reducing the reliance for agrochemicals and reduced persistence of pesticides in soil and thus less off-site impacts.

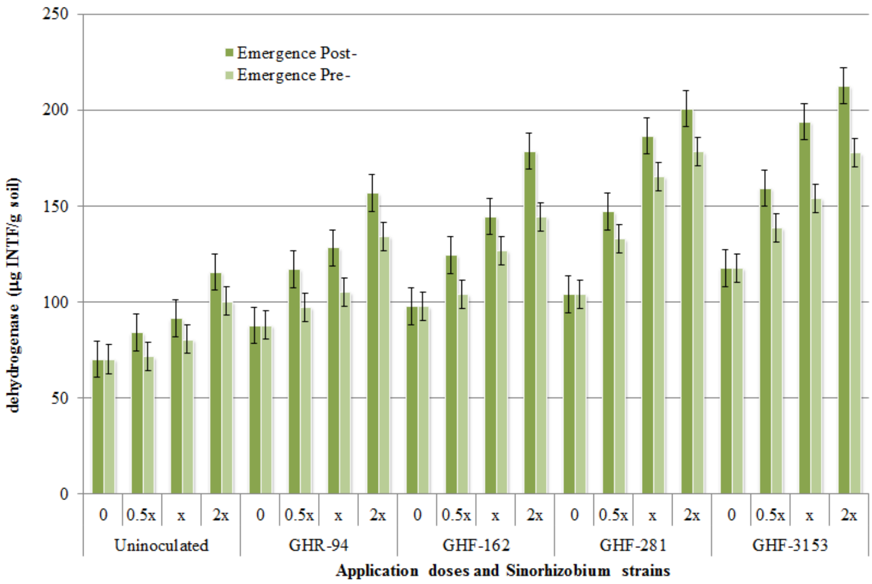

Figure 5. Impacts of post- and pre-emergence of Glyphosate on the activity of dehydrogenase (µg INTF/g soil) in the rhizosphere

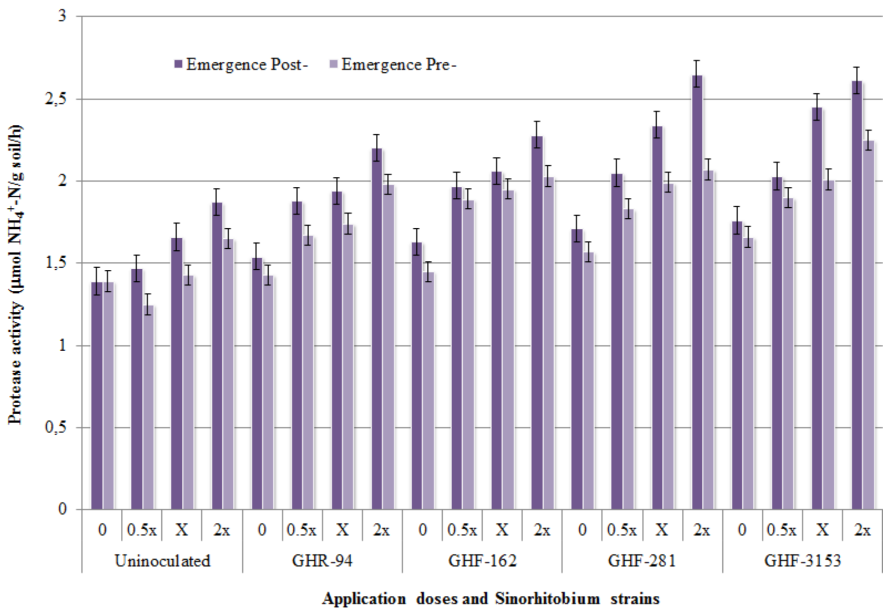

Figure 6. Impacts of post- and pre-emergence of Glyphosate on the activity of protease (µmol NH_4^+-N/g soil/h) in the rhizosphere

Application of herbicides may not affect the overall size of the soil microbiotas but selectively affect specific groups of microbiota which may result in altering the balance of biological activity and consequently nutrient availability, disease incidence and plant growth. Non-target effects of herbicides could be either positive or negative. Management of herbicides usage that cause reversible inhibitions is difficult, as reaching a balance between high herbicide efficiency and minimum non-target effects requires a better understanding of herbicide-microbial communities-environment interactions.
Different soil microbial populations and their activities were determined in a microcosms of 3 kg capacity under the stress of 8 herbicides were applied at 3 doses based on the active ingredients and incubated for 10 weeks at 25°C. Results from these investigations on the effects of a single application of selected herbicides in alfalfa growing soils indicated that: Some of herbicides currently used in alfalfa soils have a negative impact on key groups of microorganisms; Most of the negative effects were reversible partly or fully within 10-weeks after herbicide application; Some herbicides caused a significant shift in bacteria : fungi ratio, reduced the rate of cellulose-decomposition; Some herbicides applied had negative impact on symbiotic N_2-fixation by legumes in rotation and application of a post-

emergent herbicide caused significant changes in the rhizosphere microbial activity and the composition of microbial community as well as the activities of some hydrolytic enzymes. Both Glyphosate and Paraquat were reported to cause activation in soil urease and invertase soil enzymes but suppression of phosphatase [22].

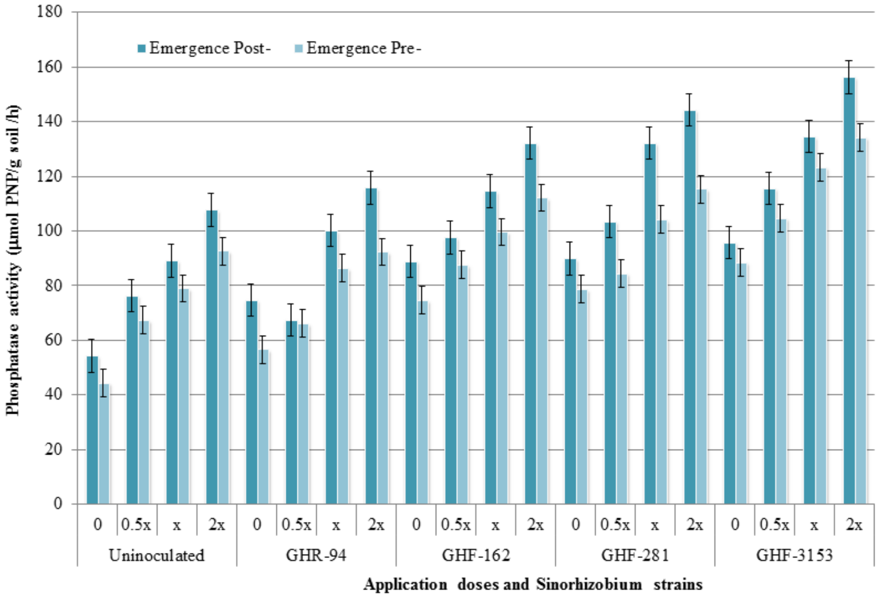

Figure 7. Impacts of post- and pre-emergence of Glyphosate on the activity of phosphatase (μmol PNP/g soil /h) in the rhizosphere

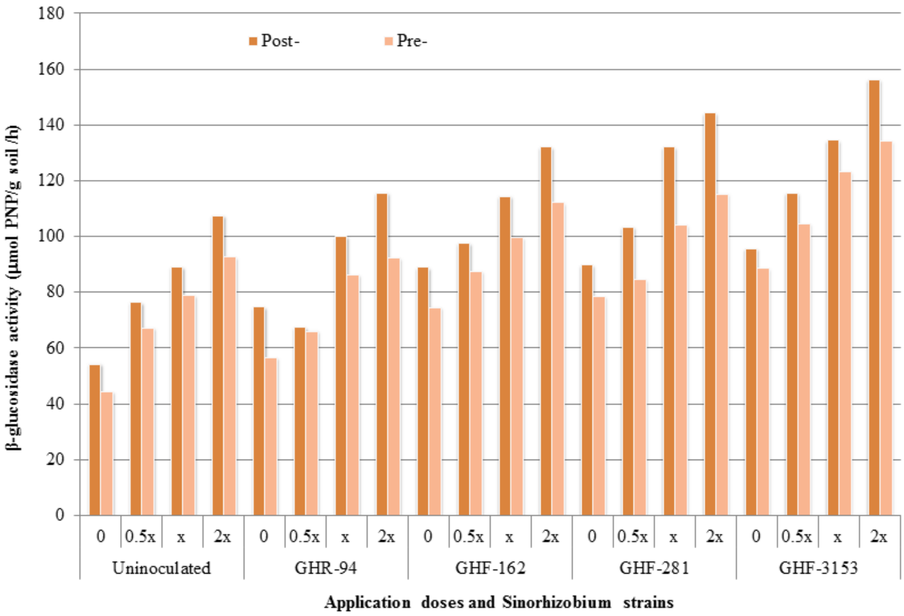

Figure 8. Impacts of post- and pre-emergence of Glyphosate on the activity of β-glucosidase (μmol PNP/g soil /h) in the rhizosphere

CONCLUSION

A generalized relationship between injury level and yield response can be established in weed-free experiments by observing the injury patterns which result from the application of various rates of glyphosate. Root-exuded glyphosate may serve as a nutrient source for soil microbiotas and stimulate soil bioprocesses.

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PHYTOREMEDIATION OF CONTAMINATED SOILS USING AROMATIC PLANTS – APPLICATIONS AND BENEFITS

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Abstract: Phytoremediation is defined as effective use of plants to remove, detoxify and immobilize contaminants in the polluted soil or water. The aim of the paper is to discuss and present the possibility of using specific aromatic herbs to grow on heavy metal polluted areas. These herbs can be used in food processing or to produce high value products (essential oils). Also, the heavy metals do not enter in the food chain through phytoremediation by aromatic plants. This technique is sustainable, aesthetic and environmental friendly.
Key words: Phytoremediation, heavy metals, aromatic plants

INTRODUCTION

The contamination of the environment with toxic metals becomes a global problem. The problem of heavy metals pollution is becoming more and more serious with increasing industrialization and disturbance of natural biogeochemical cycles. Heavy metals enter the environment from natural and anthropogenic sources. The most significant natural sources are weathering of minerals, volcanic activity and erosion, while anthropogenic sources include mining, electroplating, smelting, use of pesticides and (phosphate) fertilizers as well as biosolids in agriculture, industrial discharge, sludge dumping, atmospheric deposition, etc. [1-3]. The anthropogenic sources of heavy metals are given in Table 1.
Unlike organic substances, heavy metals are non-biodegradable and therefore are accumulate in the environment. The accumulation of heavy metals in soils and waters poses a risk to the environmental and human health. These elements are accumulating in the body tissues of living organisms. Heavy metals and metalloids are toxic in very low concentrations and they can cause toxic, mutagenic and carcinogenic properties and other disease [4-6]. Heavy metals cause oxidative stress [7] by formation of free radicals. Oxidative stress refers to enhanced generation of reactive oxygen species (ROS), which can lead to cell damage or death [8-10]. Furthermore, they can replace essential metals in enzymes and pigments, causing disruption in their function.
The most toxic and problematic heavy metals are Hg, Cd, Pb, As, Cu, Zn, Sn, and Cr [11, 12].
Over the last 20 years several physical, chemical and biological approaches have been used for soil remediation. The conventional remediation methods include *in situ* vitrification, soil incineration, excavation and landfill, soil washing, soil flushing, solidification, and stabilization of electro-kinetic systems [13]. The majority of conventional technologies have same disadvantages, like high cost, intensive labor, irreversible changes in soil properties, secondary pollution problems and disturbance of native soil microflora. Biological remediation is considered as the most effective method of toxic metal removal because it is a natural process, environmentally friendly, has a low cost, and high public acceptance [14]. Biological remediation techniques include bioremediation, phytoremediation, bioventing, bioleaching, land forming, bioreactors, composting, bioaugmentation and biostimulation. Among these approaches, bioremediation and phytoremediation are the most useful techniques. These methods have advantages over physico-chemical methods because they are green, natural and clean technologies.
Phytoremediation is based on the use of natural or genetically modified plants capable of extracting hazardous substances i.e. heavy metals including radionuclides, pesticides, polychlorinated biphenyls and polycyclic aromatic hydrocarbons (PAH) from the environment and turning them into safe compounds metabolites [15, 16].

Table 1. Anthropogenic sources of toxic heavy metals in the environment [3].

Heavy metal	Sources
As	Pesticides and wood preservatives
Cd	Paints and pigments, plastic stabilizers, electroplating, incineration of cadmium-containing plastics, phosphate fertilizers
Cr	Tanneries, steel industries, fly ash
Cu	Pesticides, fertilizers
Hg	Release from Au–Ag mining and coal combustion, medical waste
Ni	Industrial effluents, kitchen appliances, surgical instruments, steel alloys, automobile batteries
Pb	Aerial emission from combustion of leaded petrol, battery manufacture, herbicides and insecticides

Phytoremediation technology is a relatively recent technology with research studies conducted mostly during the last two decades. The concept of phytoremediation (as phytoextraction) was suggested by Chaney (1983) [17]. The term “phytoremediation” is a combination of two words: Greek *phyto* (meaning plant) and Latin *remedium* (meaning to correct or remove an evil). Green plants have an enormous ability to uptake pollutants from the environment and accomplish their detoxification by various mechanisms. The concept of using green plants for heavy metal remediation gains the popularity as green remediation of deleterious metals and metalloids, and a good alternate of physico-chemical remedial methods [18]. The idea of phytoremediation is aesthetically pleasant and has good public acceptance. It is suitable for application at very large fields where other remediation methods may not be so efficient and cost effective [3]. Phytoremediation has low installation and maintenance costs compared to other remediation options [19]. Based on economic implications, the aim of phytoremediation can be three layered: (1) plant-based extraction of metals with financial benefit i.e. Ni, Tl; (2) risk minimization (phytostabilization); and (3) sustainable soil management in which phytoremediation steadily increases soil fertility allowing for follow up crop growth with added economic value [16].

As the other conventional techniques, phytoremediation has some disadvantages: slowness of the process, affected area of the land is next to the root, several species cannot be planted in places strongly polluted, but, it is applicable at various types of remediation treatment, it does not interfere with the ecosystem and it is applies *in situ*. Also, mechanisms and efficiency of the phytoremediation depend on several factors such as the nature of contaminant, bioavailability, soil properties, plant species [20, 21]. Extraction efficiency of the pollutants also depends on the biomass produced by the plant: a big biomass is able to uptake a big quantity of metals but it will require more harvests to remove the plants.

The application of phytoremediation is not yet very strong in Europe as in the USA, where revenues exceeded the 300 million $ already in 2007 [22]. These data clearly demonstrate the commercial viability of the phytoremediation and in fact, it represents one of the innovative technologies promoted already in 2001 by the US EPA after a careful evaluation of its potential on the field [23]. However, in Europe the use of phytoremediation technologies has increased in recent years, because they represent an eco-friendly and cheaper alternative method for the environmental remediation than conventional techniques. Research from Glass (1999) [24] and Lasat (2000) [25] have shown that the cost of phytoremediation is very low compared to the resources required for the engineering technologies.

Techniques of phytoremediation include phytoextraction (or phytoaccumulation), phytofiltration, phytostabilization, phytovolatilization, phytodegradation, phytodesalination and rhizodegradation. These techniques are summarized in the Table 2.

Table 2. Summary of the different techniques of phytoremediation [3].

Technique	Description
Phytoextraction	Accumulation of pollutants in harvestable biomass i.e., shoots
Phytofiltration	Sequestration of pollutants from contaminated waters by plants
Phytostabilization	Limiting the mobility and bioavailability of pollutants in soil by plant roots
Phytovolatilization	Conversion of pollutants to volatile from and their subsequent release to the atmosphere
Phytodegradation	Degradation of organic xenobiotics by plant enzymes within plant tissues
Rhizodegradation	Degradation of organic xenobiotics in the rhizosphere by rhizospheric microorganisms
Phytodesalination	Removal of excess salts from saline soils by halophytes

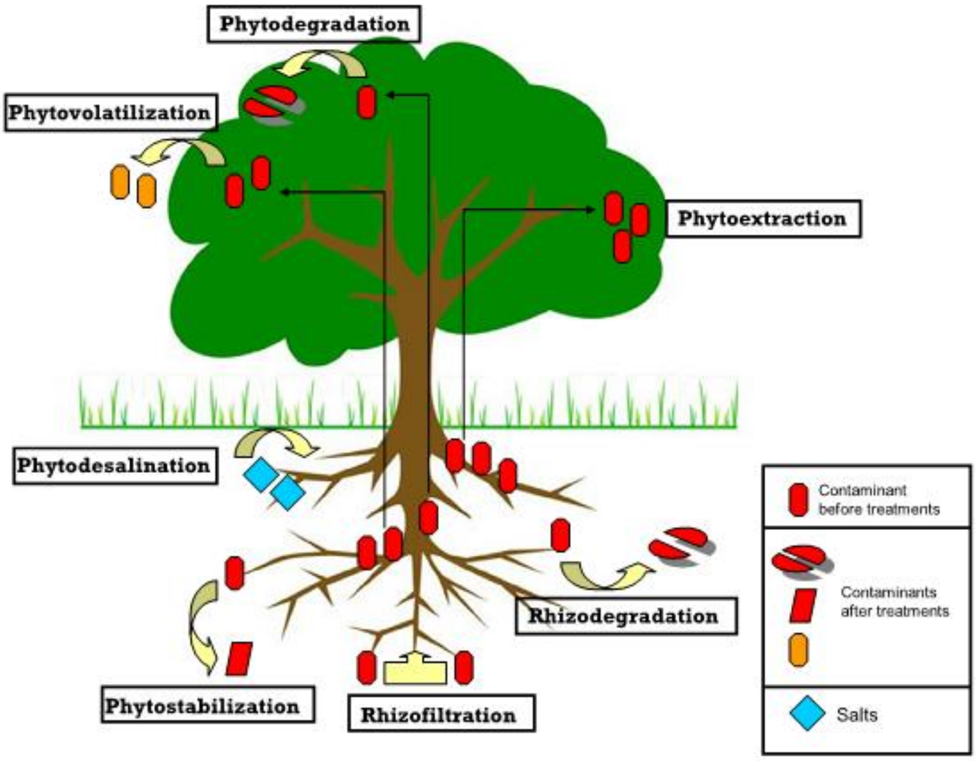

Figure 1. Mechanisms of phytoremediation and alternative destinies of the pollutants [21].

Phytoextraction is the main and most useful phytoremediation technique for removal heavy metals from soils and water [26]. Phytoextraction is also known as phytoaccumulation, uses the plant's ability to absorb and remove contaminants from the soil and “uptake” them into their leaves and stems (Figure 1). It is more situable for commercial application as compared to other phytoremediation techniques [18]. The efficiency of phytoextraction depends on many factors like bioavailability of the heavy metals in the soil, soil properties, metal speciation and concerned plant`s characteristics. Plants situable for phytoextraction should possess the next characteristics: 1) rapid growt rate, 2) more biomass production, 3) more accumulation of the target heavy metals, 4) translocation of the accumulated heavy metals from roots to shoots, 5) tolerate the toxic effect of heavy metal, 6) widely distributed, 7) resistant to phatogens and pests, 8) well adapts to climate change, 9) easy to cultivate and harvest and 10) have no attraction to herbivores to avoid itc entry into food chain [3, 18].

The aime of this work is to contribute to the discussion of possibility of applications and grow specific plants (aromatic medicinal plants) in the heavy metal contaminated fields. So, the idea is to present alternative plants using in bioremediation of soil. Also, the cultivation of aromatic plants in heavy metal contaminated soil has a lot of profound potential benefits, giving the finale products (essential oils) with huge economic value.

DISCUSSION

Research into hyperaccumulators identified more than 500 hyperaccumulator species [27], that belong to a total of 45 families. The families *Asteraceae*, *Brassicaceae*, *Caryophyllaceae*, *Cyperaceae*, *Cunouniaceae*, *Fabaceae*, *Flacourtiaceae*, *Lamiaceae*, *Poaceae*, *Violaceae* and *Euphobiaceae* accounted for the majority of hyperaccumulator species and, subsequently, were the predominant families in metal accumulation processes [28]. Amog them, aromatic plants are slightly represented, although, in the last decades the research in this field take a great attention. These plants offer a novel option for their use in phytoremediation process.

Aromatic plants like vetiver (*Vetiveria zizanioides*), palmarosa (*Cymbopogon martinii*), lemon grass (*Cymbopogon f lexuosus*), citronella (*Cymbopogon winterianus*), geranium and mint (*Mentha sp*.), basil (*Ocimum basilicum*), lavander (*Lavandula vera*) may be used for bioremediation. Some aromatic herbs like lemon grass, palmarosa, citronella, vetiver are perennial plants that are tolerant to contaminants and are resistant to stress. Herbs can be collected for years and then used in essential oils prodaction. The producted essential oils is free from the risk of heavy metals accumulation in plant biomass [29].

Zheljazkov et al. (2006)[30] found that peppermint can extract significant quantities of heavy metals from the soil. It was found that the tested varieties of mint can be successfully grown on soils highly polluted with heavy metals (in the surrounding area near Plovdiv), without contamination of the final product - the essential oil. Despite the reduction in the yield (14%) due to pollution with heavy metals, mint still remains very profitable crop and can be used as an alternative to food crops. The same author were investigated basil (*Ocimum basilicum*), dill (*Anetum graveolens*) and peppermint (*Mentha piperita*) as herbs which can be normaly grown on the soil with high concentration of Cu, Mn and Zn [31].

Research done from Angelova et al. (2015) [32] present lavander as a crop that is tolerant to heavy metals; it can be attributed to hyperaccumulator of Pb and accumulators of Cd and Zn and can be successfully used in phytoremediation of heavy metal polluted soils.

St. John’s wort, (*Hypericum perforatum*) and chamomile (*Matricaria chamomilla*) are one of the most important medicinal plants, which can accumulate high content of Cd [33]. Onother research from Lydakis-Simantiris et al. (2016) [34] present chamomile, sage and thym, as aromatic herbs capable to accumulated relatively high amounts of heavy metals (Cd, Pb and Ni). In general, all results from resaerch show that aromatic plants can accumulate significant amounts of toxic heavy metals in their root systems, and the aboveground parts accumulate a relatively small amount of heavy metal. The most important is the fact, that obtained essential oils from herbs grown at contaminated soil showed that neither the quality and the content of the oils were altered significantly, nor detectable amounts of heavy metals were found in these oils.

Some medicinal and aromatic plants such as marigold, cumin, garlic, hollyhock and black nightshade (*Solanum nigrum*) can accumulate large amounts of toxic heavy metals in their tissues. They can also be successfully used in phytoremediation and can replace food crops grown under the same conditions [32].

Until now, the Environmental Protection Agency have been identified 384 contaminated and potentially contaminated locations on the territory of Republic of Serbia. The contamination on the most of locations is related to the processes of waste disposal (43,5%), exploatation and production of crud oil (22,5%) industrial and commercial activities (10,2%) [35]. According to the data available, soil of the urban area is significantly more burdened by pollution and increased concentrations of lead and other heavy metals in relation to the soil in forest ecosystems due to proximity of major roads, i.e. pollution from local sources. In 2015, analysis of major localized sources of soil pollution shows that the highest contribution belongs to the public landfills with 42.78%. The results of soil analisys near landfills in the territory of the Autonomous Province of Vojvodina in the period 2013-2015 show exceeded limit values for Pb, Cd, Cu, Ni, Zn, Hg and for Cr, as and PAHs in a slightly smaller percentage (Figure 2). In 2015, rehabilitation and remediation were performed within NIS A.D. Company, TE Kostolac and RB Kolubara [35].

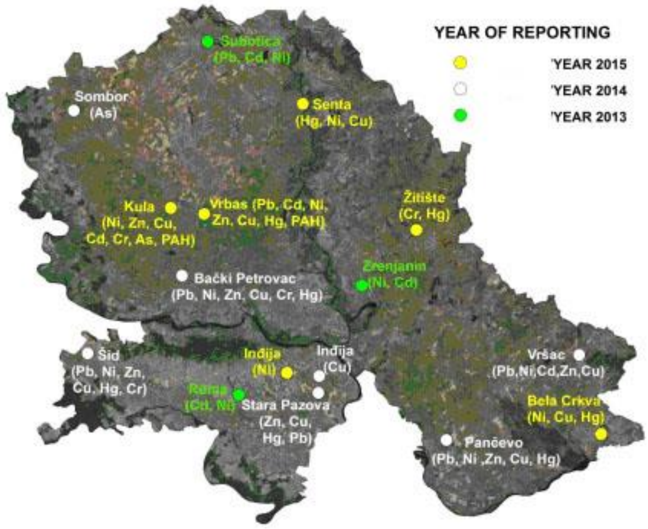

Figure 2. Location of tested landfills and hazardous and harmful substances in the period 2013-2015 [35].

According to this data, phytoremediation on the agricultural land with aromatic plants can be for great interest and with potential benefits. Furthermore, as the represented area is mostly agricultural soil further increase in heavy metals can lead to unimaginable consequences. In order to exploit the economic potential of these areas, and also to protect human and animal health, phytoremediation may represent the technology of great significant.

CONCLUSION AND FUTURE PERSPECTIVES

Phytoremediation is a promising green technology that can be efficiently used to remediate heavy metal contaminated soils. It has a low impact, *in situ*, clean up procedure that has minimal environmental disruption and large practical applicability. Despite several advantages, phytoremediation has not yet become a commercially available since the removal process is rather slow with lower efficiency as compared to many other techniques. But in future, full potential of phytoremediation as a sustainable green technology it will come to the fore.

Phytoremediation technology is still in its early development stage and full application is limited. The study with different plants, and obtained results have indicated that the plants are effective and could be used in toxic metal remediation. Furthermore, it is evident that phytoremediation with aromatic plants has benefits for environmental, as well as for commercial production of essential oils.

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APPLICATION OF POLY (PROPYLENEIMINE) DENDRIMER FOR REMOVAL OF TOXIC METALS

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Abstract: Cadmium (Cd^{2+}) and nickel ($Ni^{2+)}$ are the most generally heavy metal ions in the different industry. They are known as the common contaminant that it's discharged into the water source and due to their excessive toxicity even at low concentrations, can cause serious risks to the ecosystem. A new adsorbent poly-propyleneimine dendrimer (PPI, G2) was applied for the uptake of Ni^{2+} and Cd^{2+} ions from liquid phase. The effective parameters containing pH, PPI dosage and initial concentration of Ni^{2+} and Cd^{2+} ions were investigated in a batch model. Effect of pH and adsorbent dosage showed that by increasing of them values, the amount of metal ion removal increased, also, by increasing the concentration of metal ions, the percentage of metal adsorption were reduced. To study the mechanism of adsorption and calculate maximum values of adsorption, the Langmuir and Freundlich isotherm were used. The results showed that the removal of heavy metals by the PPI dendrimer fit the Langmuir isotherm. It is concluded that PPI dendrimer is a super adsorbent for Ni^{2+} and Pb^{2+} removal from aqueous solutions.
Key words: Dendrimer, heavy metal, removal, adsorption

INTRODUCTION

Water impurity by heavy metals has created a serious environmental difficulty in the recent years [1]. Whereas the heavy metals are toxic, resistant, non-biodegradable and agglomerative within environmental systems, they pose a significant menace to human and other organisms even at low concentrations [2, 3]. Hence, the removal of heavy metals from aquatic systems is still the attention of many researchers [4, 5]. Several technique, including chemical precipitation, solvent extraction, ion exchange, and adsorption, have been planned for the uptake of heavy metal ions from aquatic systems [6, 7]. Among these technology, adsorption is suggested to be a most effective and hopeful methods [8]. The major superiority of adsorption is the adsorbents have potent affinity and great capacity for heavy metal removal [9]. In recent years, polyamidoamine (PAMAM) and poly-propyleneimine (PPI) dendrimers are extensively applied to environmental operations [10, 11]. PPI dendrimers have the preponderance of Spherical geometry with high amino functional groups, high aggregation of nitrogen atoms which it can complex with metal ions. PPI dendrimers are macromolecules with nanostructure and nonporous that can encapsulate heavy metal pollutants. These advantages cause them promising selection as new superabsorbent [12].

MATERIAL AND METHODS

The PPI generation 2 dendrimers were purchased from Sigma–Aldrich. Standard solutions of Ni^{2+} and Cd^{2+} (1 g L^{-1}) were prepared by sulfate salts. The rest of the materials and reagents used in this study were attained from Merck Chemicals and Sigma-Aldrich Companies. Heavy metals analysis was carried out using Inductivity Coupled Plasma (ICP, Optima 2000 DV). The functional groups were assessed using Fourier transform infrared spectroscopy (FTIR) spectra in KBr pellets using a Tensor 27 spectrophotometer (Bruker Optic GmbH, Germany) in the wave numbers range of 500–4000 cm^{-1}. Atomic force microscopy (AFM; ARA Research Co, model No. 0101/A, Iran) was used to analyze the surface roughness. The pH of solutions was regulated with HCl and NaOH solution and measured with a Metrohm pH-meter (E 647, German) supplied with a glass-combined electrode. Adsorption analyses were carried out at pH, 2-7 and metal ion concentration, 50 -200 mg L^{-1} and PPI dosage, 0.04-1 g L^{-1}. To study the mechanism of adsorption and calculate maximum values of adsorption, the Langmuir and Freundlich isotherm models were used. Langmuir model is reliable according to one layer adsorption on the surface. Freundlich model is used for the explanation of several layer adsorptions with bonding among adsorbed molecules. The linear equations of Langmuir and Freundlich models are present as [13]:

$$\log q_e = \log K_F + \frac{1}{n}\log C_e \qquad (1)$$

Where K_F is the adsorption capacity and 1/n is adsorption intensity and 1/n amounts determine the type of isotherm to be double-faced process (1/n = 0), desirable (0 < 1/n < 1), undesirable (1/n > 1).

$$\frac{C_e}{q_e} = \frac{1}{K_L Q_0} + \frac{C_e}{Q_0} \qquad (2)$$

Where q_e, C_e, Q_0, and K_L are the values of metal adsorbed at equilibrium (mg g^{-1}), metal concentration at equilibrium (mg L^{-1}), maximum adsorption capacity (mg g^{-1}), and Langmuir constant (L mg^{-1}), respectively.

RESULTS AND DISCUSSION

FTIR spectra of the PPI dendrimer in the region from 500 to 4000 cm^{-1} was showed in Fig 1. The PPI dendrimer showed N–H band at 3271 and 1545cm^{-1} and C-H band at 2951 cm^{-1} and C-N between 1000 to 1350 cm^{-1}. One of the key parameters for adsorption process, as the adsorbent, which is much smaller due to the large specific surface can more adsorb high capacity of the pollutant. In order to characterize the self-assembled structure of dendrimer, dynamic light scattering (DLS) was conducted. The histogram analysis of the DLS (Fig.2) indicates that the mean diameter of PPI dendrimer is 1-10 nm. The shape and the surface topology of PPI dendrimer are presented in Figure 3. As can be seen, spherical particles are observable in regular intervals without any spreading of the molecules. This roughly spherical structure could be the reason for the aggregates of the dendrimers on the surface of the silica. Based on cross-sectional line scans along the segment, the dendrimers heights are around 15 nm.

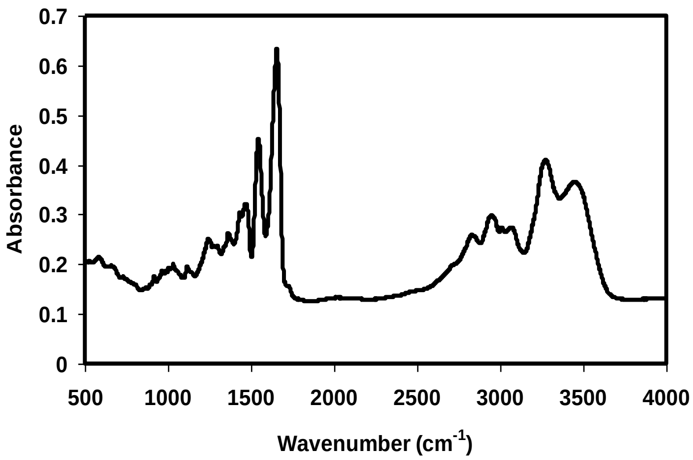

Figure 1. FTIR spectrum of PPI dendrimer

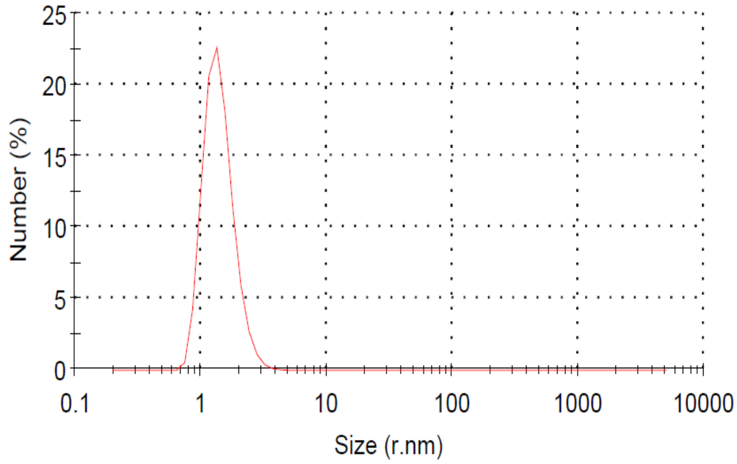

Figure 2. DLS analysis of PPI dendrimer

The pH of the liquid phase has a considerable effect on the adsorption of heavy metal ions from wastewaters, because it ascertain the surface charge of the sorbent and adsorbate. The effect of pH on the uptake of heavy metals with PPI dendrimer was investigated at the pH range of 2–7 with determined concentration of metal ions (100 mg L^{-1}). As showed in Fig. 4, uptake percentage of Ni^{2+} and Cd^{2+} enhanced from pH 2 to 7. The maximum adsorption of both metal ions was occurred at pH 7. Therefore, pH 7 was selected as the optimal pH for all future assessments. Low uptake of two metals at acidic pH is because of the electrostatic repulsion between the positively charged PPI surface and metal ions. Nevertheless, when the pH enhances, the surface charge of the PPI dendrimer is further negative [14].

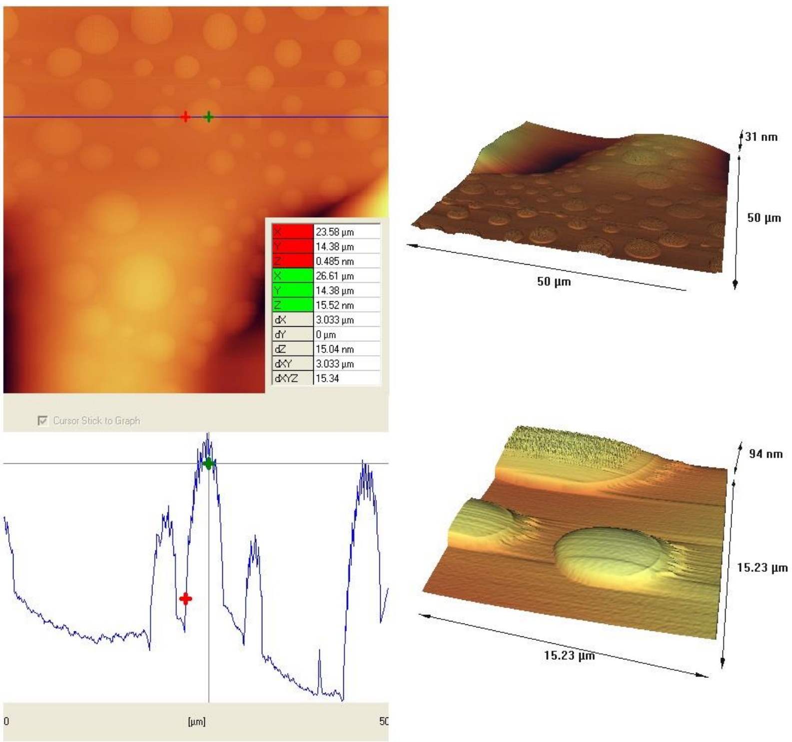

Figure 3. AFM images of dendrimer

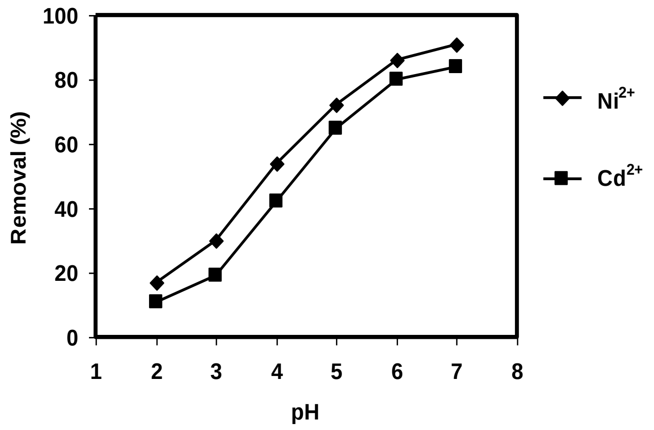

Figure 4. Effect of pH on heavy metal removal by PPI dendrimer (C_0=100 mg L^{-1}, adsorbent dosage=0.08 g L^{-1}, T=298 °K)

Adsorbent dosage is a main parameter because it specifies the capability of the adsorbent for a determined initial concentration of the heavy metals. Uptake of Ni^{2+} and Cd^{2+} metal ions was assessed applying various dosages of PPI dendrimer (0.04–0.1 g L^{-1}). As illustrated in Fig. 5, percentage uptake of metal ions increases with enhancing in PPI dosage, which can be referred to its high accessible adsorption sites. The maximum uptake of Ni^{2+} and Cd^{2+} metal ions was attained with 0.08 g L^{-1} of PPI and was selected for future analysis [14].

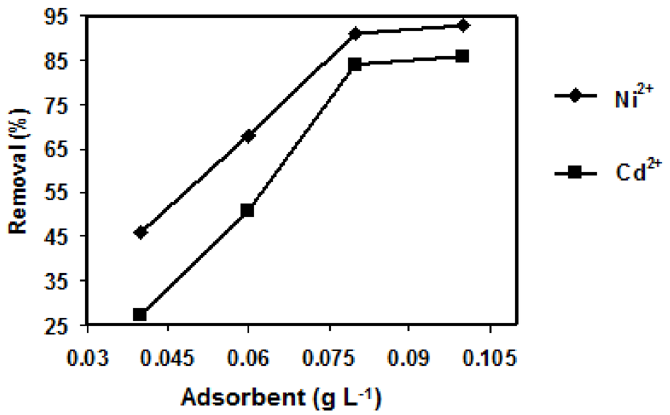

Figure 5. Effect of adsorbent dosage on heavy metal removal by PPI dendrimer (C_0=100 mg L^{-1}, pH=7, T=298 °K)

The effect of initial metal concentration was investigated in the range of 50–200 mg L^{-1}. The outcomes of this evaluation are representing in Fig. 6. From the Fig. 6, the adsorption efficiency of Ni^{2+} and Cd^{2+} ions by PPI dendrimer enhances with increasing concentration of the metal ions because of the accessibility of adsorption sites on the PPI. However, as the Ni^{2+} and Cd^{2+} concentrations become extremely high, the removal efficiency decrease [16].

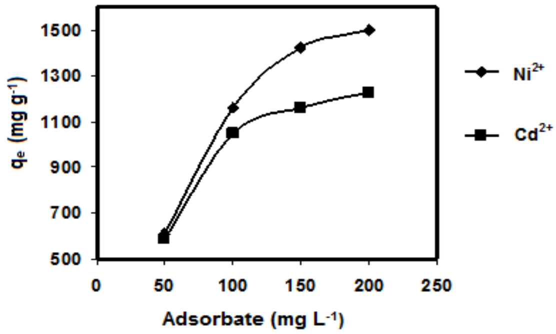

Figure 6. Effect of initial metal concentration on heavy metal removal by PPI dendrimer (pH=7, adsorbent dosage =0.08 g L^{-1}, T=298 °K)

Adsorption isotherms are applied to explain adsorption saturation for wastewater operations. In this work, the adsorption data have been fitted to Freundlich and Langmuir isotherm equations.
The results attained by coordinating the empirical saturation state data to the isotherm models with the correlation coefficients (R^2) for Langmuir and Freundlich models were showed in Table 1.

Table 1. Isotherm parameters of heavy metal adsorption by PPI dendrimer (pH=7, adsorbent dosage t=0.08 g L^{-1}, T=298 °K)

Metal	Langmuir Isotherm			Freundlich Isotherm		
	Q_0	K_L	R^2	K_F	n	R^2
Ni	1428	0.041	0.999	396	4.857	0.920
Cd	1250	0.034	0.999	363	5.464	0.919

Evaluation of the linear plots proposed that, for the adsorption of Ni^{2+} and Cd^{2+}metal ions onto PPI dendrimer, the Langmuir isotherm resulted in better fit with higher correlation coefficient, R^2 = 0.999 than Freundlich isotherm. Thus, adsorption of Ni^{2+} and Cd^{2+} ions by PPI dendrimer better conform the monolayer system (Fig 7).

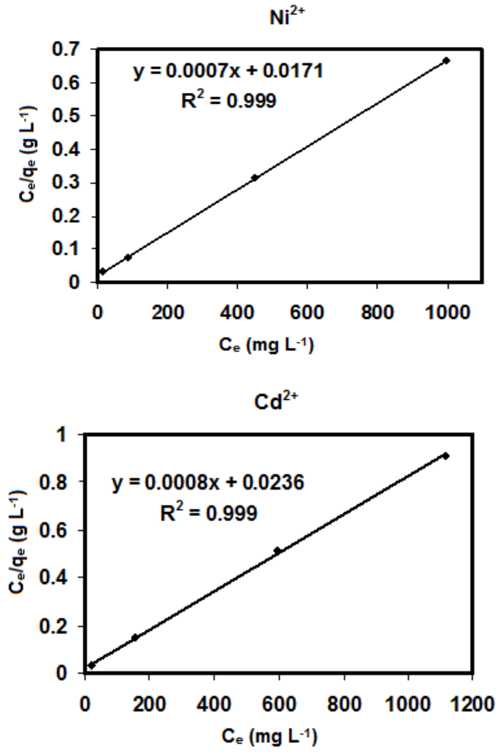

Figure 7. Liner Langmuir isotherm of Ni^{2+} and Cd^{2+} removal by PPI dendrimer (pH=7, adsorbent dosage =0.08 g L^{-1}, T=298 °K)

CONCLUSION

In this research, the ability of PPI dendrimer (G_2) to remove Cd^{2+} and Ni^{2+} from aqueous solution has been evaluated. Characteristics of PPI dendrimer were analyzed by FTIR, AFM, and DLS methods. The results of this research showed that the PPI dendrimer as the navel adsorbent can be applied for the uptake of Ni^{2+} and Cd^{2+} from aqueous solution. The experiments were carried out in a batch system and the effect of pH and adsorbent dosage showed that by increasing of them values, the amount of metal ion removal increased, also, by increasing the concentration of metal ions, the percentage of metal adsorption were reduced. To study the mechanism of adsorption and calculate maximum values of adsorption, the Langmuir and Freundlich isotherm were used. The results showed that the removal of heavy metals by the PPI dendrimer fit the Langmuir isotherm. The results showed that PPI dendrimer can be applied as an effective adsorbent for heavy metal adsorption from water solution.

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EVALUATION OF SEWAGE SLUDGE MANAGEMENT OPTIONS FOR THE CITY OF NOVI SAD

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Abstract: In this paper modeling of potential sewage sludge treatment options is performed. Energy production and environmental implications of each scenario are used as criteria's for comparison. Models were developed by Material Flow Analysis using STAN software at the level of goods (sewage sludge) as well as at the level of substances (carbon and cadmium). Alternative scenarios of sewage sludge management for the city of Novi Sad were developed, evaluated and compared.
Key words: material flow analysis, sewage sludge, energy valorization

INTRODUCTION

According to the Statistical Yearbook, the amount of municipal wastewater generated in the Republic of Serbia is 363,1 millions of m^3/year. Of the total amount of municipal wastewater, only 5.3% is purified appropriately. The sludge that occurs after treatment of wastewater is deposited in landfills, which at this moment is about 4,000 t / year and does not represent significant [1].
The problem of the disposal of waste sludge in the world is gaining in importance. One of the reasons is that sewage sludge contains significant amounts of phosphorous (P) and is therefore widely applied fertilizer [2]. However, sewage sludge also contains substances that could be harmful to plants and soil and therefore the use of sludge in agriculture is regulated to minimize potential environmental problems[3].
Practice in European countries is that stabilized and dried sludge is directly applied as a fertilizer in agriculture. In general, almost all types of sludge can be used in this way if they fulfill quality standards (heavy metal content, pathogens, pre-treatment). A typical pre-treatment in this case is that the sludge is stabilized with calcium oxide (CaO), and the calcium oxide should be 30% more than the amount of dry matter of the dried sludge. It is therefore recommended to give 10 kg of CaO / t of the raw sludge [4]. In the cement production, there are three basic ways of using sludge, or ash from sludge combustion: as a raw material for the production of clinker; as an alternative fuel in the production process; as substitute material in cement mixtures where it replaces a certain proportion of Portland cement [5]. Mono-incineration of waste sludge implies its combustion separately, without mixing with other types of waste or fuel. Before burning it is necessary to bring the dry matter content from 30 to 40% (dried sludge usually has about 25% SM), so it can be burned without added fuel. The waste heat generated during the incineration process can be used to dry the sludge. Modern incinerators' can generate electricity, so in that case the treatment of the sludge is energy neutral. During the incineration process, flue gas, flying ash and bottom ash are formed [6]. Anaerobic decomposition, or sludge digestion, is applied to sludges containing natural organic matter. Methane fermentation eliminates large quantities of organic matter, which is converted into methane, carbon dioxide and inorganic substances. In the process of anaerobic digestion, the following gases are released: methane (60-70%), carbon dioxide (25-35%), carbon monoxide (2-4%), nitrogen (up to 1%), hydrogen sulphide 0.1%). The process takes place in a closed reactor (digestor), without the presence of oxygen [7].
The concept of this paper is based on the treatment and disposal of the sewage sludge on the territory of Novi Sad, after the installation of the wastewater treatment plant. Currently, all municipal wastewater are discharged, without purification, into the Danube River.
Considering future development of municipal wastewater treatment, three possible scenarios for the final disposal of sludge after the treatment of municipal wastewater of Novi Sad, were analyzed. The first scenario is the use of sludge as a substitute for energy used in the production of clinker in the

cement industry. Another considered method of using sludge is its treatment in an anaerobic digestor, where energy can be utilized by the gas obtained after the digestion process. The third scenario is based on sludge treatment in the incinerator, where it is possible to produce energy that is in the form of steam or hot air, which can be used, for example, to heat houses or pools or to produce electricity.
The estimated quantity of waste sludge in the Republic of Serbia, if 100% of the population were connected to the sewage network, is 776 573 t / year [8]. In order to calculate the amount of waste sludge in the area of Novi Sad, the above data is required, as well as data on the number of inhabitants in the municipality of Novi Sad (319 484 inhabitants) and the number of inhabitants of the Republic of Serbia (7,040,227 inhabitants) [1]. With a simple calculation of presented data, the amount of waste sludge is about 35 240 t / year.

MATERIAL AND METHODS

For the purpose of analyzing the sludge flows, as well as important substances in the sludge composition, three scenarios have been defined and presented. Scenarios are presented as MFA (Material Flow Analysis) models. Material Flow Analysis is is a systematic assessment of the flows and supplies of materials within a system defined in space and time [9]. This is useful metodology for modelling any material based system [10]. The software tool used in the work is STAN (subSTance flow ANalysis). STAN is a free software that enables the analysis of material flows [11]. It is made according to Austrian standard ÖNorm S 2096 (Analysis of material flows - application in waste management). The process consists of creating a graphic model with predefined components (processes, flows, system boundaries), after which you can enter known data (mass flows, concentrations, transfer coefficients) for different layers (layer of goods, substances) and calculate unknown quantities. Also, for more detailed analysis, there is a possibility to consider measurement uncertainty of data [12].

RESULTS AND DISCUSSION

In all considered scenarios, sludge flows at the level of goods were considered, and at the substance level the flows of carbon and cadmium were considered, for the teritory of the Novi Sad municipality and the period of one year.

Scenario 1 - use of the sewage sludge in the cement industry

In this scenario, raw sludge is sent for pre-treatment, after which sludge can be used in cement plants. Pre-treatment in this case involves drying in the sun lagoons. This method of pre-treatment can be considered economically most cost-effective because it does not require additional energy consumption. Before pre-treatment, the dry matter content in the sludge amounts to about 4.2%, and after the pre-treatment the dry matter content is 24% SM [2]. The sludge now can be used in directly combustion in a cement kiln. After burning in a rotary kiln, a solid residue in the form of ash does not occur, however, most of the burned amount of sludge ended in the flue gas. MFA transfer coefficients which are used are as follows: 0.294 for part of the sludge that goes into clinker and 0.706 for part of the sludge in the flue gas [12].
When we look at the carbon flows in the burned sewage sludge, the amount of carbon at its disposal is calculated on the basis of carbon concentration. Carbon concentration after drying in the sun is about 286 mg C / g of sludge. It is estimated that after drying 95% of carbon remains in the sludge, while 5% is evaporated and dried [13]. After the MFA calculating, an amount of 8752.5 t / year of carbon was obtained. The situation with carbon in the combustion of sludge in cement kiln is similar to that at the level of goods. Thus, most of the carbon is terminated in the flue gas, which is the result of combustion because carbon is converted into gaseous products such as carbon dioxide. The used transfer coefficients are: 0.01 for the flow of clinker and 0.99 for the flue gas flow [12].
The average concentration of cadmium in the raw sludge for Germany and the selected European countries is taken into account and amounts to 5 mg Cd / kg of dry matter [2]. For the amount of the raw sludge of 35 240 t (dry matter content 4.2% and calculated amount of dry matter of 1480.08 t), the amount of cadmium was calculated and take out to 7.4 kg Cd / year.

Transfer coefficients for cadmium pre-treatment were received on the basis of the fact that cadmium has the binding properties for non-volatile sludge components and amounts to 2% for the fraction lost by drying and 98% for the sludge that goes into the cement. Transfer coefficients for cadmium flows during burning in cement plants are: 0.02 for waste gas and 0.98 for clinker [14].
It can also be noticed, on the basis of the diagram, that all the amount of cadmium remains bound in the clinker, and later in further processing in cement. The picture shows the MFA diagram at the goods layer.

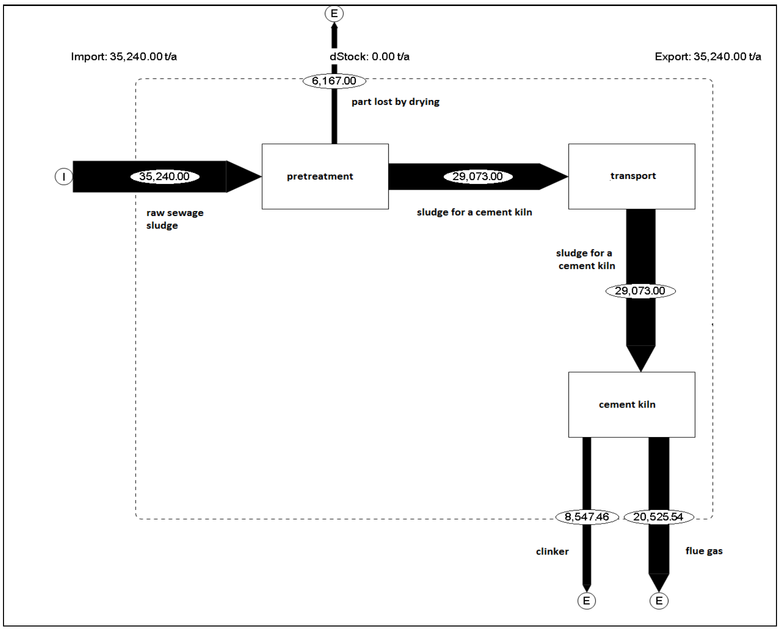

Figure 1. MFA diagram for Scenario 1 (goods layer)

Scenario 2 - sludge treatment in anaerobic digestor

For Scenario 2, which relates to the treatment of sludge in the anaerobic digestor, it is primarily considered whether pre-treatment of the sludge is required before sending it to an anaerobic digestor. According to literature, if it is one-step digestion (as in this scenario), sludge with 3-5% dry matter does not have to be pre-treated. It has been previously established that the content of dry matter in the sludge after treatment of municipal wastewater is 4.2%, so the pre-treatment is taken from the consideration.
In this scenario, the sludge of dry matter content of 4.2% is sent directly to the digestor, where anaerobic digestion of organic matter is carried out by anaerobic bacteria. Products of anaerobic degradation are produced gas and the rest of the sludge which is called digestate. Transfer coefficients used at the level of goods are 0.15 for produced gas and 0.85 for digestate [7]. The produced gas is in the case of anaerobic digestion of 40-60% methane, so it can be used for energy purposes. The digestate is considered to be used as a compost. In this case, the pre-treatment is demanding, so mechanical dehydration of the sludge is considered, from which the outflow streams will be the composting and wastewater fractions.
When carbon flows are observed, since the raw sludge is not subject to pre-treatment, the amount of carbon present in the sludge is somewhat higher than in Scenario 1. After the digestion, 33% of the sludge quantity goes to the produced gas, and 67% goes to the composting pre-treatment [7].
After the process of anaerobic digestion, 96% of cadmium is contained in the digestate, while 4% is contained in the produced gas, and after composting, most cadmium is in the composting fraction, which could be problem from the aspect of the environmental protection, if the concentration of cadmium exceeds the emission limit values. The picture shows a MFA diagram for the Scenario 2, at the carbon layer.

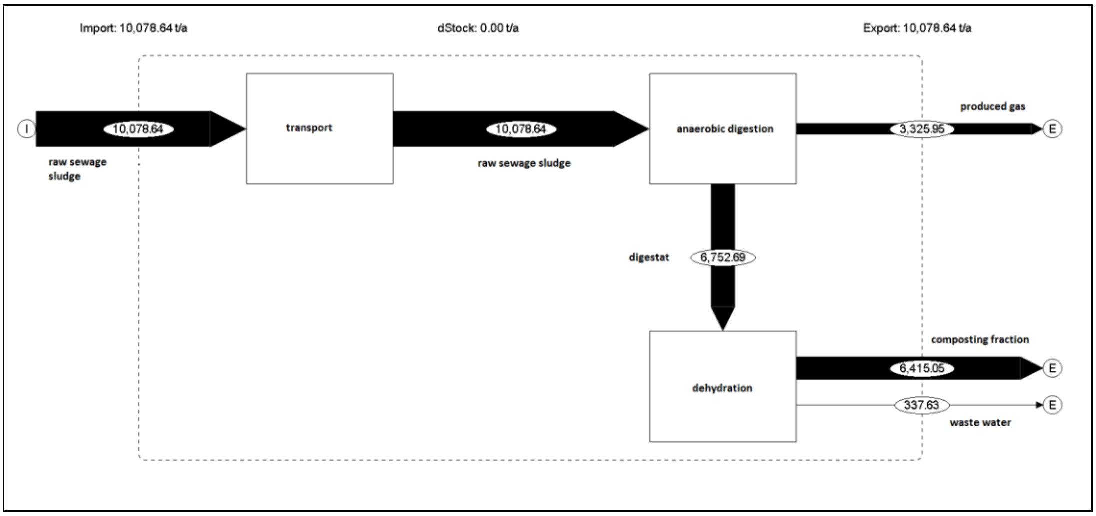

Figure 2. MFA diagram for Scenario 2 (carbon layer)

Scenario 3 - monoinsineration of the sewage sludge

For this scenario, it was considered that the sludge after pre-treatment (drying at the sun) is transported to the insineration place, where its thermal treatment, or burning, will be carried out. Direct outputs from the combustion process include the bottom ash, flying ash and flue gas. Flue gas is treated before discharging into the atmosphere, and after treatment, waste water and filter cake remains. The filter cake, together with the fly ash, is disposed on a special landfill, due to the contents of dangerous substances. The bottom ash is disposed on a sanitary landfill. Transfer coefficients were received on from the Phd dissertation and presented in the table.

Table 1. Transfer coefficients used for a model creation [14]

Product	Mass fraction	Substance					
		C	N	Cl	Cd	Pb	Hg
Fly ash	0.025	0.002	0	0.37	0.916	0.25	0.5
Bottom ash	0.27	0.014	0.01	0.09	0.08	0.75	0.04
Flue gas	0.7	0.98	0.989	0.0001	0.002	0.0002	0.02
Waste water	<0.01 (0.0001)	0.002	0.001	0.54	0.001	0.001	0.001
Filter cake	<0.01 (0.0001)	0.002	0	0.0001	0.001	0.001	0.44

If we look at the goods layer, the largest amount of sludge after insineration is contained in flue gases. This is the result of the oxidation of organic matter from the sludge. The bottom ash contains 27% of the amount of sludge. The residue is contained in flying ash and products of purification of flue gases (filter cake and wastewater). For purification of flue gases, the absorption of gaseous pollutants into the liquid was carried out. The picture shows a MFA diagram at the cadmium layer, for the Scenario 3.

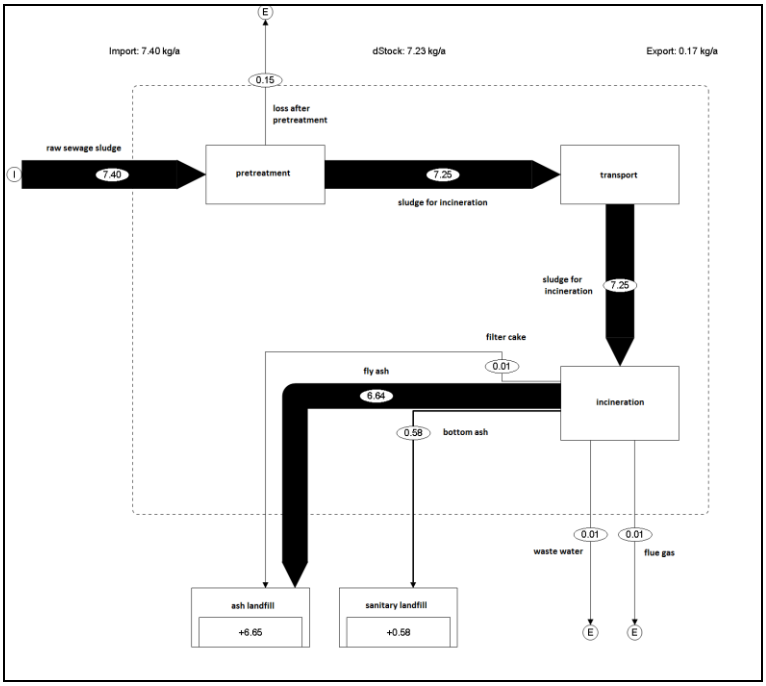

Figure 3. MFA diagram for Scenario 3 (cadmium layer)

Comparative analysis of the scenarios

For easier comparison of the input and output volumes in all three scenarios, a tabular overview of material and substance flows is made. The tables contains the flows of the given scenarios, the annual quantity of material as well as the quantity and the percentage share of substances in individual flows.

Table 2. Flows of materials and substances for Scenario 1

Flows of materials and substances	Materials (t/year)	Carbon (t/year)	C (%)	Cadmium (kg/god)	Cd (%)
Raw sewage sludge	35240,00	8752,50	100	7,40	100
A part that evaporates	6167,00	437,63	5	0,15	2
Sludge flow for cement kiln	29073,00	8314,88	95	7,25	98
Clinker	8547,46	83,15	1	7,25	0,9998
Flue gas	20525,54	8231,73	99	0,00	0,0002

Table 3. Flows of materials and substances for Scenario 2

Flows of materials and substances	Materials (t/year)	Carbon (t/god)	C (%)	Cadmium (kg/god)	Cd (%)
Raw sewage sludge	35240,00	10078,64	100	7,40	100
Digestat	29954,00	6752,69	67	7,10	96
Produced gas	5286,00	3325,95	33	0,30	4
Part for composting	24712,05	6415,05	95	6,96	98
Waste water	5241,95	337,63	5	0,14	2

Table 4. Flows of materials and substances for Scenario 3

Flows of materials and substances	Materials (t/year)	Carbon (t/year)	C (%)	Cadmium (kg/year)	Cd (%)
Raw sewage sludge	35240,00	8752,50	100	7,40	100
Sludge for incineration	29073,00	8314,88	95	7,25	98
Loss after pretreatment	6167,00	437,63	5	0,15	2
Flue gas	21351,10	8148,58	98	0,01	0,2
Waste water	116,29	16,63	0,2	0,01	0,1
Bottom ash	7849,71	116,41	0,14	0,58	8
Fly ash	726,82	16,63	0,2	6,64	91,6
Filter cake	29,07	16,63	0,2	0,01	0,1

If we consider the *rate of recycling*, we will observe carbon flows, as an element that can be reused, or recycled from waste sludge. The recycling rate is calculated on the basis of the formula:

$$SR\ (\%) = \frac{R}{G} * 100 \tag{1}$$

The following items are:
R - the amount of collected recyclables that come out of the system (t / year),
G - total quantity of generated waste (sludge) (t /year).

After the calculation we have the following results:

- Scenario 1 - Significant is carbon in raw sludge and clinker, SR = 0.95% of carbon can be recycled.
- Scenario 2 - Carbon is also significant in the produced gas (CH_4) and carbon in the digestat, whereas it can be used for composting. So in this case, the carbon recycling rate is 32% for the fraction that goes into the produced gas and about 65% for the digestate fraction. It can be noticed that carbon recycling is between 90 and 100%. A small amount remains in wastewater after dehydrating digestate.
- Scenario 3 - significant is bottom ash, because it can be used for composting, SR = 1.33% of carbon can be recycled.

According to the above, it can be concluded that Scenario 2 (anaerobic digestion of sludge) is a favored, because in this way almost 100% carbon recycling is provided.
To show *the negative impact on the environment*, the output parameters for cadmium for all three scenarios will be compared. From the below table data it is evident that the smallest amount of cadmium that is emitted to the environment is in Scenario 1 - sludge utilization in cement kiln, because in this case the cadmium content is mostly contained in the raw material for the production of cement (clinker).

Table 5. Comparative review of cadmium content in the output streams of three modeled scenarios

Cadmium flows		Output quantities (kg/year)
Scenario 1	**- flue gas**	0.0000145
Scenario 2	**- composting fraction**	6.96
	- waste water	0.14
Scenario 3	**- flue gas**	0.01
	- waste water	0.01
	- fly ash	6.64
	- bottom ash	0.58
	- filter cake	0.01

Energy analysis of the scenarios

After the installation of the waste water treatment plant in the city of Novi Sad, it is calculated the possible quantity of sludge generated, and amounts about 35240 t / year.
For *Scenario 1* **-** sludge incineration in cement plants, it is envisaged that all sludge quantities after the pre-treatment (drying in the sun) will be burned in a rotary kiln. The amount of sludge after drying would be 29073 t / year. One of the paper with a similar topic have calculated that the capacity of the Lafarge cement plant, located near Novi Sad, is about 1004000 t / year, and that the maximum usage of the waste sludge is 50200 t / year, which means that the resulting quantity of sludge after the pre-treatment could be managed in the mentioned cement plant [8]. Since in this case sewage sludge would be used as a coal substitute, from the energy consumption point, this would be a positive action.
In the calculation, we will take the heat value of sludge from 18 MJ / kg, which is 18 GJ / t, then the quantity of the produced energy would be:
18 GJ / t * 35 240 t / year = 634 320 GJ / year
In further calculation, we will use the thermal value of coal, which is used as a fuel in a cement plant. That thermal value is amounted about 27 GJ / t, and now it can be calculated which amount of coal can replace the sludge.
634 320 GJ / year: 27 GJ / t = 23 493 t coal / year
For *Scenario 2, we will* observe the amount of gas produced during anaerobic digestion. From the total quantity of sludge, according to the transfer coefficients, 33% goes to the produced gas. Since 50-70% of biogas is methane (CH_4), for the calculation we will consider the methane content of 65%. The thermal power of biogas depends on the content of methane. For methane content of 65% the thermal power ranges from 16.2-19.8 MJ / Nm^3. Average daily generation of biogas per capita is about 18.3l, if we consider a plant with technical potential to process sewage sludge from 50,000 inhabitants [15].
For Novi Sad city, the amount of biogas, according to the number of 319 484 inhabitants, is:
18.3 l / day / cap * 319 484 inhabitants = 5 846 557.2 l / day = 5 846, 6 m^3 / day =
= 2 134 009m^3 / yr.
In addition, if we take into account the thermal power of biogas from 17 MJ / Nm^3, the possible produced energy can be obtained and amounts to 36 278 153 MJ / year = 36 278 GJ / year.
In *Scenario 3* we will take into account the quantity of heat (energy) generated by burning the sludge. This amount of heat is equivalent with the quantity generated by sludge incineration in the cement plant and amounts to 634 320 GJ / year. During the incineration, energy can be used in various ways, such as the production of hot water or the production of electricity.

CONCLUSION

In all considered scenarios, material flows (sewage sludge) as well as substances (cadmium and carbon) were analyzed using MFA. Analyzed scenarios have been modeled using material flows and substance flows as well as processes which occur during the treatment of waste sludge. Scenarios/Models are also presented in graphic form.
After the development of graphic models and the output flow calculation, a comparative analysis of the scenarios was made for easier comparison of the model. In this sense, the comparison of the carbon recycling rate, the negative impact on the environment and the energy analysis of all three scenarios were carried out.
Regarding the recycling rate, carbon flows are considered as an element that can be reused or recycled, and conclusion is that from this aspect Scenario 1 is the most suitable, because almost 100% of carbon can be reused, by the solid residue after digestion, use for composting. After that, Scenario 2, where the bottom ash can be used, is also for composting, and Scenario 1 has the lowest recycling rate.
From the environmental protection point, the streams of cadmium are observed. Therefore, by comparing the output data of all three scenarios, conclusion is that the smallest amount of cadmium is emitted into the environment in Scenario 1, because cadmium is mostly contained in clinker.
In the energy analysis, for Scenario 1 and Scenario 3, the heat value of the sludge was of importance, and therefore the obtained values of the possible energy produced are equal, since the same quantities of sludge are burned. In the first scenario, the sludge would be used as a coal substitute, and in the

third scenario, the produced waste heat could be utilized after the sludge was burnt in the incinerator. Under Scenario 2, energy could be produced from the obtained biogas.
Taking into consideration all of the above analyzes, if the aspects of energy production and environmental protection are taken into account, Scenario 1 - sludge utilization in the cement industry could be a favorable model. Another reason that contributes to this is that already in the area of Novi Sad there is a built cement plant that has the necessary capacities to manage the generated quantity of sewage sludge. The use of sludge in cement plants could substitute a significant amount of coal, and from the aspect of environmental protection, this method of treatment of sludge is suitable because there are no solid waste products since all the resulting ash is incorporated into clinker.

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APPLICATION OF ELECTROCOAGULATION PROCESS USING IRON ANODE AND GRAPHITE CATHODE FOR DECOLORIZATION OF TEXTILE WASTEWATER

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Abstract: In the present study, an azo organic dye was removed from the aquatic phase by applying iron anode and graphite cathode in a batch flow mode reactor. Sodium sulfate was used as supporting electrolyte. The residual concentration of the target compound was measured using a UV-visible spectrophotometer. According to the results, increasing the reaction time along with decreasing the initial concentration of textile dye was favored the decolorization efficiency. The addition of persulfate ions led to the enhanced removal of the target pollutant, indicating that this ionic compound can be acted as enhancer in removing the target azo dye. Moreover, the presence of scavenging compounds such as methanol, chloride and especially carbonate resulted in decreasing the decolorization efficiency. It can be stated that the electrocoagulation process in the presence of persulfate can be effectively applied for treating dye-polluted solutions.
Key words: electrochemistry, supporting electrolyte, textile dye, persulfate ions

INTRODUCTION

The presence of organic azo dyes in aquatic environments threatens aquatic life due to their toxicity. In addition, the penetration of light into the bulk solution containing organic dyes is limited [1, 2]. Therefore, the removal of azo dyes from the aquatic phase is essential considering environmental point of view. Many treatment processes have been applied for the decolorization of aquatic solutions, including membrane technologies, chemical oxidation, coagulation/flocculation, advanced oxidation processes (AOPs), adsorption and electrochemical processes [3]. In the present study, the application of electrocoagulation process on the basis of iron anode and graphite cathode was considered for the removal of Dired Red 31 (DR31) azo dye as model organic dye from the aqueous solutions. The electrocoagulation process involves the generation of coagulants by means of using direct electric current through sacrifice anode (iron). In fact, the anode is oxidized to generate metal ions and subsequently, corresponding hydrates and hydroxides. Hydrogen gas is also evolved at the surface of cathode. The formation of hydrogen gas at the surface of cathode results in the floatation of the coagulated pollutant [4]. As a novel work, in the current research study, persulfate was added to the electrochemical cell to enhance the efficiency of the treatment process. In the following, the efficiency of the process was also checked in the presence of competing compounds.

MATERIAL AND METHODS

DR31 (molecular formula: $C_{32}H_{21}N_5Na_2O_8S_2$) was prepared from Alvan Sabet Company (Iran). A batch flow-mode experimental reactor was applied for conducting the systematic experiments. Sodium chloride was used as supporting electrolyte for the electrocoagulation process. The electrocoagulation cell was a glass reactor (working volume of 100 mL) equipped with iron anode and graphite cathode. The effect of initial dye concentration (50 – 200 mg/L) and reaction time (0 – 20 min) on the decolorization efficiency of DR31 was evaluated. For the analysis of residual concentration of DR31 after treatment, 10-mL samples were withdrawn from the electrocoagulation cell and centrifuged at 10000 rpm for 5 min. Then, the prepared samples were analyzed using a UV-Vis spectrophotometer (Hach, USA) with maximum wavelength of 526 nm.

RESULTS AND DISCUSSION

Effect of DR31 concentration and reaction time

The effect of DR31 concentration on its removal efficiency was carried out by changing the concentration in the range of 50-200 mg/L during the reaction time of 20 min. Fig. 1 shows that decreasing the initial concentration of DR31, along with increasing the reaction time, leads to the enhanced removal efficiency (%). At reaction time of 20 min, the removal efficiency (%) of DR31 increased from 38.2 to 63.3% as the initial DR31 concentration decreased from 200 to 50 mg/L, respectively. Overall, the lower the initial solute concentration, the higher the decolorization efficiency of the electrocoagulation process [5].

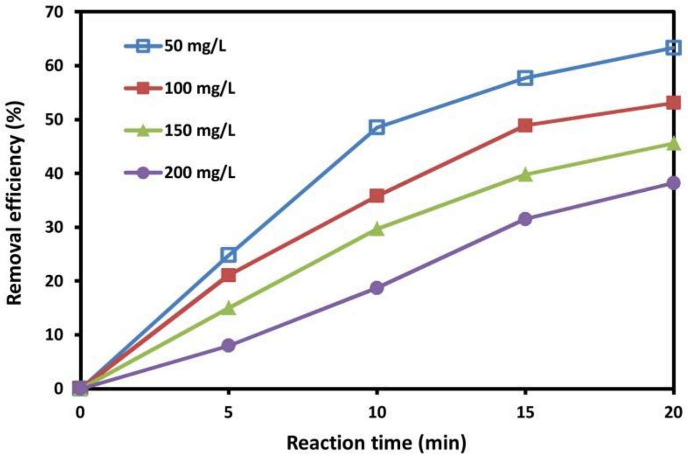

Figure 1. Effect of initial dye concentration on the efficiency of electrocoagulation process

Effect of persulfate ion

The persulfate ion was added to the electrocoagulation cell in order to improve its efficiency in removing DR31. The results of this set of experiments are provided in Fig. 2. As shown, the addition of persulfate ion resulted in the enhanced removal of DR31 through the electrocoagulation process. At initial dye concentration of 100 mg/L, the removal efficiency (%) of DR31 increased from 53.1 to 96.4% in the presence of persulfate ion.

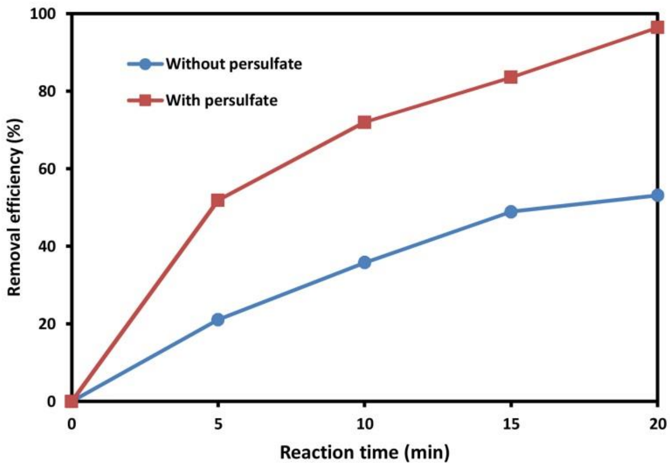

Figure 2. Effect of persulfate ion on the efficiency of electrocoagulation process

Effect of Scavengers

To evaluate the efficiency of the electrocoagulation process in decolorization of DR31 under real conditions, some competing organic and inorganic compounds such as methanol, carbonate and chloride were added to the electrocoagulation cell. The results are given in Fig. 3. The results demonstrated that the presence of competing compounds results in decreasing the decolorization efficiency. In the presence of chloride, methanol and carbonate, the removal efficiency decreased from 96.4 to 89.4, 79.3, and 41.8%, respectively. Therefore, the presence of carbonate ions led to the most inhibiting effect on the removal of DR31 via the electrocoagulation process. It is observed and reported that the presence of carbonate ions in an electrochemical process results in the passivation of anode surface, inhibiting the release of iron hydroxide as the effective coagulant [6].

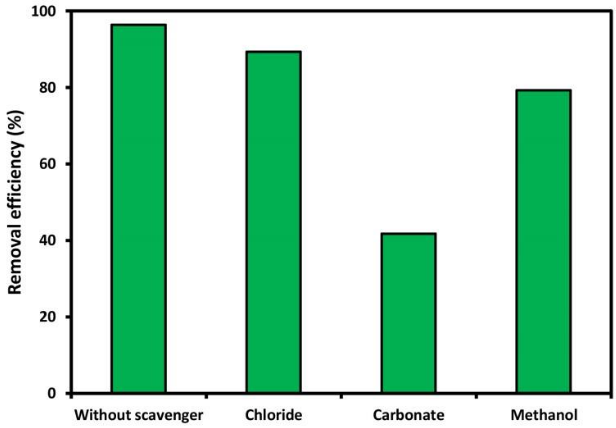

Figure 3. Effect of scavenging compounds on the removal of DR31

CONCLUSION

An electrocoagulation process equipped with iron anode and graphite cathode was used for treating dye-polluted solutions. Overall, the treatment process was efficient even at relatively high concentration of textile dye within a short reaction time. The addition of persulfate ions resulted in the enhanced efficiency, while the presence of competing ions, especially carbonate, led to decreasing the removal efficiency. On the basis of the results, the electrocoagulation process on the basis of the application of iron anode and graphite cathode can be proposed as an efficient treatment technique for the decolorization of aquatic environments especially in the presence of enhancing compounds like persulfate.

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SUPERVISORY CONTROL OF WASTEWATER TREATMENT PROCESS IN THE GALVANIZING PLANT

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Abstract: Hot galvanizing is a process in which the purified iron or steel products are immersed in a molten zinc bath, forming a thin, corrosion-resistant surface layer. In the technological process of hot zinking a significant amount of water is consumed. As a result of the wet treatment of metal products which are zinked, large amounts of polluted waste water are produced. This paper presents the configuration of wastewater treatment and neutralization of wastewater and supervision and plant control system.
Key words: hot dip galvanization, wastewater, neutralization, concentrates, control

INTRODUCTION

One of the most effective ways of protecting steel products is hot-dip galvanizing. In this process reactions between steel and sweat occur when a series of fero - zines layers are formed. Applying elements usually lasts 4 to 5 minutes, while for larger and harder elements this time takes longer. After performing zinc plating and cooling with water or air, the elements show a clear and glossy shine characteristic of the zinc-plated products [1-4]. The technology scheme of hot-dip galvanizing plant is shown in Figure 1. The following equipment is included in the plant: degreasing bath, pickling bathub, hot rinsing, hot-dip galvanizing bath with burners, drying chambers DC1, DC2; cooling chamber, plant for purification and neutralization of wastewater, hot water boilers (TK1, TK2, TK3) for heating the rooms and contents in the bathubs.The temperature is measured in the zinc bath and bathtubs. (sensors Bi, i = 1, 2, ..., 12, 101, 102).There is a certain number of circulation pumps in the hot water system and transport pumps connecting the tubs with the waste water treatment line [5].

The method of hot galvanization takes place in two stages:

• chemical preparation of the surface of zinc-plating elements and
• hot-dip galvanizing phase.

The chemical preparation of surface for hot–dip galvanizing is carried in several steps:

• batching (preparation of galvanized metal elements),
• degreasing,
• rinsing,
• pickling,
• rinsing,
• fluxing,
• drying and preheating.

The hot dip galvanizing phases are:

• hotdip galvanizing,
• cooling,
• de-charging
• finishing and packaging - storage.

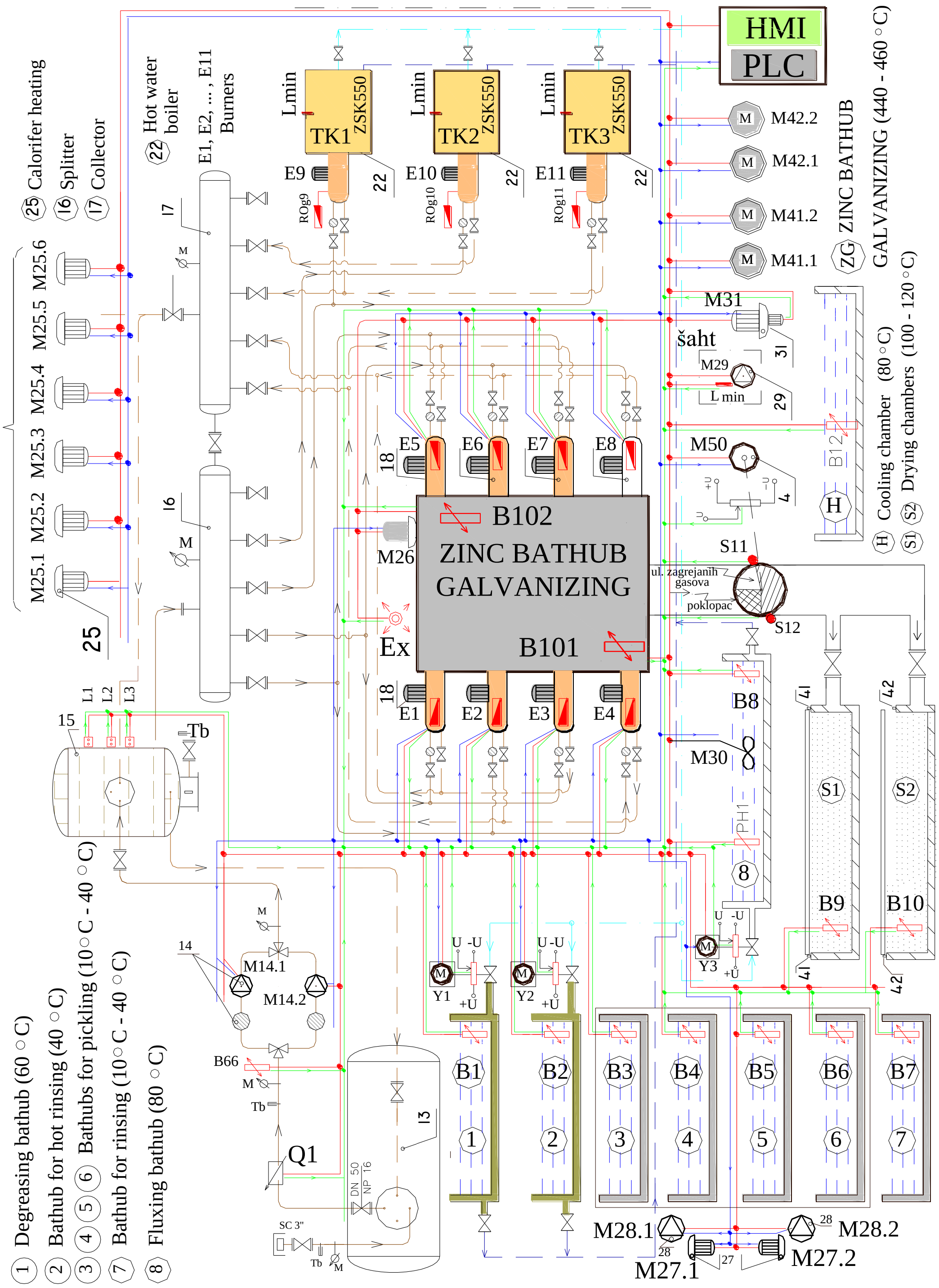

Figure 1. Technological scheme of the zinc hot-dip galvanization

WASTEWATER GENERATION

Before placing the metal objects in a zinc bath, where the application of a protective zinc coating is being done, cleaning the surfaces by degreasing and corrosion is necessary. Degreasing is mainly performed in hot alkaline solutions (industrial detergents), and dilution in dilute technical acid solutions (usually HCl). By this procedure and by intermediate washing in water, pure and active metal surfaces are obtained. After degreasing, rinsing and rinsing, objects are immersed in flux. After fluxing, the drying of the object is carried out and then immersion into the melted zinc, which serves as a finishing layer [5-7]. During these phases, wastewater and concentrates are produced, which is given in Table 1.

Table 1. Presentation of the stage in the process of hot-dip galvanizing and wastewater generation

PROCEDURE ON THE PLANT	COMPOSITON OF THE BATHING	CHEMICAL CHARACTER OF SOLUTION	APROXI-MATE VOLUME[m^3]	FLOW RATE OF RINSING WATER [m^3/h]	NOTE
DEGREASING	5÷10 % aqueous solution of an industrial detergent	Alkaline concentrate	27	-	Changing the bath every one7 – 10 days
RINSING	Water from the water supply	Alkaline rinsing water	27	5	Use of showers for additional rinsing
PICKLING	10÷20% a solution of technical HCl	Acid concentrate	4*27	-	About 30 l of acid is consumed per ton of processed material, i.e. about every 3 months one bath of acid is changed
CASCADE RINSING	Water from the water supplay	Acid rinsing water	27	5	Use of showers for additional rinsing
FLUXING	Water solution HCl, $ZnCl_2$, NH_4Cl	Acid concentrate	27	-	The bath serves to activate the metal surface prior to hot galvanizing and does not affect the quality and composition of wastewaters

All wastewater sources, apart from quality and type of water, are connected to the purification plant. Purification operations are performed in plastic pools in which discrete levels (lower Ldi levels and upper Lgj levels, i, j = 1, 2, ..., 6) and continual ones(Lci, i = 1, 2, ..., 6) are measured. Preparation of solutions as well as rinsing of elements is carried out with water from the water supply system.
Wastewater from chemical preparation are aggressive and toxic due to the untoward pH value and high content of iron ion. Essentially, they are formed as waste of sour - alkali water and concentrates. Concentrates are working baths in processes such as degreasing, pickling and fluxing, and they are released only occasionally (when are time-worn) in a wastewater treatment plant. Worn concentrates contain 120 g/l HCl and 270 g/l Fe. The rinse wastewaters or so-called continual wastewaters are flowing and they are generated in the process of rinsing the elements between individual phases in the technological process and containing up to 100 mg/l HCl and 70 mg/l Fe [5, 6].

WASTEWATER CLEANING TECHNOLOGY

The decontamination and neutralization of the wastewater (block scheme shown in Figure 2) is carried out in several phases:

- wastewater collection and spent concentrates,
- equalization of all waters,
- neutralization,
- inspection,
- precipitation,
- sludge treatment.

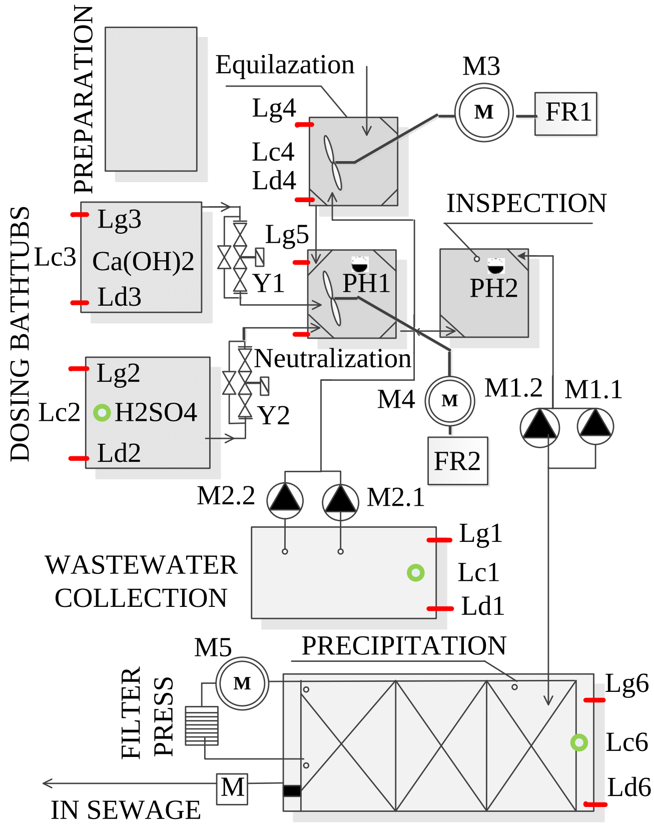

Figure 2. Block diagram of the neutralization plant

WASTEWATER COLLECTION AND DEPLETED CONCENTRATES

During the regeneration or replacement of the baths, worn out solutions are released from bathtubs into the collection pool. The biggest problem is wasted acids possessing a high content of HCl and Fe. Occasional regeneration and alkalizing discharging agent only partially mitigates the aggressiveness of said concentrates. The process produces about 30 l of poisonous acids per ton of processed material (about one ton of metal products is processed for one hour and about 720 l during one day) [5]. Concentrate with such high content of HCl and Fe can not be successfully processed in a flow neutralization device. For this reason, the acidic concentrates are passed through the pump (M2.1 or M2.2) into the pool of worn acid, whereupon they are subsequently dosed into the neutralization plant. In collection pool is collected and all waste water (rinse) is mutually neutral and then transfer to the egalization pool.

WATER EQUALIZATION

Acidic and alkaline rinsing water from the collection pool is continually drained into a pool for egalitization by means of said pumps. Concentrates are occasionally dosed in the pool. The aim is to mix all the water here to partially neutralize and to neutralize the waste water itself when neutralizing the spent concentrates. This simplifies the neutralization process and reduces the use of chemicals. At the same time, the ammonium water (NH_4OH) was dosed in the pool to remove bivalent Fe (reaction 1):

$$FeCl_2 + 2NH_4OH \rightarrow Fe(OH)_2 + 2NH_4Cl. \quad (1)$$

This is done by mixing the air so that the aeration is also necessary to finally convert Fe into a solid precipitate - reaction (2):

$$4Fe(OH)_2 + 2H_2O + O_2 \rightarrow 4Fe(OH)_3. \quad (2)$$

By the addition of ammoniacal water generated reaction (3) and partial neutralization of HCl are formed:

$$HCl + NH_4OH \rightarrow NH_4Cl + H_2O. \quad (3)$$

The maintenance of the pH value is in the range of 5,5-6. This procedure is only applied when neutralization of acidic concentrates, due to the amount of Fe^{++} ion.

NEUTRALIZATION

Neutralization is the reaction between equivalent amounts of acidic and alkaline components. The final product and reactions are neutral as well as water. Since wastewater does not neutralize to pH = 7, the pH value is regulated at intervals of 8-8.5. The retention time is about 40 minutes. Chemical dosing time is required for 15 to 20 minutes. Neutralization is performed using a 20% H_2SO_4 solution and 15% $Ca(OH)_2$ solution. Considering the water content of the plant, mainly $Ca(OH)_2$ is used. Dosing of the chemical is performed by means of regulating electropneumatic valves Y1, Y2 and in function of pH value. The reaction is accelerated by the intensive mixing of the air bubble when the necessary aeration is performed due to the removal of hydroxide. Neutralization takes place at reaction (4):

$$2\ HCl + Ca(OH)_2 \rightarrow CaCl_2 + H_2O. \quad (4)$$

Final precipitation of iron and zinc is performed in accordance with the reactions (5), (6), (7):

$$FeCl_2 + Ca(OH)_2 \rightarrow Fe(OH)_2 + CaCl_2, \quad (5)$$

$$4\ Fe(OH)_2 + 2\ H_2O + O_2 \rightarrow 4\ Fe(OH)_3, \quad (6)$$

$$ZnCl_2 + Ca(OH)_2 \rightarrow Zn(OH)_2 + CaCl_2. \quad (7)$$

The water stands out from the neutralization pool in the pool to complete the reaction, where it is held for about 40 minutes. Water here does not melt and the laminar movement is achieved. At the pool outlet the pH value (pH1) and the final control pool (pH2) are measured. The speed of mixer motors in the pools for egalization and neutralization is regulated by frequency inverters (FR1, FR2).

PRECIPITATION AND SLUDGE TREATMENT

Water from the pool is being conducted to precipitator where metal hydroxides are deposited in order to complete neutralization and inspection over the working pump. (M1.1 or M1.2). The precipitation time is about four hours but is often higher due to the high concentration of iron in the waste water. After that, from precipitator over the drainage channel stands out the clear water in the sewage system. Blurred water in theprecipitatoris a sign of a high level of sludge and it has to be cleaned. The sludge at the bottom of the sediment contains mainly impurities and iron hydroxides and has about 2-4% of dry matter. This sludge is occasionally pumped through the M5 pump to the filter press (FP) where it is processed (Figure 2). The filtrate returns to the equalization pool, and the filter cake, which consists of iron hydroxide, is packed in PVC bags as solid waste and taken to a proper disposal [5].

CONCEPT OF CONTROL AND SCADA SYSTEM

The plant whose structural scheme shown in Figure 3 is viewed as a multivariable system, here is:

$r^T = [L_{d1}, L_{d2}, L_{d3}, L_{d4}, L_{d5}, L_{d6}, L_{g1}, L_{g1}, L_{g2}, L_{g3}, L_{g4}, L_{g5}, L_{g6}, pHg]$ input vector (given values, where reaching the pHg value produces an alarm (exceeding the pH). Alarms (light, sound and text with an

appropriate message on the touch panel display) occur in cases of reaching the limit values of the lower and upper levels in the pools: L_{dg5}, L_{dg6}; L_{g1}, L_{g2}, L_{g3}, L_{g4}, L_{g5}, L_{g6},
$e^T = [\pm dT_{pH1}, \pm dT_{pH2}, \pm dL_{C1}, \pm dL_{C2}, \pm dL_{C3}, \pm dL_{C4}, \pm dL_{C5}, \pm dL_{C6}]$ is a deviation vector (errors),
$y^T = [y_{dv1}, y_{dv2}, \dots, y_{dv21}, y_{dm1}, y_{dm2}, y_{dm3}, y_{dm4}, y_{arv1}, y_{arv2}, y_{pH1}, y_{pH2}]$ is the output vector - the status of the switching elements (gate cabinets, discrete levels in the pools), the level values in them (continuous meters), current position of electro-pneumatic control valves, pH value.

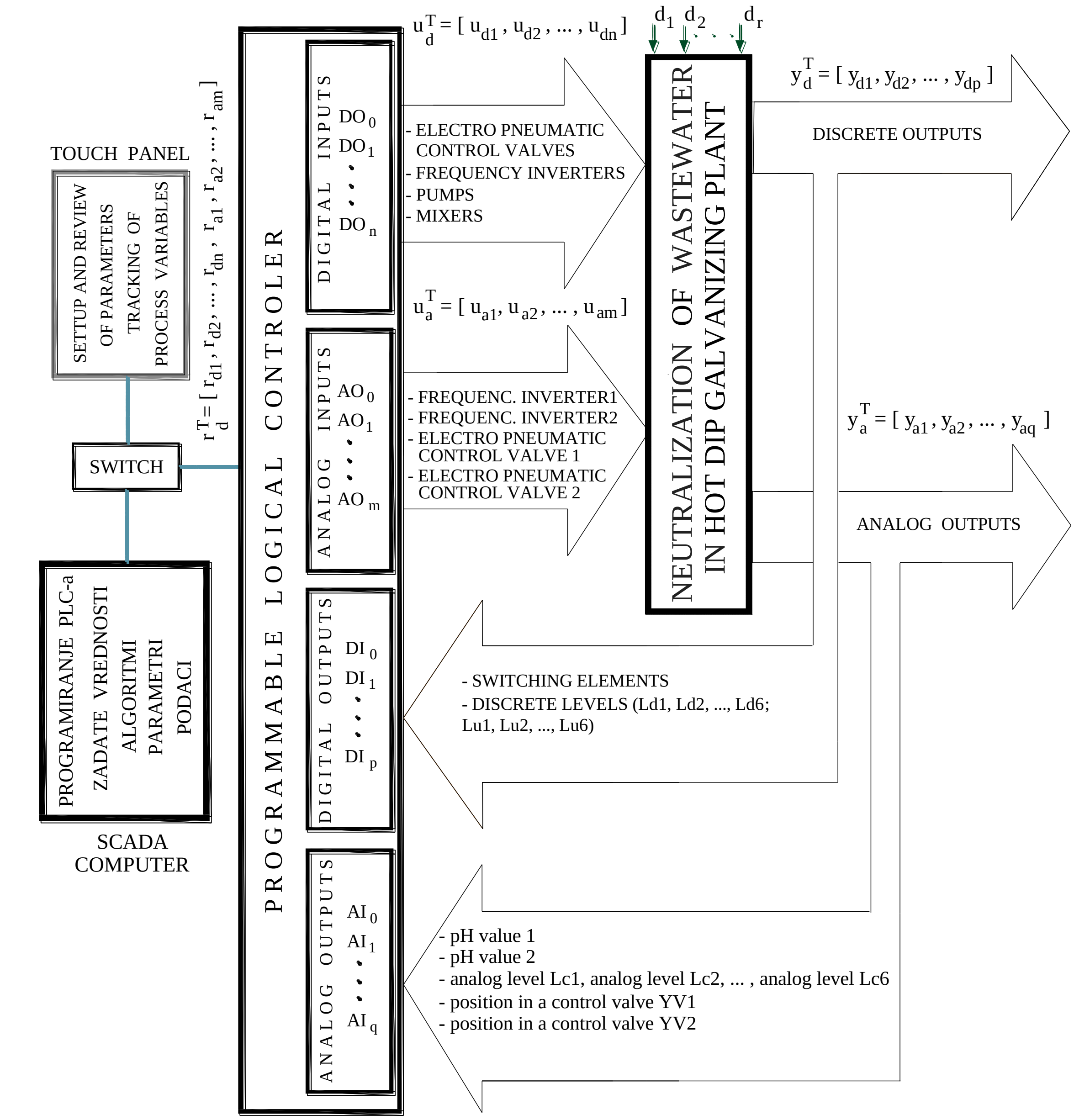

Figure 3. Structural scheme of the treatment plant and neutralization of wastewater

$u^T = [DO_{M1.1}, DO_{M.1.2}, DO_{M2.1}, DO_{M2.2}, DO_{M3}, DO_{M4}, DO_{M5}, DO_{YRV1}, DO_{YRV2}, AO_{FR1}, AO_{YRV2}, AO_{FR2}]$ is control vector - digital signals for controlling motors of pump aggregates and control valves (DO signals), continuous signals - references for regulating electropneumatic valves and frequency regulators (AO signals).

Automation of the process ensures constant quality and repeatability, which reduces the operator influence and thus the possibility of error generation. On the other hand, it is possible to increase the efficiency of the built-in equipment and save energy through constant maintenance of the working tempo. High Performance Control Unit - The PLC controller provides proper operation of built-in equipment and precision execution of line operations. The operator graphical panel provides insight into line operation and the ability to set and track the characteristic process sizes and parameters. The technology-prescribed recipes allow precise dosing of the media, which contributes to achieving the desired quality. Manual operation is used to test the correctness of individual elements when maintaining systems, overhauling or replacing certain parts, and in automatic mode, the work is done based on programs in the PLC.

The control is performed with a Siemens S7 1200 controller, which has a modular structure. Different types of signaling and communication modules are added to the central processor unit according to the requirements of the process being managed. The machine's color display and overview is performed on the operator color panel KTP1000, which is connected to the PLC with a control system under which the switching elements, sensors and executive organs are controlled. The configuration and programming of the S7 1200 unit and the development of the supervisory control for the operator panel are performed using the TIA Portal software package that has integrated STEP 7 Basic controller and WINCC visualization via the KTP panel. Supervision of the cleaning line is performed by a SCADA system for real time monitoring and acquisition of data, storage and processing of data, comparison of working parameters with set limit values and automatic setting of values. This enables monitoring of the technical condition of installed devices and equipment, and timely elimination of potential problems. SCADA allows the operator to display event information in objects that are monitored [7-10].

Electric and hydraulic plant parameters as well as pH value are displayed. Parameters that are shown in the electric scheme are: (current-average value of phase motors of the pump), active power (sum of phase power), reactive (sum of phase power), apparent power, cos φ, frequencies. One SCADA line screen is given in Figure 4 on which the line configuration is displayed. Some fields are painted with a certain color when the value of a parameter changes.

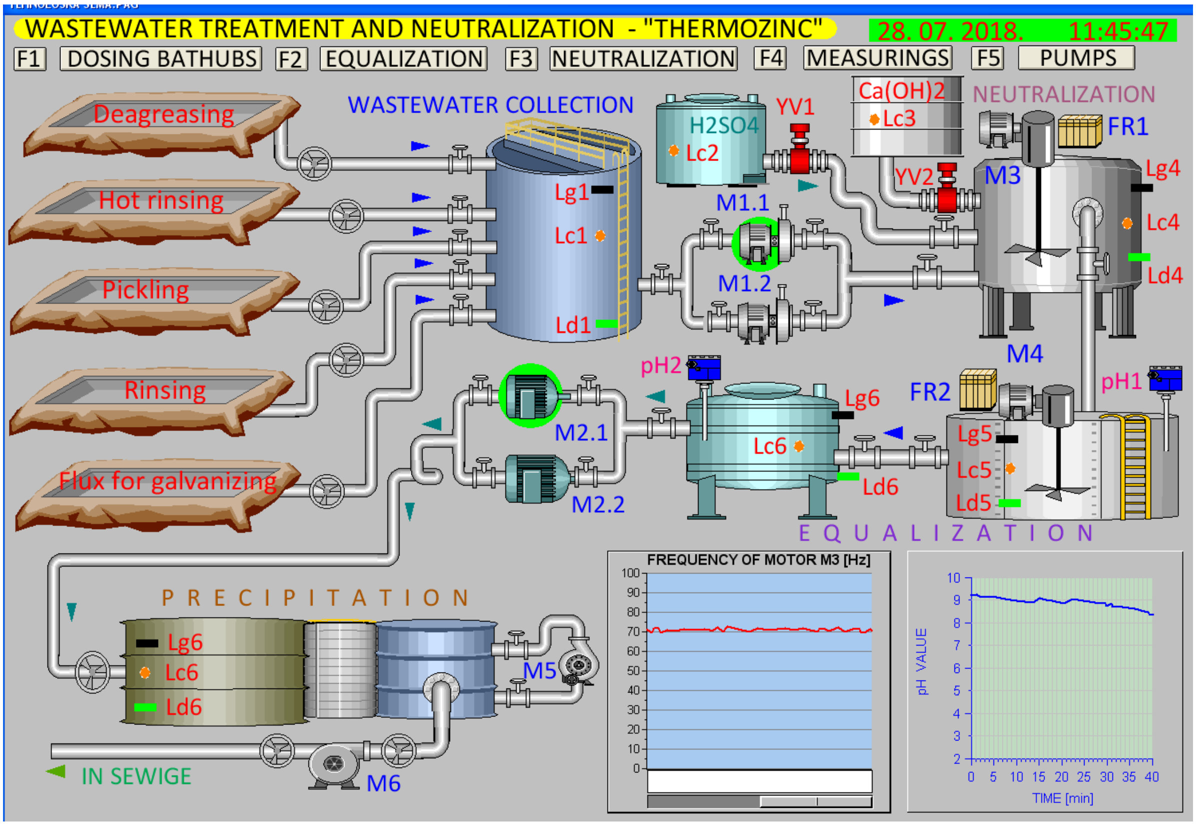

Figure 4. Displaying the SCADA screen of the cleaning line

For example, if the asymmetry is higher than the faulty phase, the field is colored yellow and when, for example, a voltage drops or the fuse is blown, the field is red in color and the cause of the fault is described. When changing the nominal motor parameters (eg when overloading up to 5%, the symbol representing the colored engine is yellow, and if the overload becomes larger then this symbol is red colored). The normal state of the pump aggregate is indicated by a green color. The date is the option

of right-clicking on any of the engines to open a menu that offers options such as: number of on/off (current, month or year), number of hours of work (for selected interval), used electrical energy (active and reactive), and the overlapping information is also monitored and updated. Within the image are two trend graphs - one is an overview of the M3 motor speed control in the pool for egalization and the second graph of pH regulation [5].
Discrete and continual levels in the pools are hydraulic parameters that are displayed. The flooded sensors are colored green (Figure 4), while the sensor that is between the last sunk and next color is orange in the blink. Achieving limit (safety) levels, which are practically alarmed by the red color of the sensor. By this, the operator clearly knows what is happening in a particular pool, and this view opens when the operator positions the pool. When a pool is positioned in the mouse, the right click offers options such as: pool level diagram, daily maximums and minimums, limit values, irregular states (eg overflow, discharge below the lower boundary level, no pool information in pool for a longer time interval, whereby the user is also given information on the most probable cause of the irregularity.

CONCLUSION

This paper presents the configuration of a hot-dip galvanizing plant and a control supervisory system for cleaning and neutralizing waste water. Control and monitoring are based on PLC and SCADA systems. The operator has several dynamic graphical screens that provide a realistic picture of the wastewater treatment process, with current values of characteristic values and parameters, the state of the equipment with the interpretation of alarms occurring due to exceeding the set value or reaching the critical levels. This enables timely intervention when needed and reduces the time of the downtime. All the operations by the operators are documenting what contributes to better organization and efficiency in the work. Daily, weekly and monthly reports are generated and printed with relevant parameters and statistical data.

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PRESENCE OF MICROCYSTINS IN STAGNANT WATERS AND THE POSSIBILITIES OF DEGRADATION

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Abstract: Cyanobacteria otherwise known as blue-green algae (Cyanophyta) are one of the oldest living organisms on earth. Inhabiting terrestrial, freshwater and marine ecosystems, cyanobacteria play a very important role in the functioning of these ecosystems, particularly as primary producers and participants in the circulation cycles of the elements nitrogen and sulfur. Mass occurrence of cyanobacteria in aquatic ecosystems has become a significant environmental problem worldwide. In Europe, Asia and America more than 40% of lakes and reservoirs are eutrophic and represent a favorable environment for the massive development of cyanobacteria. A large number of species of cyanobacteria, especially planktonic representatives from aquatic ecosystems depending on the metabolic activity, produce different types of cyanotoxins. For this reason, many studies have been devoted to finding adequate processes of elimination of cyanotoxins. The paper deals with the possibilities of conventional and advanced processes for removing these toxins.
Keywords: blue-green algae, microcystin, oxidation and advanced oxidation processes

INTRODUCTION

Concerns about the effects of cyanobacteria on human health have increased in many countries in recent years for several reasons. First of all cyanobacteria not only change the taste and smell of the water but also have the ability to produce deadly toxic compounds. The presence of cyanobacteria includes cases of poisoning attributed to cyanotoxins as products of cyanobacteria. Cyanobacteria also attracted attention because of published incidents of poisoning of animals and humans. Reported were poisonings of humans attributed to the toxic cyanobacteria in Australia, after being exposed to contaminated drinking water, and in the UK, where army recruits were exposed to cyanotoxins while swimming the channel [1,2]. The greatest outbreak of cyanobacteria with fatal outcome was reported when patients on hemodialysis were directly exposed to cyanotoxins intravenously via the dialysate prepared with contaminated water [3,4]. This time exposure to cyanotoxins resulted in toxic hepatitis, multiple organ failure and even death of [5,6]. Fortunately, such serious acute effects on human health are rare, but little is known about the scale and nature of the long-term effects (such as tumor growth and liver damage) or milder short-term effects, such as contact irritation.
People are most commonly exposed to harmful cyanobacteria through contaminated water. They can be orally, dermally and periodically by aspiration exposed to aquatic microbial communities that contain cyanobacterial cells and mixtures of cyanotoxins during recreational activities on or in crude surface water [7,8,9,10]. Cyanotoxins are toxic biologically active substances of different chemical structures and influence and are toxic secondary metabolites of cyanobacteria. Problems that may arise in people affected by these toxins are various types of dermatitis, cancer, gastrointestinal disorders, hepatic enteritis, atypical pneumonia and neurological problems. The World Health Organization [11] has established the recommended concentration permitted for the most toxic microcystin-LR (MC) in drinking water, 1 mg / dm3. Microcystin-LR (MC) contains two unstable amino acids, leucine and arginine.
As shown in Figure 1, MCs contain three D-amino acids, alanine (Ala), methylaspartic acid (MeAsp), and glutamic acid (Glu), two unusual amino acids, N-methyldehydroalanine (Mdha) and 3-amino-9-methoxy-2,6,8-trimethyl-10-phenyldeca-4,6-dienoic acid (Adda), and two variable L-amino acids (X and Z). Human activities, such as increasing the concentration of nutrients, increase of CO_2,

temperature increase and vertical stratification, lead to domination of cyanobacteria in large numbers of aquatic ecosystems, as well as spreading of invasive species [12].

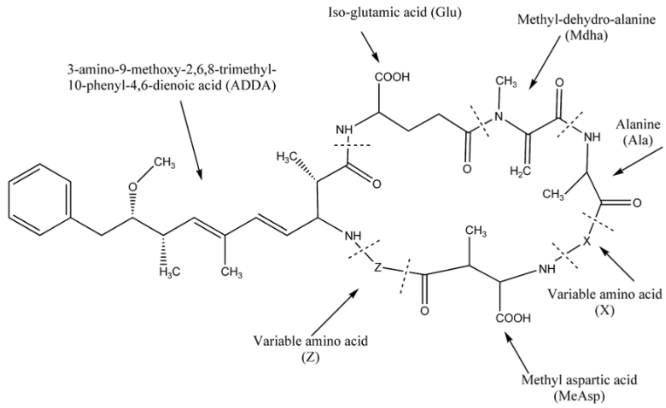

Figure 1. Structure of microcystins [26]

Recently in the Republic of Serbia a number of papers have been published that address the state of many aquatic ecosystems in terms of toxic cyanobacteria which tells us that there is monitoring and evaluating present [13,14,15,16,17]. Table 1 presents some data from literature reviews related to the presence of MC in aquatic ecosystems of the Republic of Serbia.

Table 1. Selected data from literature on the concentrations of MC in waters in R. Serbia [18]

Measuring location	**Year**		
	2005 Microcystins μg/L	2006 Microcystins μg/L	2007 Microcystins μg/L
Channel DTD- Bečej	summer: 85.75; autumn: 65.32	spring: 16.85; autumn: 142.60	winter: 21.55 spring: 36.93 summer: 50.6 autumn: 41.5
Channel DTD-Vrbas	summer: 7.99 autumn: 10.63	winter: 4.24 spring: 9.78 summer: 13.53 autumn: 48.4	winter: 6.92 spring: 13.8 summer: 7.88 autumn: 19.74
Krivaja- Srbobran	summer: 14.01 autumn: 79.56	winter: 1.43 spring: 33.11 summer: 13.34 autumn: 41.2	winter: 16.2 spring: 9.1 summer: 27.6 autumn: 29.25
Tisa-Novi Kneževac	summer: 6.87 autumn: 5.48	winter: 8.44 spring: 10.37 summer: 12.04 autumn: 29.8	winter: 38.1 spring: 15.67 summer: 25.93 autumn: 19.3
Palić	summer: 60.98 autumn: 119.43	winter: 9.45 spring: 136.68 summer: 322.76 autumn: 389.30	winter: 87 spring: 199.87 summer: 317.91 autumn: 49.3
Ludoš	summer: 80.59 autumn: 362.68	winter: 4.21 spring: 268.07 summer: 603.61 autumn: 176.30	winter: 144.87 spring: 238 summer: 527.25 autumn: 55.81

MCs synthesized in the cyanobacterial cells are released into the aqueous environment after death and decomposition of the cells. Therefore, they may enter into the water treatment plants, in both intracellular and extracellular forms, and thus must be removed. Removing toxins which contain cells must be carried out so as to prevent damage of cells in order to avoid the further discharge of MC. For removing extracellular toxins, used are physical and / or chemical oxidation methods. Physical methods, for example, use activated carbon, [19] filtration [20,21], flotation [22] or coagulation [23], which can adequately remove the MCs, but these methods are not destructive and attention must be paid to the regeneration of active material as well as the disposal of contaminated residual material. [24]. On the other hand, using chemical oxidation processes is a better way of treatment due to the complete destruction of MC cells and their transformation to less toxic by-products. Common chemical oxidants used in water treatment are chlorine, chlorine dioxide, hydrogen peroxide, ozone, and permanganate.

Advanced Oxidation Technologies (AOT) are attractive alternatives to traditional water treatments and much attention has lately been devoted to them. AOT include the generation of OH^- ions as the major form responsible for degradation of pollutants / toxic materials.

Additionally, advanced oxidation processes (AOP) such as ultraviolet (UV) radiation, a combination of UV/H_2O_2, Fenton reaction mixture (Fe^{2+}/H_2O_2), technologies based on the generation of sulfate radicals, radiolysis, ultrasound - based technologies, photocatalytic oxidation in the presence of TiO_2, and ferrate(VI) (FeO_4^{2-}) have also been suggested for the removal of MCs [25–29].

CONVENTIONAL METHODS OF MC OXIDATION

Chlorination

Chlorination is still the most frequently used pre- and post-treatment process in drinking water production in the world and has been considered the most significant public health advancement in the 20th century. It is effective, easy to use and affordable in both centralized and point-of-use treatments. The decline in death and illnesses associated with water-borne diseases has been attributed to drinking water chlorination. Chlorine is a strong oxidant widely used as a disinfectant at one or two point(s) in the water treatment process: for pre-treatment to induce disinfection at the beginning and/or for post-treatment to control the growth of microbiological pathogens in the distribution and storage systems [30]. In general, chlorine is added to drinking water as elemental chlorine (chlorine gas), sodium hypochlorite solution or dry calcium hypochlorite. Cl_2, HOCl, and ClO are formed depending on the temperature and pH; HOCl is the major reactive compound. The efficiency of chlorine thus depends on experimental conditions, including the nature of the chlorine compounds used. The concentration of MCLR decreased by more than 95% with aqueous chlorine and calcium hypochlorite and only by 40% with sodium hypochlorite in 30 min treatments at 1 mg/L dose of the oxidant [31]. The observed difference is due to the effect of pH as sodium hypochlorite solutions are highly alkaline.

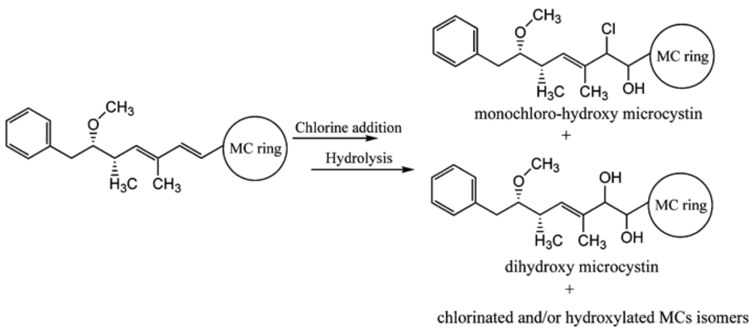

Figure 2. Chlorination by-products of microcystins [26]

Drinking water chlorination, and processes using other oxidants/disinfectants, has its drawbacks. Chlorine can react with certain types of naturally occurring organic compounds in water forming by-products such as trihalomethanes and haloacetic acids, some of which are toxic compounds. In addition, chlorine can impart objectionable taste and odor to some consumers and its volatility may reduce its effectiveness with time. Alternatives to chlorination such as permanganate, membrane filtration, and UV disinfection are available but also have limitations, such as high operating and maintenance costs and requirement of high technical expertise. Current regulations in some countries when alternative disinfection processes are used still require maintenance of chlorine residual to control growth of microbes over time during distribution and storage.

Ozonation

With ozonation being one of the most affordable water treatment technologies [31], it was inevitably tested for the removal of cyanotoxins. The majority of research studies focused on the required doses for removal and detoxification of the toxins [32,33], as well as the effect of water quality parameters [32,33,34]. A more elaborate study by Rositano et al., 1998 [35,36], was supported with laboratory scale ozonation experiments on pure toxin solutions, freeze-dried and cultured live material. In Milli-Q grade water, at pH = 7.0, it took only 15 s and an ozone dose of 0.22 mg /L to completely remove 1.0 mg/L MC-LR. When the experiment was repeated in a Microcystis aeroginosa extract, 1.0 mg/L of ozone was required to remove 220 µg/L of MC-LR in less than 5 min. The authors also investigated the effect of pH for the removal of MC-LR in algal extracts and found that at alkaline pH the efficiency of O_3 was significantly reduced (50%). The authors attributed the lower degradation rates to the lower oxidation potential of O_3 at alkaline pH (1.24 V) compared to that of acidic conditions (2.07 V) and the accelerated decomposition of O_3 to HO• in the presence of OH•. Finally, two studies investigated the reaction intermediates of MC-LR and MC-RR with O_3 [37] and associated the formation of reaction by-products to ozone doses. High ozone doses degraded the toxins into small molecular weight by-products below 450 amu with linear structures. When low ozone doses were applied, larger molecular weight intermediates, $510 \leq m/z \leq 837$, were detected.
Furthermore, the toxicity of the treated solution was also found to be related to the ozone dose since higher doses can oxidize the Adda moiety, which is linked to the toxic properties of MC-LR.

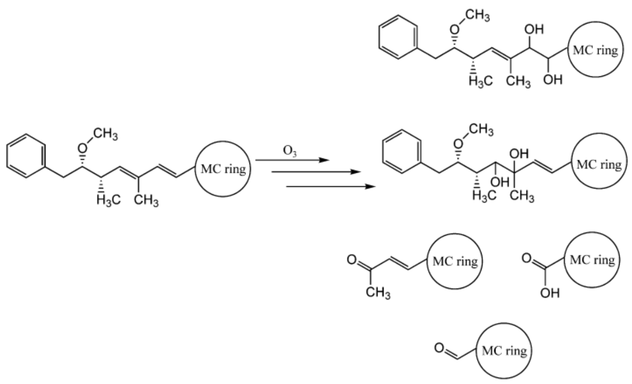

Figure 3. Ozonation by-products of MCs [26]

Oxidation with permanganate

Permanganate was first used for water treatment in 1910 in London but did not begin to grow in use until the 1960s, when it was applied successfully for taste and odor control. Since then, potassium permanganate has been accepted by the water industry as one of the most versatile oxidants available. Among other applications in water treatment, it may oxidize organic compounds via several reaction pathways, including mainly electron exchange, hydrogen abstraction or oxygen donation. In general, it attacks functional groups with multiple bonds inducing hydroxylation on alkenes with the formation of diols. The removal of MCs by permanganate was also tested in natural water [38]. Initially, a fast consumption of permanganate occurred, which may be due to the reactivity of the oxidant with the matrix components of water. This fast decay of permanganate was followed by the removal of MCs. Under the experimental conditions applied (1.1 mg L^{-1} permanganate at pH 7) the complete removal of MCs took about 1 h with final concentrations below the WHO provisional guideline value of 1 µg/L. The degradation of MC-RR and MC-YR was slightly faster than MC-LR. Wu et al. [39] incorporated permanganate with periodate to study the degradation of MC-LR. It was found that MMPB was also formed during this oxidation process, supporting again that permanganate attacks at the Adda moiety of the MCs. Even when the concentration of permanganate was 50 mM and periodate was under the saturation condition (200 mM), a minimum of 85% yield of MMPB was achieved [40]. Although a first approach on identification of by-products has been performed, the complete oxidative destruction pathways of MCs by permanganate have not yet been elucidated. The

PPIA toxicity tests for MC-LR and MC-RR treated with permanganate showed the removal of toxicity and the reaction products were also non-toxic [40]. Toxicity studies in natural waters showed no possible interactions between MCs or their oxidation products with the matrix components of natural waters. This further supports the feasibility of applying permanganate to remove MCs in natural waters.

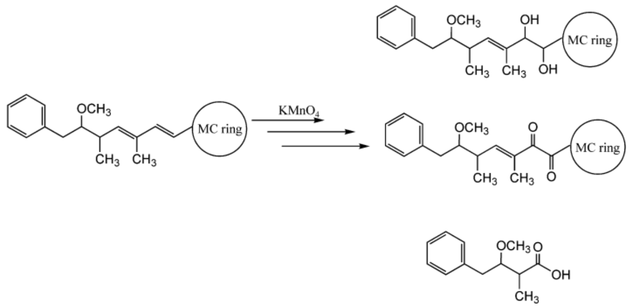

Figure 4. Decomposition by-products of MC-LR with $KMnO_4$ [26]

Advanced oxidation processes

In order to protect the environment it is increasingly resorted to use of environmentally friendly agents and methods for water treatment. This involves the use of oxidants and oxidation processes without toxic by-products and other consequences for the environment. Such processes are called Advanced Oxidation Processes (AOPs), which include: UV light in the presence of hydrogen peroxide or ozone, UV-near visible light in the presence of TiO_2, Fenton reagent, sonolysis, Ferrate, the salt of iron(VI) oxyanion FeO_4^{2-} etc. These methods can achieve mineralization of pollutants and are based mainly on the formation of the highly oxidizing HO• radicals at ambient temperature and atmospheric pressure.
Conventional oxidants, such as chlorine, are selective as to which compounds they can degrade, whereas AOPs are able to convert a great variety of organic compounds into CO_2 and mineral acids. HO• radicals are effective in destroying pollutants because they are electrophiles that react rapidly and nonselectively with nearly all electron rich organic compounds.

Photolysis

Some pollutants can be dissociated only in the presence of UV light. For this to happen, the pollutant must absorb light at a wavelength which is the same as emitted by the light source and have a reasonable quantum yield of photo-dissociation. Many organic pollutants absorb light at lower wavelengths, especially below 250 nm. For that reason, sunlight alone does not lead to their significant direct degradation because solar ultraviolet radiation is only a very small part of the solar spectrum (3.5–8%) [41]. This is also the case for MCs which have UV–vis absorption maxima at low wavelengths, λ = 238 nm and 210 nm resulting from the conjugated double bonds of Adda and the unsaturated bond of Mdha amino acids, respectively. The degradation of MC-LR was studied under natural sunlight in distilled water. Over 86% of MC was found to be present in the water after 26 days under these conditions. On the other hand, the toxins were decomposed by UV-C light while decomposition depended on the intensity of the light. The half-life of MC-LR under UV irradiation of 147 $\mu W/cm^2$ using a germicidal lamp which mainly emits (ca. 85–95%) UV at 254 nm, was 10 min and the toxin was completely decomposed using 2550 $\mu W/cm^2$ after 10 min [42].

UV/H_2O_2 process

It is known that H_2O_2 upon illumination with approximately, k < 370 nm, undergoes homolytic splitting into HO radicals, which can cause mineralization of a great variety of pollutants [43]. This process is influenced by many factors such as pH, concentration of H_2O_2, wavelength and intensity of irradiation, as well as initial concentration of the substrate [44]. UV/H_2O_2 has been widely studied and used to degrade organic pollutants in water [45]. Recently, this technology has been applied for the degradation of MCs in water because of its advantages, such as, relatively low operational cost, no sludge production, and ease of operation.

Fenton reagent

Reductive metal ions can catalyze the hydrolysis of H_2O_2 to form hydroxyl radicals. Fenton reagent, a mixture of ferrous ion and hydrogen peroxide, has been known as a powerful oxidant for organic contaminants. Bantala et al. [46] investigated the degradation of MC-LR in water using Fenton reagent. They reported that at low concentrations of hydrogen peroxide (0.25–0.5 mM), the extent of MC-LR degradation was low (20%), even after prolonged reaction time (up to 600 min). Higher H_2O_2 concentrations (2.5–5 mM) resulted in higher degradation rates that yielded MC-LR degradation as high as 61% in approximately 180 min. Gajdek et al. [47] also reported similar results for the decomposition of MC-LR in the presence of Fenton reagent. These authors observed MC-LR degradation with initial concentrations of H_2O_2 and Fe^{2+} in the reaction mixture being as low as 5 and 0.5 mM respectively. Increasing these concentrations threefold resulted in a very fast decay of the toxin while a slower reaction was observed when Fe^{2+} was substituted by Fe^{3+}.

Ferrate (VI)

The effectiveness of processing water using ferrate(VI) is explained by the high oxidation-reduction potential in acidic and neutral media (+ 2.2 V), higher than the oxidation-reduction potentials of the compounds that are commonly used in the processing and treatment of waste water, while during water oxidation with ferrate(VI) releases nascent oxygen, a strong oxidizing agent [48].
The degradation of MC-LR by ferrate(VI) has been studied as a function of ferrate(VI) dosage, pH, and contact time [49]. Low dosages of ferrate(VI) (5–10 mg/L) were insufficient for removing MC-LR while complete removal of MC-LR was achieved using 20 and 40 mg/L ferrate dosages at contact time of 40 min and pH values greater than 8. HPLC analysis of the reaction products suggests a modification of the Adda site and the heptapeptide ring of the MC-LR after the ferrate treatment [49]. The photocatalytic oxidation of MC-LR in the presence of ferrate(VI) has also been studied [50] The removal efficiency of MC-LR by ferrate depended on the dosage of ferrate(VI) and the pH of the reaction solution. Under optimum ferrate(VI) dosage (0.08 mmol/L) and solution pH (pH = 6), about 54% MC was removed after 30 min contact time.

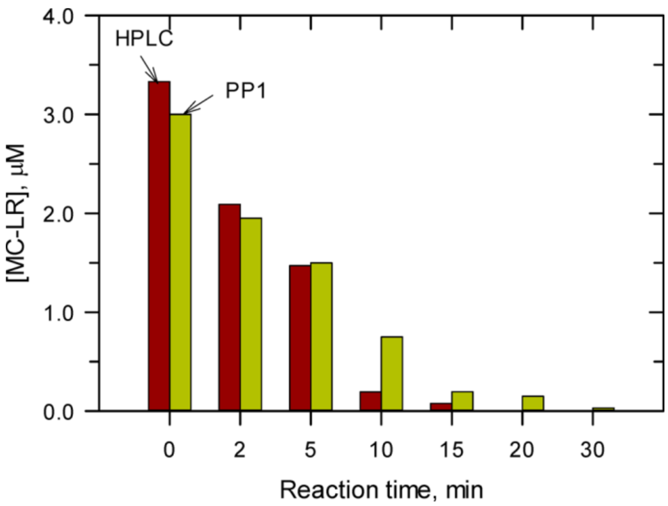

Figure 5. Oxidation of MC-LR by Fe(VI) in buffered deionized water. The residual concentration of MC-LR was monitored by HPLC and PP1 assay. (Experimental conditions: [MC-LR]0 = 3.33 µM; [Fe(VI)] = 66.6 µM; pH 8.0.)

CONCLUSIONS

Researches on conventional oxidation methods for degradation of MC are mainly related to clean, river, lake or reservoir water where in the presence of MCs (mostly MC-LR) determined is the reactivity of a variety of oxidants. Water quality parameters, such as pH, DOC and oxidizing agent doses play an important role in the whole process. Although literature information is relevant to the elimination of MC, only a rough comparison of different oxidants can be taken into account because of the results significantly depending on the nature of the treated water. As a result, although there is a general trend for the oxidation of MCs (ozone> permanganate> chlorine> oxidants based on chlorine), the selection of an appropriate oxidant for the elimination of toxins during water treatment should be evaluated for each particular water source.

ACKNOWLEDGEMENT

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UPGRADING THE SMALL WASTEWATER TREATMENT PLANTS BY LIME STABILIZATION OF DISPOSAL SLUDGE

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Abstract: There are already a large number of small wastewater treatment plants (WWTPS) in Iran. These plants are often decentralized and operated in an extended aeration activated sludge process. In this process, aeration reactors with a long hydraulic retention time (18 to 36 hours) show an energy consumption rate between 3 to 6 times more than conventional activated sludge process. Production of the stabilized sludge without the need for additional sludge facilities is referred to these types of WWTPS. However, many studies showed that due to increased organic and hydraulic loads, most of these plants could not stabilize sludge well. The purpose of this study was to improve the microbial quality of the sludge outlet from these WWTPS along with reduced energy consumption rate.
This research is a cross-sectional study. In the first part, the status of stabilization of disposal sludge in a number of small WWTPS in Tehran city, which work with extended aeration activated sludge method was studied. In the second part, the microbial quality of the sludge from the secondary sedimentation tank of Jonoob WWTP of Tehran, which is operated with the activated sludge process was studied. Then, lime stabilization of this sludge in a reactor with 5 liter capacity was investigated. Finally, the microbial quality of lime-added sludge was determined. The status of stabilization and reusability of sludge was carried out using the microbial indicators provided by the US Environmental Protection Agency (USEPA).
The microbial indicators of waste sludge from one small WWTP was at the level of class B of USEPA (Fecal Coliforms lower than 2×10^6 MPN/g of dry solids), while 3 other small WWTPS did not provide this minimum index. The sludge samples of Jonoob WWTP of Tehran did not meet any sludge microbial standards. After the lime addition, the microbial indexes in these sludge reached to class B of USEPA. By lime addition with the ratio about 0.35 g $Ca(OH)_2$ per g of dry solids, pH did not drop below 12 and any growth of fecal coliform was not detected before 30 days.
To improve the economic situation in these small WWTPS, the reduction of aeration time of the facilities to one-sixth of the existing rate can be considered. To upgrade sludge stabilization condition in these plants, lime addition reactors can be added.
Key words: Small WWTPs, Upgrading, Sludge stabilization, Lime addition

INTRODUCTION

Sewage sludge is an inevital by-product of domestic wastewater treatment plant [1]. Sewage sludge has been considerably increased in amount with the rapid progress urbanization and industrialization in Iran. Hence, operationional management of sludge is an integral part of municipal wastewater treatment plants (WWTPs) [2].
The disposal of sewage sludge is both expensive and environmentally sensitive following continuously increasing amount of municipal wastewater produced [3]. Therefore, treatment of sludge has drawn much attention and importance worldwide. Sewage sludge representing an alternative source of nutrients for plant growth and soil conditioner has been already utilized in agricultural and horticultural applications for several years [4]. However, sewage sludge may contain pathogenic organisms and pollutants, a range of toxic metals, which may negatively affect the soil properties [5]. Recently much attention has been paid to sludge management according to stringent regulations issue in USA and European Union. Wastewater treatment plants in Iran are often operated with extended aeration which is reffered with sludge characteristics compliance with EPA guideline for sludge disposal [6]. However, increased organic and hydraulic loads make failure extended aeration to meet these guidelines for land application. Lime is considered as one of the most common amendment materials for sewage sludge stabilization [7], as it plays significant role in reducing the microbial

content of sludge (pathogens), as well as the availability of heavy metals, enhancing the agricultural benefits and lowering the respective environmental risks [8]. Lime stabilization of municipal sewage sludge is a procedure that involves the addition of hydrated lime (Ca(OH)2) to liquid sludge until the sludge reaches a pH of approximately 12 for 2 h and maintains at pH above 11.5 for 22 h [9]. Many studies reported lime as applicable methods for stabilization of sludge for agricultural uses and land application [1, 10]. Lime is ubiquitous and is considered as inexpensive material for sludge treatment. The purpose of this study was to improve the microbial quality of the sludge outlet from small WWTPS by lime stabilization along with reduced energy consumption rate.

MATERIAL AND METHODS

This cross-sectional study was conducted within a time period of 12 months (2016-2017) to survey the sludge characteristics: Total Coliform (TC) and Fecal coliform (FC) of four local wastewater treatment plants which are operated with extended aeration method and one centralized wastewater treatment plant. Fig.1 shows the four decentralized WWTPs (Shoosh, Ekbatan, Qaitarie, Shahrak-Gharb) and a centralized one (Jonoob) sludge examined in this study. It is important to note that, Jonoob WWTP uses an activated sludge process for wastewater treatment.

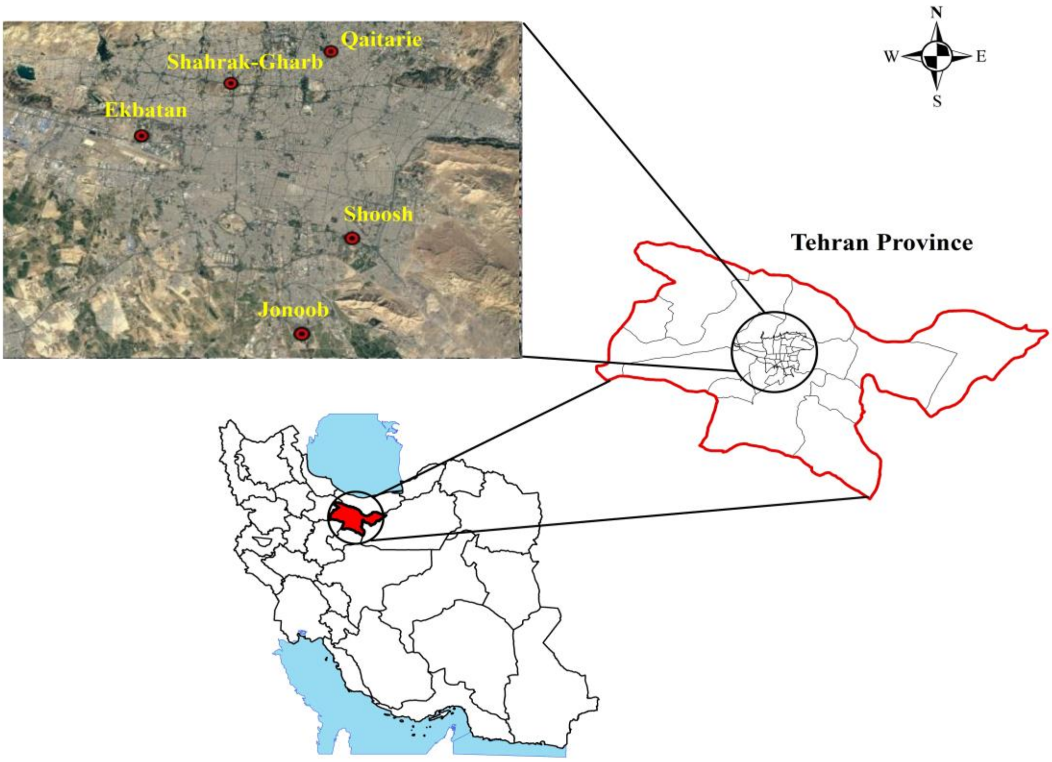

Figure 1. Location of WWTPs studied in the present research in Tehran, Iran.

Samples were taken at the sludge outlet from the WWTPs. The sludge was tested for stability and reuse potential indices such as: pH, TC and FC. Finally, the characteristics of disposal sludge were compared with the well-stabilized sludge criteria, recommended by USEPA [11]. TC and FC per each of sludge dry solid were measured based on the approaches outlined in APHA [12].
The experiments for sludge lime stabilization were carried out in a 5-L glass reactor. The reactor was loaded by raw sludge obtained from different WWTPs. Then different amount of hydrated lime ($Ca(OH)_2$) gram relative to per gram of dry solids of sludge (0.15, 0.2, 0.25, 0.35, and 0.4) were added and mixed with sludge. The optimum proportional dosage for each five different WWTPs sludge were determined. Finally, the two microbial indicators (TC and FC) were measured and compared to the values recommended by EPA to answer whether this dosage can meet the standards or not. The statistical analyses were conducted with SPSS (version 18) at the 95% confidence level (significance

was defined as P < 0.05).

RESULTS AND DISCUSSION

Microbial characteristics of sludge from different WWTPs

The characteristics of disposal sludge from different WWTPs are presented in Table 1.

Table 1. Characteristics of sludge prepared from five WWTPs.

Indicator	Qaitarie	Shahrak-Gharb	Ekbatan	Shoosh	Jonoob	EPA guideline
pH	7.43	7.87	7.8	7.15	7.35	….
TC*	1.4×10^7	1.9×10^7	1.25×10^7	2.1×10^7	2.5×10^7	---
FC*	0.3×10^7	0.8×10^7	1.7×10^6	0.9×10^7	1.0×10^7	$< 2.0\times10^6$

* MPN/g ds.

As presented in Table 1, the maximum and minimum two microbial parameters belonged to Jonoob and Ekbatan WWTPs, respectively. Out of four decentralized WWTPs which are operated with extended aeration, only Ekbatan could provided the standards for fecal coliform (< 2 million most probable number (MPN) of fecal coliform per gram of dry solids). However, it is the same about the only centralized WWTP (Jonoob) with the activated sludge process, this WWTP could not also meet the standard for FC. As observed from the data reported in Table 1, there was a significant difference between measured FC and the guideline value (p-value<0.01). Based on the USEPA criteria for well-stabilized sludge, the maximum amounts of FC density are <1000 and <2×106 MPN per g of dry solids for class A and class B, respectively. Therefore, there is utmost importance to reduce these values due to adverse effects associated with using sludge for agricultural uses and land application.

Lime addition for sludge stabilization

To meet class B requirements using lime stabilization, the pH of sludge must be increased to more than 12 for 2 h and subsequently maintained at more than 11.5 for 22 h. While, the regulations about class A are more stringent; class B must be elevated by a heat-producing system (70 ◦C for 30 min) [13]. The optimum proportional dosage (gram of lime relative to per gram of dry solids of sludge) for Ekbatan with lowest observed FC were 0.15. While, this value for three other small WWTPs which were operated with extended aeration were found to be 0.25. However, the optimum dosage for one WWTP with activated sludge was speciefied 0.4, which was higher compared to that used for sludge produced from extended aeration processes. The high pH makes an environment halting microbial reactions, otherwise, leads to odor production and vector attraction [14]. The pH of lime-added sludge were daily monitored within experiment period (45 days).

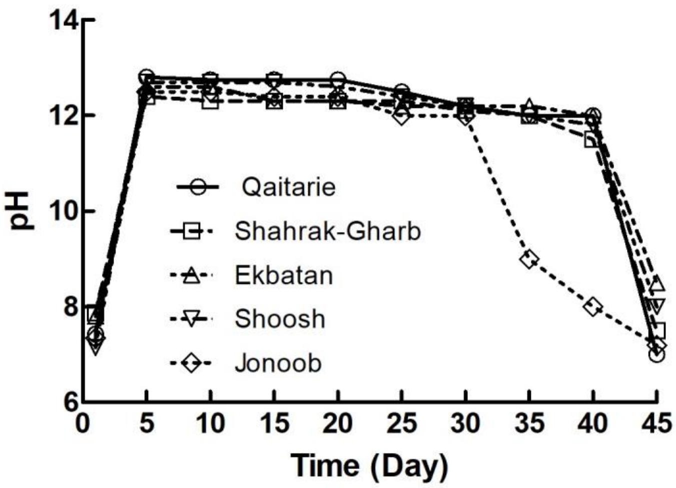

Figure. 2. The variation of pH during lime stabilization of sludge in five different WWTPs.

As indicated in Fig.2, the pH of sludge samples of 4 small WWTPs which were contacted with lime were not dropped below 12 and fecal coliform were maintained below value recommended by EPA for class B in 40 days. The pH of Jonoob WWTP sludge dropped below 12 at days 30 and fecal coliform was observed to regrowth. The variation of fecal coliform density in lime stabilized sludge and Class A and B of USEPA criteria were shown in Fig 3.

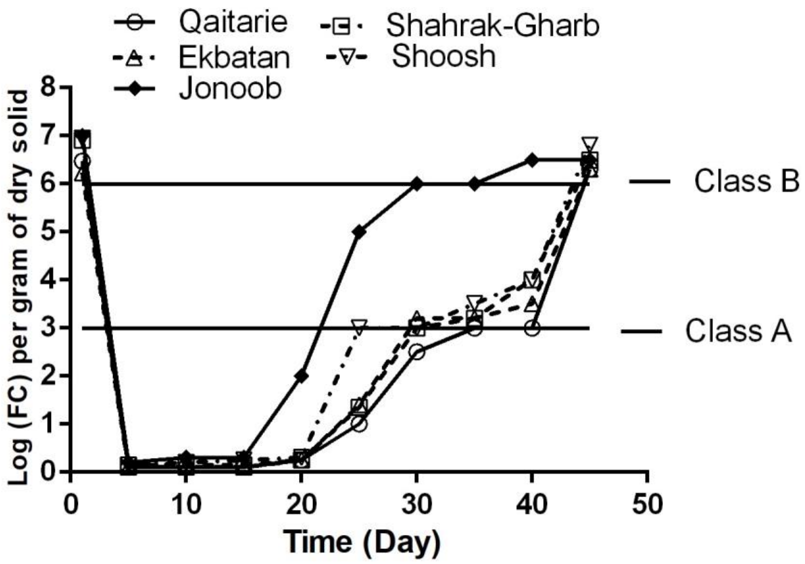

Figure 3. The variation of fecal coliform density in lime stabilized sludge and Class A and B of USEPA criteria.

CONCLUSION

The present study investigated that the characteristics of sludge produced by four decentralized WWTPs, operated with extended aeration with 18-24 aeration in the aeration tank and a centralized WWTP, which apply activated sludge for wastewater treatment. Among the WWTPs with extended aeration, only Ekbatan meets the standard for FC before discharging sludge into the environment. In addition, activated sludge also doesn’t provide standards corresponding to FC. Due to the characteristics of sludge, lime addition with a dosage from 0.2 to 0.35 g per each g of dried solid was used to stabilize sludge. The pH of all samples prepared from both extended aeration and activated sludge was not dropped below 12 in the initial 30 days, meaning it meets the standards enacted by the EPA for sludge disposal. Therefore, as lime can provide the standards for sludge disposal and on the other hand is a ubiquitous material throughout Iran adequently, it is definitely suggested to authorities involved in wastewater treatment to use it as alternative for extended aeration, requiring long-term aeration which subsequently considerably increases the energy consumption and cost. It is estimated that applying lime rather than extended aeration lower the annual and capital cost for WWTPs approximately 45- 55%.

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WATER SALINIZATION IN IRAN: SPATIAL VARIATION OF SALINITY IN GROUNDWATER RESOURCES OF NORTH WEST (URMIA LAKE)

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Abstract: This study presents the quality of drinking water in terms of salinity in the western margin of Lake Urmia, Iran. During the study a total of 121 samples from 116 wells and 5 springs were collected which constitute drinking water resources of 301 villages in the study area. Approximately more than 30% of the water resources were brackish or saline. The maximum EC is recorded at 3060 µs/cm, which is more than 2500 µs/cm recommended by the European Union. The minimum EC is 410 µs/cm with an average of 980± 495µs/cm. The brackish water resources were located in the northern parts, middle parts and also in the southeast. Unfortunately, in water resources of the study area, salinity seems to be high. This issue should be addressed as a serious concern by managers of water sector.
Key words: water quality, groundwater, salinity, electric conductivity

INTRODUCTION

One of the important characteristics of drinking water supplies is the amount of salts measured in the form of total dissolved solids (TDS) or salinity [1]. The salinity shows the suitability of water for defined purposes such as drinking, industrial and agricultural applications. According to definition, water is classified as fresh, brackish or saline [2] as following:

Table 1. Water classification [2]

Salinity (mg/L)	**Category**
up to 1,000	Fresh
1,000 to 3,000	Fresh to brackish
3,000 to 5,000	Brackish
5,000 to 35,000	Saline
35,000 and above	Hyper-saline

According to the Australian Drinking Water Guidelines the taste of drinking water is graded according to salinity as follows [2]:

Table 2. The taste of drinking water **[**2]

Salinity (mg/L)	**Quality**
< 80	excellent
80 - 500	good
Error! Not a valid link.	fair
800 - 1,000	poor
Error! Not a valid link.	unacceptable

Increasing the trend of salinity of soils and subsequently water resources is considered as a serious threat for many societies in the world [3]. The presence of high levels of TDS may be objectionable to consumers, due to excessive scaling in water distribution pipes, heaters, boilers and household appliances. World health organization (WHO) considered the palatability of water with a TDS level of less than about 600 mg/l as good [4]. At TDS levels greater than about 1000 mg/l, drinking-water

becomes significantly unpalatable. According to the Iranian national standard for drinking water (1053), desired limit and permissible limit for TDS is 1000 and 1500 mg/L, respectively [5]. No health-based guideline value for TDS has been proposed. TDS 1500 mg/L is almost considered equal to 2500 µs/cm electric conductivity (EC).
Salinity of water is considered as a function of precipitation, evaporation and geological structure, saltwater intrusion, land use, climate change and etc. [3]. There are three forms of salinity including primary salinity (also called natural salinity); secondary salinity (also called dry land salinity), and tertiary salinity (also called irrigation salinity). Dissolved salts are usually sodium and chloride ions, although there can also be many others such as potassium and bicarbonate ions. The aim of this study was to investigate the amount of salinity in the drinking water resources of the western margin of the Urmia (Ormiyeh) Lake in the northwest of Iran. This lake is one of the largest hypersaline lakes in the world with a total surface area between 4750 and 6100 km^2. During recent years, the salinity of the lake has risen to more than 300 g/L due to drought and increased demands for agricultural water in the lake's basin [6]. Now many parts of the lake are dry.

MATERIAL AND METHODS

Sampling and analysis

The study area is in West Azerbaijan Province (WAP) in the northwest of Iran. Samples were collected from rural drinking groundwater resources of five cities including Salmas, Urmia, Naghadeh, Mahabad and Miandoab. These cities are located in the northwest, west and southwest of Urmia lake. From a total of 121 samples, 13, 82, 17, 5, and 4 samples were collected from rural water resources of Salmas, Urmia, Naghadeh, Mahabad and Miandoab counties, respectively [7]. The samples were taken from 116 wells and 5 springs which constitute drinking water sources of 301 villages in the study area [7]. All samples were collected and analyzed based on the standard procedure of sampling, transportation, preservation and analysis. In this paper we have reported results of Electric conductivity (EC) and chloride of samples which were determined with EC meter and titration, respectively.

Mapping

As mentioned in our published work all the data were entered into a spatial database and spatial variations of the results were developed using inverse distance weighting (IDW) method [8]. Arc GIS software (version 10.0) was also applied for developing maps. IDW interpolation assumes that each measured point has a local influence that diminishes with distance. Thus, points in the near neighborhood are given high weights, whereas points at a far distance are given small weights. Complete assessment of the energy balance of fuel cycle includes not only the energy content of biodiesel and energy is spent in the production, but also energy that is absorbed welcome by all the necessary process to reach the final product. The advantage of IDW is the efficiency and intuition, that's why IDW method is widely used in spatial interpolation of groundwater quality [8].

RESULTS AND DISCUSSION

Figure 1 shows the amount of EC by studied counties. The shape of the box plots indicates the abnormal distribution of electrical conductivity in some parts studied areas. According to the figure, in some of the water sources, EC is higher than the desired value of 850 µs/cm (= TDS 600 mg/l by WHO). In total, 68.6% of the samples had an EC value of less than 1000 µs/cm. The maximum EC is recorded at 3060 µs/cm, which is more than 2500 µs/cm recommended by the European Union. In other words, most water sources are brackish and in two cases the water sources are saline. The minimum EC was 410 µs/cm and the average was 980± 495 µs/cm. According to the permissible limits for classes of irrigation water, water with EC of 750-2,000 µs/cm is considered as Class 3 which is permissible for irrigation. However, water with EC of 3000 µs/cm is considered as Class 5 which is unsuitable for irrigation [1]. Regarding chloride as the main anion of salinity, in the most water sources the measured value is less than the maximum allowed level of 400 mg/l [5], but in three sources this amount exceeds the maximum permitted level up to 950 mg/l, indicating the salinity of water sources (Figure 2).

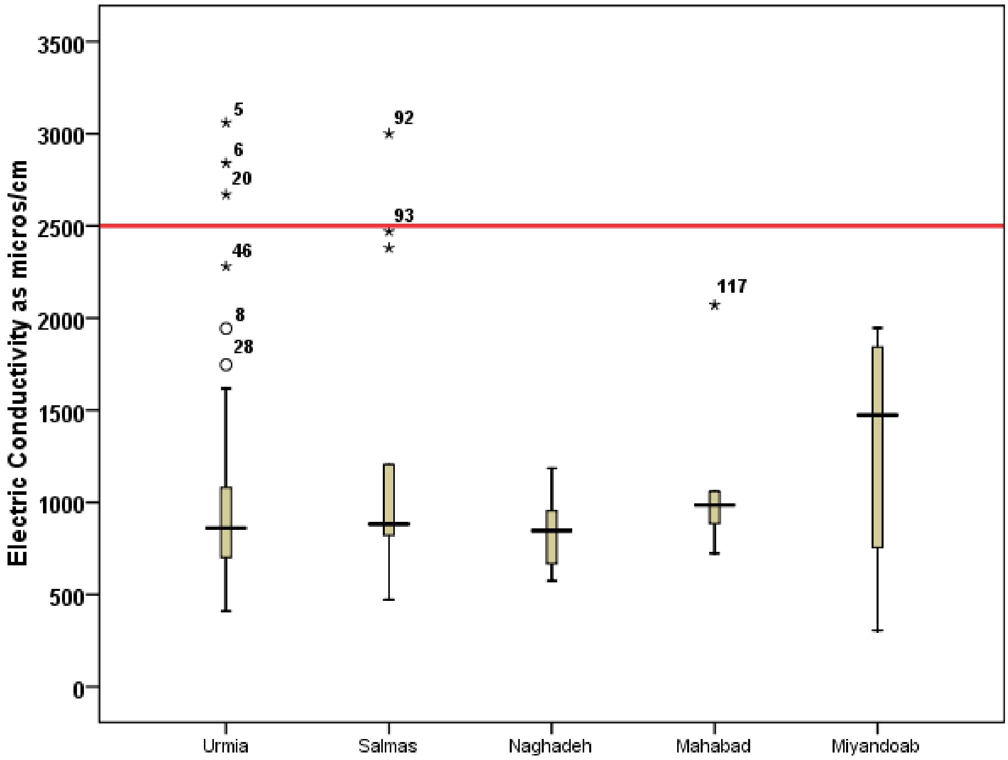

Figure 1. Range of EC in groundwater resources of the study area

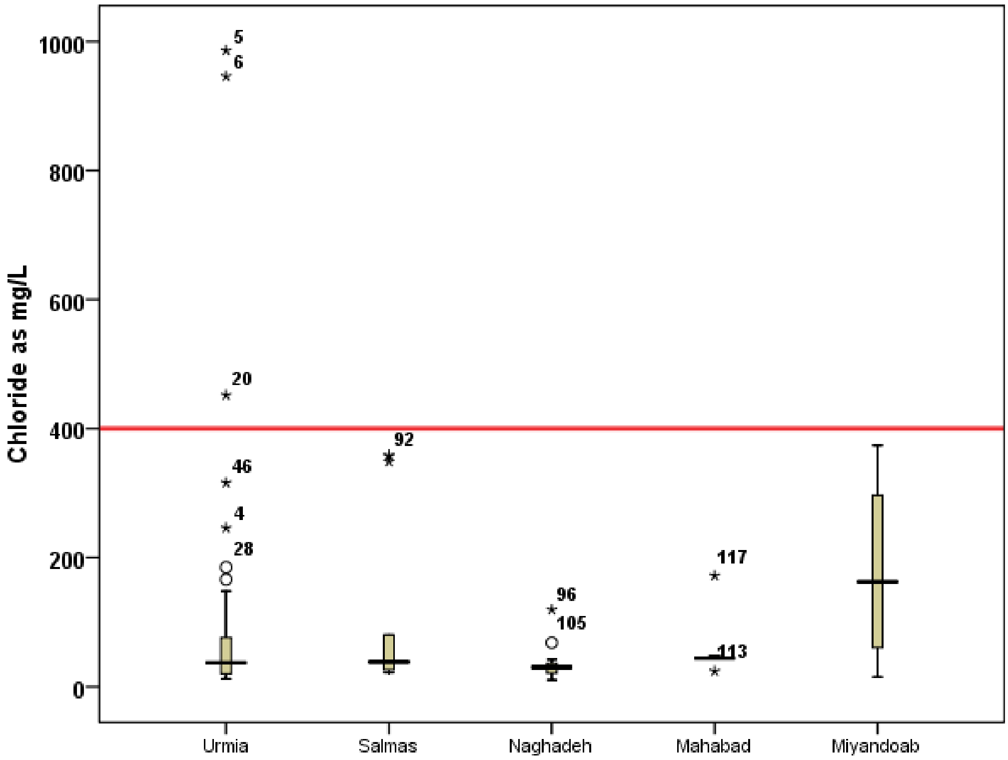

Figure 2. Range of chloride in groundwater resources of the study area

According to the Figure 3, distribution of electrical conductivity in analyzed water resources is not similar throughout the studied region. As the brackish water resources are more visible in the northern parts, middle part and in the southeast. It appears that the amount of TDS in water in the areas adjacent to Urmia Lake is higher than non-adjacent areas. In other words, the salinity of some water resources close to Urmia lake may be increased due to the salt water intrusion. Whereas, in water resources which are brackish or saline but away from the lake, salinity may arise from geological formation or other causes that need to be more investigated. It should be noticed that salinity can be vary during the year because of dilution due to the rain and high salinity is usually recorded in the summer and low salinity in the winter. As a general rule, salinity is relatively low during periods of high flow and vice-versa [9].

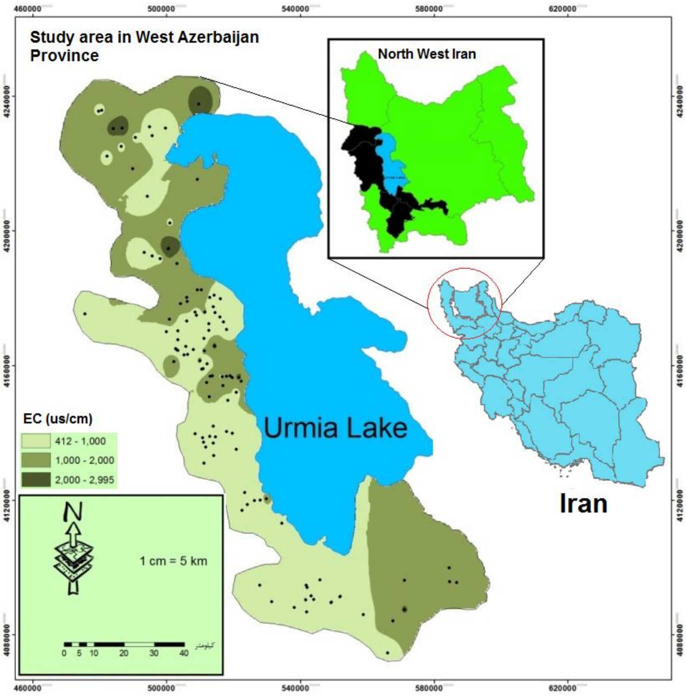

Figure 3. Spatial distribution of EC in the drinking groundwater resources of the study area

The phenomenon of salinization of groundwater resources is increasing in most parts of the country due to over-impressions, incorrect irrigation practices, as well as naturally processes due to saline geology [10, 11]. Consequently, high EC is observed in the most aquifers and for example, in aquifers which EC was previously below 1000 µs/cm now it reaches at least 3000 µs/cm and in some rivers, from 800 µs/cm has increased to more than 5000 µs/cm [12]. Such this water is not only suitable for drinking purposes, but also for agriculture irrigation. The use of brackish or saline water sources in agriculture will increase the risk of salinity hazard and sodium hazard, and eventually the salinization of agricultural lands [1]. The salinization of agricultural land soils will subsequently increase TDS of irrigation drainages and runoffs which ultimately, salinity of water resources will double. When consider the cost of desalinization of brackish and saline water for drinking purposes using known methods such as RO[13], the cost of occurred damage of water salinization are quite obvious.

To solve the problem, as the first step, the water managers should accept the phenomenon of salinization and water crisis [14] of the country, and know about the damage caused by this phenomenon and its cost value. Obviously, after this step and understanding the importance of the issue, we can establish the necessary policy to deal with the phenomenon of the water resources salinization. The following suggestions can be made for adopting suitable solutions to address the salinity of water resources:

- Identify the status, trend and zoning of TDS and salinity of the water resources along with soils [15]
- Sequence of different regions of the country in terms of identifying the factors creating and increasing the salinity of surface water and underground resources
- Large-scale policy to reform and change irrigation practices and agricultural land cultivation practices to reduce water resources salinity

- Policies to reduce evaporation from soil and water resources as one of the important factors of salinity
- Policies to reduce water withdrawal as an important factor in salinity
- Policies to direct surface runoff and to prevent passage of lands with saline geological structures
- Policies to ban dumping and construction of reservoirs in areas with reserves, mines and salt domes and salt formations
- Policies for the implementation of saline water treatment projects
- Policies for the development of fresh water production technologies form saline water and the achievement of technical independence in order to produce reverse osmosis membranes as a growing and accepted method in the world.

CONCLUSION

According to present study, in a significant number of investigated water resources, EC is more than desired limit. Approximately more than 30% of the water resources are brackish or saline. Increasing TDS in some sources can be due to intrusion of saline water from Urmia Lake and in distant areas of the lake may be caused by saline geology or the impact of agriculture activities. In total, considering the quality of water in different areas, water resources in Iran are becoming salty. This issue should be addressed as a serious concern. Water managers in the country needs to have the appropriate policy to deal with the salinity of water resources. It is recommended to study the trend of salinity of the all plains and aquifers throughout the country.

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PHOTOCATALYTIC DEGRADATION OF DIAZINON FROM AQUEOUS SOLUTIONS USING TiO_2/ZnO NANOCOMPOSITE

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Abstract: Diazinon is an organophosphate pesticides widely used against agricultural pests and vectors. Diazinon resists to biodegradation so there is major environmental concern. The aim of present research was to study the degradation of diazinon using TiO_2/ZnO nanocomposite in the presence of UVC radiation.
This work is a laboratory-experimental study. The characterization of nanoparticles was determined through TEM pattern. The number of samples were determined by the Taguchi statistical method. The samples with definite concentration of diazinon and nanoparticles in different operational conditions were exposed to UVC radiation, individually. Diazinon concentration was measured through HPLC.
The results showed that the removal of diazinon increases with increasing reaction time however the removal efficiency decreases with increasing the nanoparticles dose or Diazinon concentration. The highest removal efficiency rate was 98%. The combination of catalysts is a new method for the removal of diazinon. It is concluded that the TiO_2/ZnO nanocomposite is an effectiveness nanocomposite on diazinon degradation.
Key words: Diazinon, photocatalystic degradation, water treatment, TiO_2/ZnO nanocomposite

INTRODUCTION

Photocatalytic degradation of organic pollutants with some semiconductors, has been attracted attention in the past decades. ZnO and TiO_2 are two Semiconductor which are most used among other semiconductor because of increased lifetime of charge carriers, more efficient charge separation and enhanced efficiency of the interfacial charge transfer to adsorbed substrates. In recent years, the combination of two semiconductors together is a new approach towards achieving a more efficient to remove contaminations [1,4]. The presence of the UV is required for a photo catalytic reaction. When the UV is absorbed in the semiconductor surface, due to excitation of electrons in the volcanic band (VB) and their movement towards conduction band (CB).Then some series of redox reactions accrue on semiconductor surface [5].The wide band in these two semiconductors has been limited because it only absorbs 3 - 5 % of the UV wavelength range [6]. The rapid recombination of electron-hole pairs together is another limitation of this semiconductor. Because the lack of electron donors or acceptors leads to loss of energy and reduced photocatalyst performance [7]. In the zno-tio2 system, the electron transfer from conduction band (CB) to the valence band (VB). This transfer from conduction band (CB) to the valence band (VB) surpasses the energy of the band of gaps when the photon irradiation. Electron transfer from ZnO to TiO2 due to their potential difference but electron transfer from ZnO to TiO2 occur under UV radiation [8]. This process begins when the composite absorbs photons and having energy equal to or greater than the band gap of the composite. when band gap excitation, highly reactive holes (h^+) and electrons (e^-) are generated, these two go on to generate highly oxidizing hydroxyl radical (OH%) and reductive superoxide (O^{-2})[9,10]. In general, nanoparticles and nanocomposites applying in vast range. Along of the high oxidative potential of hydroxyl radicals, many organic compounds, can be decomposed [11, 12, 13]. Hydroxyl radicals plays a major role in decomposing pollutants and mineralization to CO_2. However, radical hydroxyl production is heavily dependent on the surface properties of the catalyst [14]. To increase properties like large specific surface area and proper pore size distribution, doping has been discovered. N-doped done by given amount of nitrogen into carbon via a post treatment process, such as treat with ammonia, urea, amine, etc [15]. Organophosphate insecticides by disrupting acetylcholine enzyme can affect the nervous system of humans. Diazinon is the most insecticide that detected in surface waters, rice fields and fish in Iran. The conventional water treatment process is inefficient in removing pollutants, including diazinon. [16, 17, 18]. The main purpose of this study removal of diazinon by ZnO-TiO_2 composite followed by n-doping by means of ammonia treatment with various NH3 mass fractions in different situation like various pH, diazinon concentration, irradiation time and nanocomposite dosage.

MATERIAL AND METHODS

Sol-gel is a wet-chemical technique and one of the most widely used means of catalysts preparation. In this study, sol–gel process was used for catalyst synthesis. This method is mainly used to produce catalyst powders or thin films [19]. Tetra butyl titanate (TBT, Aldrich, 99.99%) applying for prepare transparent TiO_2 sol at room temperature. 5 mL TBT was dissolved in 20 mL ethanol and stirred for 30 Minutes To get a precursor solution. A mixture of 0.26 mL distilled water, 3.4 mL glacial acetic acid, and 5 mL ethanol, Drop of drop is added into the precursor solution under a strong stirring. After that, the solution was incessantly stirred for 1 hr to achieve a transparent yellow TiO_2 sol.
Zinc acetate (Aldrich, 99.99%) as a precursor to provide ZnO sol. Firstly 3.29 g zinc acetate was dissolved in 20 mL ethanol and stirred for 5 Minutes at 50 °C in water bath for make a precursor solution. A mixture of 0.26 mL distilled water, 1.58 mL diethanolamine, and 5 mL ethanol, dropped into the precursor solution drop per second under a strong stirring. After that, the solution was continuously stirred for 2 h to achieve a transparent ZnO sol.
For provide ZnO-TiO_2 composite, the prepared ZnO sol was then directly merge into the TiO_2 sol at an atomic molar ratio of Ti to Zn of 3/1 as gr. The composite sol was remained at room temperature and then dried at 80 °C for 1day in a muffle. After that, the gel was pulverized and soaked in ammonia with NH_3 mass fractions 7% for 24 h at room temperature then, thermal calcinations for 2 h at temperatures 700 °C in air [20].
The prepared TiO_2/ZnO composite powder was characterized in detail by transmission electron microscopy (TEM, JEM-2100, JEOL, Japan) and Brunauer- Emmett-Teller (BET) (XRD, XPERT-PRO).
To determine the synthetic composite performance, removal of diazinon was investigated. In this process used the reactor with a volume of 2 liters. A UVC 6.5 W low-pressure mercury lamp (OSRAM-HSN Co.) emitting radiation mainly at 254 nm used as irradiation source. The concentration of diazinon was used in this study 15, 30, 50 and 100 mg/L. pH adjusted with NaOH and HCL In range 3, 5, 7 and 9. The amount of nanoparticle consumed 0.2, 0.5, 1 and 2 gr/L and Reaction time was 2, 5, 15 and 30 minutes. Fig1, showed the reactor schematic that used in this research.
The diazinon concentration was measured using a Knauer HPLC (C18 ODS reverse phase column; 250 × 4.6 × 5) with a UV-PDA detector at a wavelength of 247.5 nm. The mobile phase was a mixture of acetonitrile and water with a volumetric ratio of 75/25 and an injection flow rate of 1 mL/min. Samples before injection in HPLC¸ Centrifuge at 4000 rpm For 2 min.

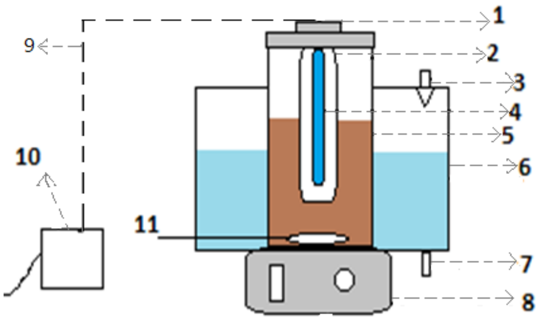

Figure 1. Characteristics of the reactor
1. Reactor door, 2. Quartz Protector 3. Water Injection Vapor 4.UVC Lamp 5. Glass 6.Blue Fluid 7.Water Exhaust Vent 8. Magnetic Mixer 9. Flow Connector Wire 10. Transmission Lamp 11. Magnet

RESULTS AND DISCUSSION

In this section, important cases that should be addressed include (1) Characteristics of synthesized catalyst, (2) the effect of pH, (3) the effect of diazinon concentration, (4) The effect of irradiation time, and (5) The effect of nanocomposite dosage.

Characteristics of synthesized catalyst

Fig. 2 illustrates TEM images of synthesized ZnO–TiO_2 powder samples with molar ratio 3:1. The small amount of agglomerations can be seen in the micrographs. TEM images indicate that the average crystallite size of synthesized material is in nanometer range [39]. The specific surface area of ZnO–TiO_2 composite is usually calculated by the multi-point Brunauer- Emmett-Teller (BET) model and the correlation of isotherms and hysteresis loops to the pore-size distribution curves can be unveiled through Barrett-Joyner-Halenda (BJH) model[40]. The TEM image of the composite obviously proves the spherical particles of the composite and its average particle size of 12.5-25 nm. Like Tian achieved it [20].

The Brunauer Emmett Teller (BET) surface area was measured by nitrogen adsorption in a Micromeritics ASAP 2020 Accelerated Surface Area and Porosimetry System, USA. The BET method is considered to be the most useful method to measure the surface area, and is based on the theoretical model of a monolayer formation in the physical adsorption of gas molecules. All surface properties, such as surface area and pore volume of N_2 doped ZnO-TiO_2 samples are given in Table1 and compared with their corresponding values of the pure ZnO and TiO_2 samples. It is noticeable that with increased concentrations doped with N_2, the volume of adsorbed gas increased and the hysteresis loops became broader under a range of relative. These results are attributed to the increased surface area with increased ion concentration. From Table 5 it can be observed that for all concentrations of N_2 doped ZnO–TiO_2, the surface areas are higher compared to those of pure ZnO and TiO_2. This result confirms that the doping process enhances the surface area of ZnO–TiO_2, even at low concentrations [41].

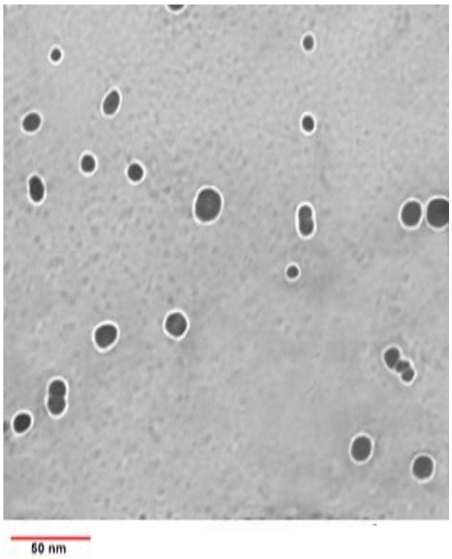

Figure 2.TEM Image of nanocomposite

Table 1. The BET experimental range and their levels

Runs	y_1	y_2
1	166.66	1.05
2	144.25	1.02
3	131.56	0.13

The effect of pH

The influence of water pH (3, 5.7, 9) on the performance of ZnO-TiO_2/UVC processes for the degradation of diazinon (15 mg/L) in distilled water was examined. pH has an important role in the photocatalytic process of various pollutants. Because pH effects on the semiconductor surface charge, so affects the transmission of electrons and the photo redox process and its bond to the ionic form of the organic compound [21]. Fig. 3 shows that degradation efficiency was enhanced from 79 to 98. % by increasing the initial pH from 3 to 7 and then decreased to 79 at pH 9. One reason for the maximum degradation efficiency at neutral pH can be a photo corrosion of ZnO in acidic and basic solutions. The pH_{zpc} of ZnO–TiO_2 was~6. The pH_{zpc} of TiO_2 and ZnO is known are 6.5 and 9 respectively, from previous studies. The pKa value of diazinon is known as 2.6. Different photocatalytic activity at different solution pH can be explained by different electrostatic interaction between photocatalyst surface and diazinon. As the pKa value of diazinon is 2.6, it has negative charge above pH 2.6, whereas ZnO–TiO_2 composite is positively charged below pH 6. As expected, an optimal condition can be developed pH range between pKa diaiznon and pH_{zpc} of ZnO–TiO_2 at which the positively charged ZnO–TiO_2 and negatively charged diazinon should readily attract each other. At high pH, both diazinon and ZnO–TiO_2 have negative charges. Therefore electrostatic repulsion between diazinon and ZnO–TiO_2 composite causes reduced adsorption of diazinon onto ZnO–TiO_2 composite and results in decreased photocatalytic removal efficiency. From this study, pH 7 was identified as an optimum condition for the removal of diazinon using ZnO–TiO_2 composite [22]. These results are consistent with the results of previous studies [23,25]. The results of the Kruskal-Wallis test show that there is a significant difference in different pH. This means that pH can have a positive effect on removal rate (P_{value} <0.001).

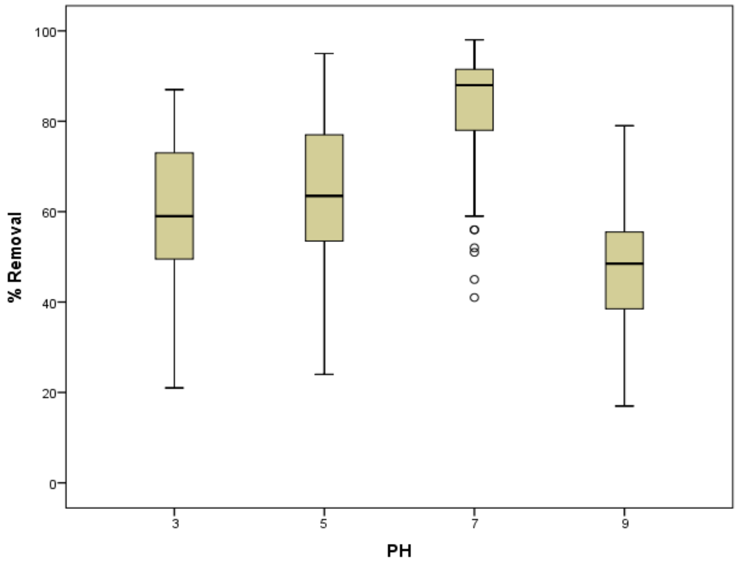

Figure 3. The effect of pH on the removal of diazinon by of ZnO-TiO_2/UVC process (Diazinon concentration=15mg/L; nanocomposite dosage=0.5 g/L; contact time=30min)

The effect of diazinon concentration

The influence of the initial reactant concentration is a determining agent in the photocatalytic activity in pollutant degradation. The relation between the photocatalytic activity and initial concentration is affiliated with the adsorption of reactant on the photocatalyst surface and the screening effect due to reactant overloading. The photocatalytic activity of composite normally decreases as the initial reactant concentration increases [26]. By increasing the concentration of diazinon, more organics adsorption on the ZnO–TiO_2 nanocomposite surface, so there will be less active sites for adsorption of hydroxyl ions and this leads to a reduction in the production of hydroxyl radicals. In addition, with increasing concentrations Diazinon, the photon is broken down before it reaches the catalyst level, and the photon absorption by the catalyst is reduced and subsequently decomposition percentages are reduced[27,28]. According to Fig 4, the maximum removal of diazinon occurred at a concentration was 15 mg /L, equivalent to 98%. It decreased with increasing concentration of diazinon and finally at a concentration of 100 mg /l was lowest. These results are consistent with previous studies [29, 32]. Kruskal-Wallis test results show that there is a significant difference in different concentrations, meaning that diazinon concentration can have a positive effect on removal rate ($P_{value} < 0.001$). Also, the results of the mann-whitney test, which compare two to two variables, show a meaningful relationship between all two variables.

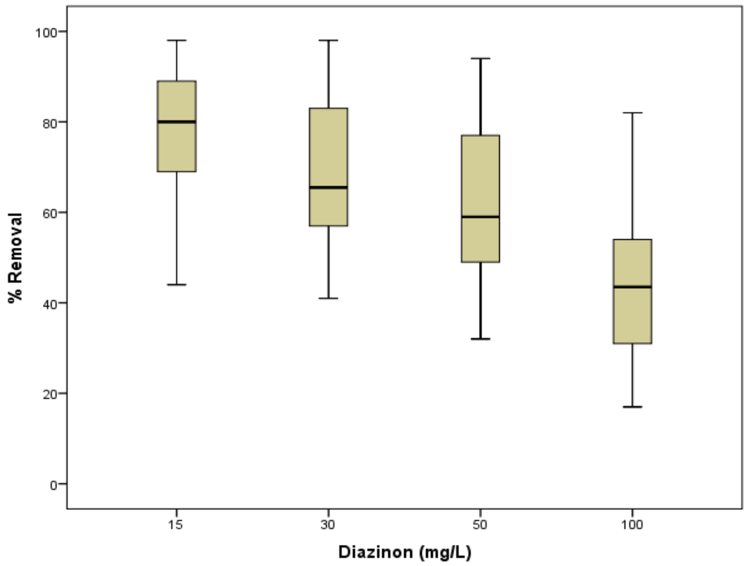

Figure 4. The effect of diazinon concentration on the removal of diazinon by of ZnO-TiO_2/UVC process (pH=7; nanocomposite dosage=0.5 g/L; contact time=30min)

The effect of contact time

TiO_2 and ZnO are highly active photocatalysts under UV light irradiation since their photo generated electrons and holes are efficient oxidizing and reducing agents. They are two semiconductor with same band gap (3.2 and 3.3 eV) which needs excitation light to start to photocatalytic activity. In recent years, the Doping method has been considered to improve ZnO and TiO_2 photocatalytic activity. Doping of two photocatalysts is a method used for retarding the rapid charge recombination and enabling visible light absorption by creating defect states in the band gap [26]. The effect of photo irradiation time on the photocatalytic process were investigated at different times of 2, 5, 15 and 30. According Fig5, the maximum removal was observed at 98% for 30 min. Increasing the contact time leads to increasing efficiency. This is due to increase in the amount of hydroxyl radicals which is followed by the increase of electrons Holes occur in nanoparticles and lead to the further removal of diazinon [33]. In other study, it was demonstrated [34]. The results of the Kruskal-Wallis test show that there is a significant difference at different times in the sense that time can have a positive effect on the degree of removal ($P_{value} < 0.001$). Also, the results of mann-whitney test, which are two or two variables, show that time 2 with 5, 5 with 15 min is not significant but in other times it is significant.

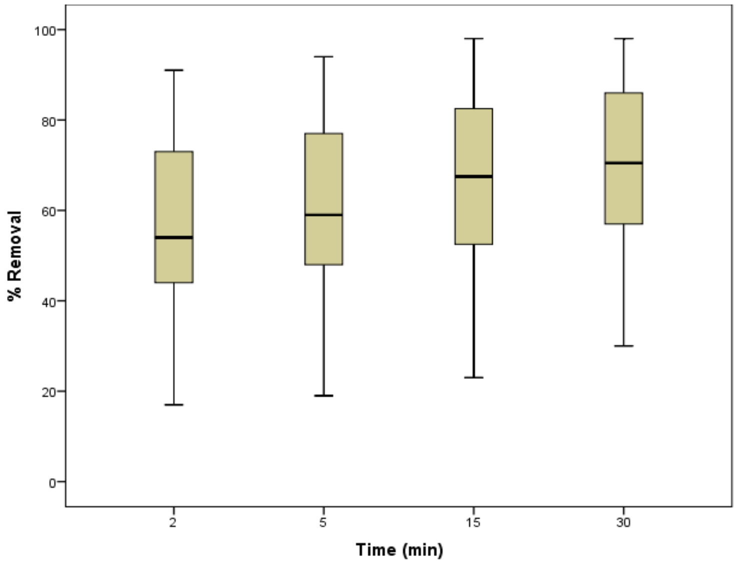

Figure 5. The effect of contact time on the removal of diazinon by of ZnO-TiO_2/UVC process (pH=7; nanocomposite dosage=0.5 g/L; Diazinon concentration=15mg/L)

The effect of nanocomposite dosage

Using the optimal nanocomposite dosage minimizes the cost and energy of the photocatalytic process. According to research results, with increasing photocatalyst dosage, the number of photos that absorbed on the photocatalyst surface increases. And subsequently increases the generation of electron-hole pairs and the number of hydroxyl radicals. Nonetheless, the amount of organic pollutants adsorbed on the photocatalyst surface increases, which contributes to higher degradation efficiency. In this study, effect of nanocomposite dosage investigated in different dosage 0.2, 0.5, 1 and 2g/L. With increasing nanoparticle concentration up to 0.5 g/L system efficiency decreases. The catalyst dosage does not significantly disturb the degeneration of diazinon.

According Fig 6, the photo degradation efficiency increased with an increase nanocomposite dosage up to 0.5 g/L and after that the increase in nanocomposite loading dosage not affect the degradation significantly. This observation can be explained in terms of availability of active sites on the catalyst surface and the penetration of UV light into the suspension. The total active surface area increases with increasing catalyst dosage. At the same time, due to an increase in the turbidity of the suspension, there is a decrease in UV light penetration as a result of increased scattering effect and hence the photo activated volume of suspension decreases. Further, at high catalyst loading, it is difficult to maintain the suspension homogenous due to particles agglomeration, which decreases the number of active sites [21, 23, 35, and 38]. The results of the Kruskal-Wallis test show that there is a significant difference in different doses, meaning that the dose of Nano-particles can have a positive effect on removal rate (P value <0.05). Also, the results of the mann-whitney test, which showed two to two variables, were statistically significant at doses of 0.2, 0.5, 0.15, 2, and 1, respectively.

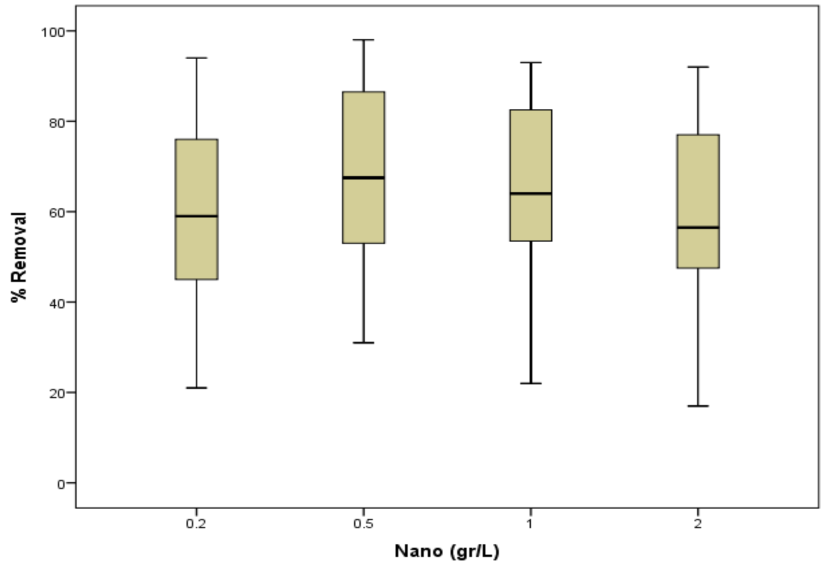

Figure 6. The effect of nanocomposite dosage on the removal of diazinon by of ZnO-TiO_2/UVC process (pH=7; Diazinon concentration=15mg/L; contact time=30min)

CONCLUSION

Nanocomposite was constructed using sol-gel method and properties confirmed by TEM and BET analysis. The highest degradation efficiency of 98% was shown by 0.50 g/L ZnO-TiO_2 by 30 min irradiation time. The enhancement of photocatalytic degradation of diazinon by ZnO-TiO_2 was attributed to the increase of separation of the photo-generated electrons and the photo-generated hole traps, producing more highly reactive • OH and •¯O2 radicals. Therefore, this simple route to produce higher-activity photocatalysts for environmental remediation of toxic compounds is shown to be cost effective and to apply particularly in industrial production in the future.

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THE EFFECT OF A HIGH CONCENTRATION OF POLLUTANT ON METABOLIC ACTIVITY OF SELECTED FUNGI AND THEIR BIOREMEDIATION POTENTIAL

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Abstract: The effect of ethoxylated oleyl-cetyl alcohol at a high concentration (1%) on the growth and metabolism of *A. niger*, *F. oxysporum* and *T. roseum* was evaluated in the current study. The growth of tested fungi was investigated by monitoring the diameter of colonies on solid Czapek-Dox media during 8 days. *T. roseum* had the best response to a high concentration of pollutant and lowest level of growth inhibition. The metabolic activity of fungi was examined during their cultivation in liquid Czapek-Dox media with and without pollutant (control). The following physico-chemical and biochemical parameters were carried out: pH, quantity of free and total organic acids, proteolytic activity. The pH values of polluted media of fungi with, exemption of *T. roseum*, were higher compared to pH values of controls media. The pollutant caused a stimulatory effect on amount of free organic acids of *A. niger* and *T. roseum*, and total organic acids of all tested fungi. Proteolytic activity of *T. roseum* and *F. oxysporum* was moderate inhibited whereas the enzyme activity of *A. niger* was strongly enhanced (239%) by applied pollutant. The obtained results indicate on potential application of tested fungi in mycoremediation of alcohol ethoxylated contaminated environments and biotechnology.
Key words: colony diameter, fungi, organic acids, pH value, proteolytic activity

INTRODUCTION

Fatty alcohol ethoxylates (FAEs) are an important group of nonionic surfactants. These chemicals are used in a wide range of personal care and cleaning products, due to they have been recognized as high volume chemicals in environment. The major disposal route of FAE is down-the-drain through sewage systems and municipal wastewater treatment plants (WWTP) into receiving surface waters. They are extensively biologically degraded by WWTP in excess of 95–99%, [1], [2]. However, even biodegradable surfactants can have a toxic effect upon the living beings if they are present in quantities above permitted. The investigation of wastes after primary biodegradation indicated considerable toxicity of the intermediate metabolites derived from FASs. Due to, it is necessary to applied different methods for reduce the level of these surfactants in environment. In purpose of the reduction of pollutants and environmental cleanup it has developed combinations of physical, chemical and biological methods, [3]. At present, bioremediation is considered as less expensive and eco-friendly alternative to physical and chemical technology for decontaminating sites which are contaminated with wide range of pollutants, [4]. Mycoremediation is an innovative biotechnology that uses living fungus for *in situ* and *ex situ* cleanup and management of contaminated sites, [5]. Filamentous fungi have ability to grow on wide spectrum of substrates by secreting extracellular hydrolytic enzymes, even capable of growing under ambient environment. Furthermore, due to the low substrate specificity of their degradative enzyme machinery, fungi are able to perform the breakdown of a wide range of organic and xenobiotic pollutants: polycyclic aromatic hydrocarbons, petroleum hydrocarbons, chlorophenols, polychlorinated biphenyls, dioxins and furans, herbicides, pesticides, nitroaromatic explosives, [6], [7]. These fungal properties are utilized in a variety of processes (biological control agent, biobleaching, bioremediation, waste treatment).
Among numerous micromycetes isolated from household wastewater, several species of fungi (*A. tenuis*, *P. verrucosum*, *F. oxysporum*, *etc.*,) have been identified according to their ability to grow and metabolize ethoxylated oleyl-cetyl alcohol at a wide concentration range, [8-10]. Isolation and identification of fungi from aquatic ecosystems that are resistant to the presence of high concentrations

of this pollutant on the one hand, and the effect of a pollutant on their metabolism on the other hand, are crucial parameters for application of fungi in mycoremediation. Thus, the current study was conceptualized in order to investigate the effect of mentioned pollutant at a very high concentration (1%) on the growth of selected fungi and changes of their metabolic activity. The obtained results should serve as a theoretical basis for practical application of tested fungi in mycoremediation of environment.

MATERIAL AND METHODS

Isolation and identification of fungi from wastewater

The fungi used in this study were isolated from the sample of wastewater river basin of Lepenica, Kragujevac (the place of wastewater flood, sewage). The sample of water was taken in a sterile container. The sample was transferred to the microbiology laboratory and was afterwards inoculated onto Petri plate's nutrient malt agar with streptomycin (in duplicates). The Petri plates were then incubated for 5–7 days at standard temperature 28±2 °C. Pure cultures were obtained by the method of exhausting on poor malt agar plates and potato dextrose agar (PDA) plates. Identification of the fungi was based primarily on the macroscopic and microscopic morphology and was carried out by Systematic keys at the Faculty of Biology, University of Belgrade, Serbia. The fungi selected as test organisms in this study were: *Aspergillus niger* van Tieghem (1867), *Fusarium oxysporium* Schldl. (1824) and *Trichotecium roseum* (Pers.) Link (1809). The fungi were maintained on PDA plates, stored at 4±0.5 °C and subcultured monthly in sterile conditions.

Preparation of spore inoculum

Spore suspensions were prepared according to procedure described in our previous work [10]. The concentration of spores in the suspension was evaluated by microscopic enumeration with a cell-counting hemocytometer, Neubauer chamber (Lonza Cologne AG, Germany) and adjusted to $5.0 \cdot 10^6$ spores/mL.

Cultivation of fungi on solid and liquid media and culture condition

The Czapek Dox's liquid media (100 mL) were prepared in 250 ml Erlenmeyer flask, according to the following procedure (g/L): $NaNO_3$ – 3.0, K_2HPO_4 – 1.0, $MgSO_4 \cdot 7H_2O$ – 0.25, $FeSO_4 \cdot 7H_2O$ – 0.01, sucrose – 30.0 (control – C). The same medium was supplemented with 1% EOCA (Henkel, Serbia) (medium EOCA). The solid media was prepared identical, with addition of 20 g agar-agar. The both type of prepared media were autoclaved at 121 °C for 20 min (autoclave pressure, 0.14 MPa). After cooling to 45°C, culture media with agar-agar were dispensed into sterile Petri dishes for solidification. The tested fungi were inoculated at the center of the agar plates. The plates were incubated at room temperature over 8 days, in order to examine the exponential growth of fungi. The liquid media were cooling to room temperature. Then, 1 mL spore suspension of each fungus was inoculated in Erlenmeyer flasks with liquid media and they were placed on an orbital shaker (Kinetor-m, Ljubljana). All Erlenmeyer flasks with liquid media were incubated at room temperature, under alternate light and dark for 8 days. Sampling has begun at 4th day and repeated daily until the end of experiment. All experiments were conducted in triplicate.

Determination of colony diameters

The fungal biomass DW produced in C and EOCA media was determined gravimetrically according to standard procedure, [8]. The obtained results were expressed in g/L of submerged culture.

Measurement of pH value

A pH value of the fermentation broth was measured by a pH meter (type MA-5705, the product "Iskra", Kranj) during fungal growth from 4th day to 8th day.

Determination of concentrations of total (TOA) and free organic acids (FOA)

The concentration of free and total organic acids (FOA and TOA) was determined by ion exchange chromatography according to method by Bullen *et al.*, [11], as described in greater detail in our previous work, [10].The results are presented as percentages (%).

Assay of alkaline protease activity (EC 3.4.21-24)

The assay of alkaline protease was carried out by Anson's method, [12]. Reaction mixture, which contained 5 mL of casein and 1 mL fermentation broth, was incubated at 37 °C for 30 min. The reaction was stopped by adding 1 mL of 5% trichloroacetic acid (TCA). The mixture was centrifuged at 4.000 rpm/min and then 5 mL of 6% Na_2CO_3 and 1 ml diluted Folin–Ciocalteu's phenol reagent were added to supernatant. The solution was kept at room temperature for 30 min and absorbance was read at 660 nm using tyrosine standard. One unite of alkaline protease activity was defined as the amount of enzyme capable of producing 1µg of tyrosine from casein in a minute under assay condition.

Statistical analysis

The results were expressed as mean ± standard deviation of data obtained from three independent measurements. The database was analyzed using the Software Package for Social Science for Windows 14.0 (SPSS Inc., Chicago, IL).

RESULTS AND DISCUSSION

The capacity of fungi to growth on solid media

For testing of fungal growth, the fungi were grown previously on solid media with (EOCA) and without pollutant (C) over a period of 8 days. The colonies diameters (CD) were measured daily and growth curves were constructed (Figure 1).

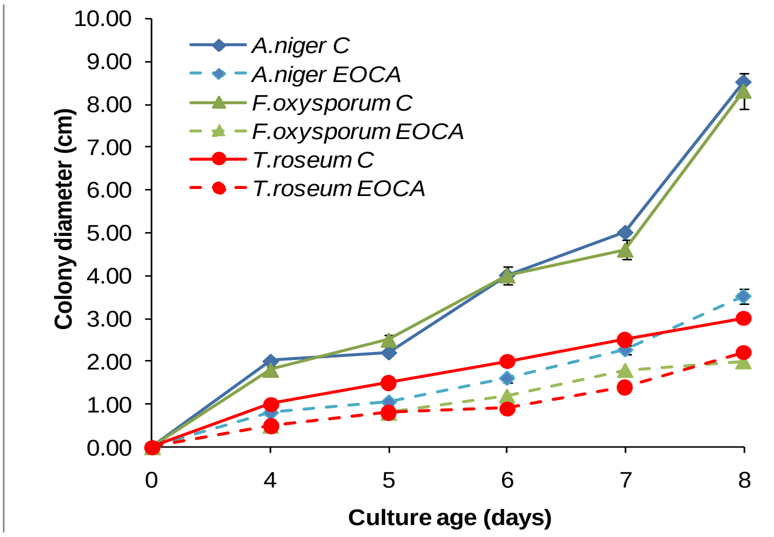

Figure 1. The colonies diameter of fungi during their 8-days growth on solid medium with pollutant (EOCA 1%) and without it (C-control)

As the Figure shows, fungi had different growth rate depending from the type of medium, fungi species and growth phase. On C medium, the growth rate of *A. niger* and *F. oxysporum* was very similar and almost identical during whole cultivation time, with the highest rate noted between 7th and 8th day. However, *T. roseum* had significantly lower growth rate (about 3-fold) compared to mentioned fungi. The differences in growth of colony among tested fungi could be explained by their morpho-physiological characteristics that affect different response for the adoption and nutrient transport, [13]. The growth of fungi on solid medium with addition of pollutant (EOCA 1%) was significantly or considerable inhibited compared to control. The most tolerant species to a high concentration of pollutant was *T. roseum*, considering its CD was about 1.4-fold lower compared to control. In contrast, *F. oxysporum* and *A. niger* expressed very low tolerance to EOCA 1%, since its CD were about 4.2-fold and 2.4-fold lower compared to control. The obtained results are in line with results of our previous study, [10]. Generally, the impact of surfactants on the growth and metabolism of fungi is very complex. It could be explained by the interaction of the surfactant with functional groups in fungal membranes, influence on rheological properties and pH value of medium, oxygen uptake, and on active centers of the key enzymes of fungal metabolism.

The changes in pH values of liquid media

The pH value is significant parameter of microbial growth and biodegradation efficiency. It strongly influences many enzymatic processes and transport of various components across the cell membranes, which in turn support the cell growth and product production, [14]. The changes in pH value of fermentation broths of fungi in C and EOCA media from 4th to 8th day were evaluated in this study and results are presented in Figure 2. After four days of inoculation, the pH value of C fermentation broth of fungi was in alkaline range. The highest pH value (7.25) was measured in C medium of *T. roseum* followed by *F. oxysporum* (6.75) and *A. niger* (6.25). Afterwards, pH values of C media were decreased to different intensity, depending on the fungal species. The most significant decrease in the pH value was observed in C medium of *A. niger* from 4th to 6th day followed by in medium of *F. oxysporum* from 4th to 5th day. In C medium of *T. roseum*, the minor changes in the pH value were observed during whole cultivation time.

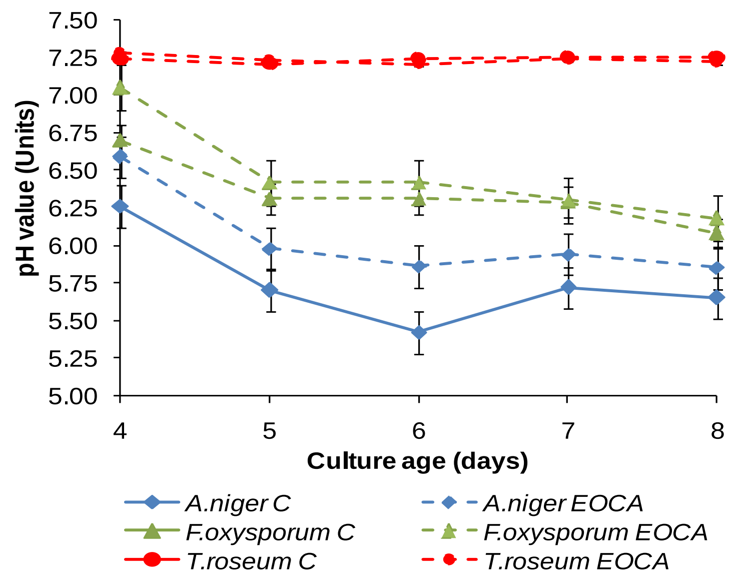

Figure 2. The changes in pH value of fungi in liquid media with pollutant (EOCA 1%) and without it (C-control)

The addition of pollutant in growth medium influenced the change the initial pH value according to alkaline condition. As result, the pH values of EOCA media were higher compared to C media, especially in early phase of fungal growth. From inoculation until 5th day, the pH values of EOCA media of *A. niger* and *F. oxysporum* were considerable decreased. Among tested fungi, the highest decrease in the pH value was observed in EOCA medium of *A. niger*. It was expected since the fungus has ability to secrete strong organic acids as response to alkaline condition. It is important to note that the pH value of *T. roseum* in EOCA medium was very uniform and stable throughout the whole cultivation time and almost similar to pH values measured in C medium. These results indicate that tested fungi have different mechanism regulation of external pH, which depends from numerous factors (pH value, chemical composition of medium, fungal morphology, *etc*.). This observation is in line with our previous studies, [10], [13].

The production of free and total organic acids in media

Organic acids production by filamentous fungi has attracted considerable attention for their role in natural ecology and their potential industrial applications. Concerning their direct interaction with the environment, organic acids participate in metal detoxification by metal complexion and oxalic acid plays a major role in biomass degradation, [15]. In light of aforementioned, the current study investigated the capacity of tested fungi to excrete the organic acids in presence of EOCA.
The tested fungi excreted variable amounts of organic acids in the liquid media, depending on medium composition, culture age and type of fungi (Figure 3). The quantity of FOA produced in C media of fungi was insignificantly (*A. niger*) or significantly higher (*F. oxysporum* and *T. roseum)* at 8th day compared to 4th day. The maximal amount of FOA produced by fungi in this medium was: 1.00% (*F. oxysporum*), 0.83% (*T. roseum*) and 0.43% (*A. niger*). In EOCA medium, amount of excreted FOA by *A. niger* and *T. roseum* was significantly higher compared to C medium. The opposite effect was observed in EOCA medium of *F. oxysporum;* the amount of excreted FOA was lower compared to control On the other words, the addition of EOCA in medium caused a stimulatory effect on amount of FOA produced by *A. niger* (3.4-fold) and *T. roseum* (1.41-fold) but inhibitory effect on amount of FOA of *F. oxysporum* (1.56-fold).

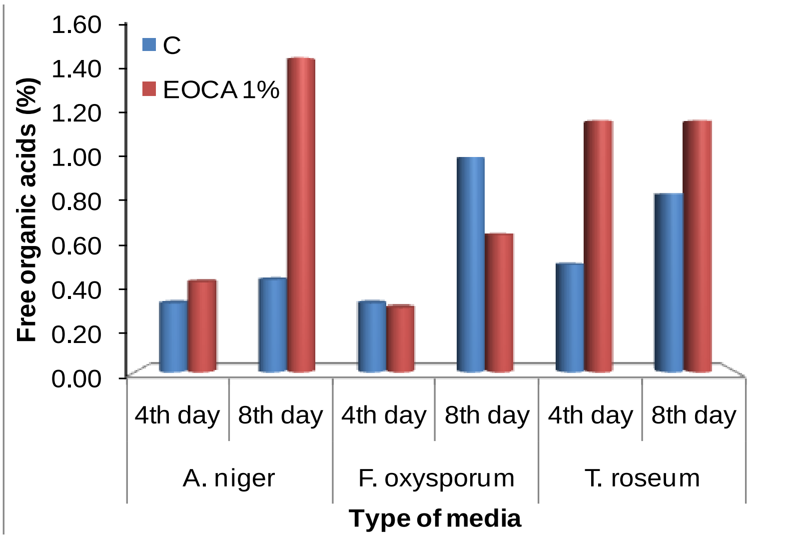

Figure 3. Amount of free organic acids (%) excreted by fungi in growth media with pollutant (EOCA 1%) and without it (C-control)

The amount of TOA measured in C medium of *F. oxysporum* and *T. roseum* was significantly lower or, as in the case of *A. niger*, significantly higher at 8th day compared to 4th day. As Figure 4 shows, the maximal values of TOA measured in C medium were: 3.04% (*F. oxysporum*), 2.33% (*T. roseum*) and 1.95% (*A. niger*). The addition of EOCA in medium stimulated excretion the higher amount of TOA by all tested fungi compared to control. The highest amount of TOA was measured in EOCA medium of *T. roseum* (6.67%) followed by *F. oxysporum* (6.00%) and *A. niger* (4.00%). The obtained results are is in line with our previous studies, [8], [10], [13] which revealed stimulatory effect of tested pollutant at a concentration of 0.1-1% on quantity of TOA produced by different fungi. Therefore, regardless of the applied concentration, the presence of pollutants in fungal growth medium stimulated the production of TOA in such way that higher concentration of pollutants caused higher amount of TOA.

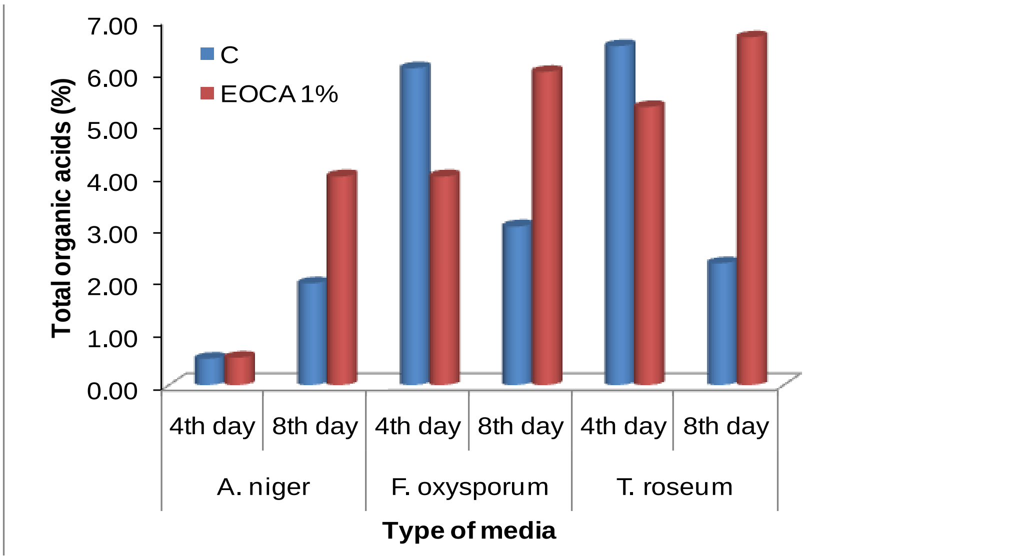

Figure 4. Amount of total organic acids (%) excreted by fungi in growth media with pollutant (EOCA 1%) and without it (C-control)

Proteolytic activity of fungi in growth media

Until now, many fungal species have recognized according to their ability to produce extracellular protease. The production and stability of those enzymes in presence of pollutants such as EOCA make them very useful in different industrial products and processes such as detergent, food, pharmaceuticals, tannery, waste treatments, *etc*.

The current study evaluated proteolytic activity of tested fungi during their growth in liquid media with EOCA at a concentration of 1% and results are compared to C media. As Figure 5 shows, enzyme activity of *T. roseum* in C medium had tendency to increase from 4th to 8th day, when the maximal value (3.00 µg/mL) was observed. On the other hand, proteolytic activity of *A. niger* and *F. oxysporum* in same medium was significantly lower with maximal values observed at 6th (0.40 µg/mL) and 7th (0.42 µg/mL) day respectively. The addition of EOCA at a concentration of 1% in growth media had moderate inhibitory effect on enzyme activity of *T. roseum* and *F. oxysporum* but strong stimulatory effect on enzyme activity of *A. niger*. Precisely, proteolytic activity of *T. roseum* and *F. oxysporum* was inhibited for 26.67% and 25.78% respectively, whereas the enzyme activity of *A. niger* was strongly enhanced (239%) by applied pollutant. An overview of literature provides the contradictory data related to the impact of nonionic surfactants on proteolytic activity of microorganisms.

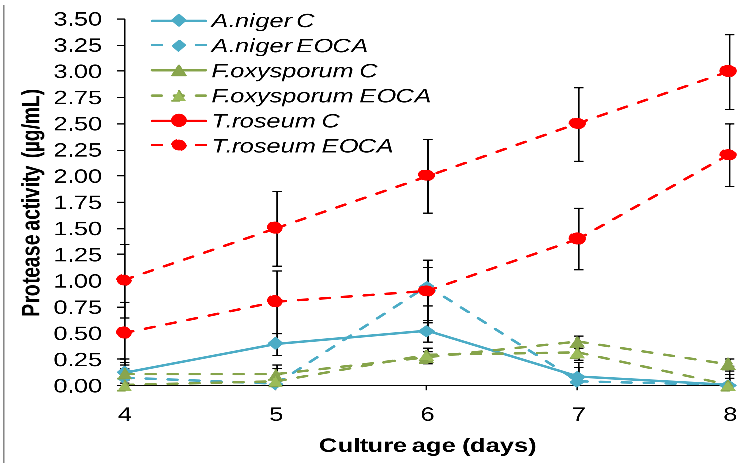

Figure 5. Alkaline protease activity of fungi in liquid media with pollutant (EOCA 1%) and without it (C-control)

According to Evans and Abdullahi, [16], surfactants may have improved the permeability of the cell membrane through disruption of lipid bilayer thereby increasing the uptake of nutrient into the organism and the secretion of enzyme into the culture medium. Nonionic surfactants type of ethylene oxides, bind to active site of enzymes through hydrogen bonds in order to enhance conformation flexibility, [17]. Zeng *et al.*, [18] revealed that incorporation of Tween-80 into fermentation medium have shown to enhance production and secretion of protease. On the other hand, our previous study, [13] showed a partial (*A. tenuis*) or complete inhibition (*P. verrucosum*) of proteolytic activity by EOCA 1%. Generally, the differences in the proteolytic activity of fungi in medium with the pollutant could be conditioned by the morpho-physiological differences among fungi, the type and concentration of pollutants, experimental conditions, *etc*. Overall, the current results suggest that protease produced by tested fungi, especially *A. niger* protease, could be commercially exploited in biotechnological bioprocesses, particularly those involving the synthesis of laundry detergent formulation, and beyond, in bioremediation processes.

CONCLUSION

Based on the presented results the following conclusions can be underlined. The tested fungi, especially *T. roseum* tolerate EOCA at a high concentration (1%), which indicates its potential use in the treatment of environment with a high volume of the pollutant. Further, EOCA had influenced on the increase in amount of TOA of all tested fungi. This finding points to the potential application of fungi in the production of organic acids for the purpose of detoxifying of environment. The alkaline protease activity of *A. niger* was strongly enhanced (239%) whereas the enzyme of *T. roseum* and *F. oxysporum* retained a significant percentage activities (73.33% and 74.22% respectively) in 1% EOCA. Overall, obtained results clearly indicate that tested fungi could be very useful for detergent industry and bioremediation processes.

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ANALYZING THE QUALITY ASPECTS OF THE EEW MANAGEMENT IMPROVEMENT PROCESS

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Abstract: The problem of electrical and electronic waste (EEW) management is present in developing countries as well as in developed countries. Inadequate EEW management leads to exposure of hazardous materials into the environment. In this paper a theoretical EEW management model is developed. Additionally, the use of quality practices and quality management systems for EEW management improvement is addressed. For every element of the developed model, an appropriate quality practice is suggested. The proposed quality practices are generic in nature in order to provide a broad framework for future research on specific EEW management system segments. In sum, the paper provides a solid basis for future research in the domain of quality practices and EEW management.
Key words: EEW, quality practices, improvement, EEW management model

INTRODUCTION

The problem of electrical and electronic waste (further referred to as EEW in the article) is a growing problem in developed countries, and in developing countries as well [1]. The management of EEW and the recycling process of EEW is complex. It includes various processing steps such as shape separation, magnetic separation, electrostatic separation and others [2]. EEW often contains hazardous materials, thus their management often faces several challenges. These may include issues in the separation process, sorting process and classification process. Therefore, recycling, as the main part of EEW management, has to be conducted in accordance with defined legislations. It was noted that EEW recycling includes three major steps. These are disassembly, upgrading and refining [2]. A large set of legislations provide guidelines for a safe handling of EEW. However, the EEW management processes can and should be improved. This is conducted through various registered companies (manufacturers, recycling facilities, transportation, and storage facilities) and an important factor for improvement is quality. The consistency of quality as an output is a crucial part of successfully managed processes [3]. Some of the factors of quality management are customer approach, management commitment, leadership, continuous improvement, involvement of employees, and process management [4]. Now, total quality management (TQM) brings a new paradigm on how quality is managed. There is a large body of literature that addresses the positive impact of TQM on overall performance in organizations [5]. In the same article it can be seen that TQM practices are similar to quality management factors such as management leadership, employee relations, and process management [5]. Nevertheless, how can quality factors and/or practices affect the improvement of EEW management? It is assumed that if driven by quality, EEW management could face drastic improvement in several sections of the recycling and reusing procedures. Quality can be viewed as a degree in which pre-defined requirements of product and service characteristics are met [6]. If quality of the obtained recycled raw material or secondary parts is put forward as a goal, then there is a higher chance that the overall EEW management process will be improved in order to meet the quality requirements.
In this paper the important quality factors of EEW management improvement are analyzed. This includes a thorough analysis of empirical and theoretical research in the domain of EEW management and quality management principles. Furthermore, a theoretical model for EEW management improvement through quality practices is proposed. The whole paper consists of three main sections. The first section analyses the quality factors that may contribute to the improvement of EEW management systems. The second section is the review of EEW management and the future potential of EEW management. The third section proposes a theoretical model which is based on the previously conducted analyses. Finally, conclusions are drawn and future research is recommended.

QUALITY MANAGEMENT PRACTICES

Quality management is an imperative for developing competitive positions on the market. This includes several procedures and defined plans that positively affect the quality aspects of products and services. One step further is TQM, where the focus on quality becomes part of the organizational culture, and its goal is to satisfy customers [7]. However, in this paper the quality management is not focused on customers per se, but on the improvement of EEW management. Before, this issue is thoroughly addressed, quality management needs to be analyzed. According to the ISO 9001:2015, there are eight quality management principles. These are leadership, process approach, customer focus, leadership, involvement of people, factual approach to decision making, system approach to management, and mutually beneficial supplier relationships [8].

TQM is known for its long-term approach to business excellence through continuously satisfying the customers' needs [9]. However, when it comes to EEW management, the customer satisfaction aspect of quality is not crucial. In fact, customers are mainly in the form of wholesale buyers of raw, unprocessed EEW, and wholesale buyers of various categories of recycled EEW. However, some of the principles of quality management are indeed important for overall improvement of EEW. The whole improvement process should include quality as this factor further positively affects other aspects of EEW management. If quality is in the focus of improvement, then sloppy management techniques will be consequentially eliminated as they can't fulfill quality requirements. After all, quality management can be viewed as an integrated whole made up from sets of principles, techniques and practices [10].

There are ten generic quality management practices. These are top management commitment and support; employee training; continuous support; employee participation; quality system improvement; organization for quality; information and analysis; statistical techniques for achieving quality; customer focus; and supplier quality management [11].

In order to correctly implement some of these practices into the EEW management improvement process, it is necessary to broaden the meaning and scopes of these practices.

Top management commitment and their support is an imperative for adequate workflow and efficiency. This practice may include reporting, and communicating important data to employees. This data may provide support and it can reduce bottlenecks on the workplace. Other actions of top management include effectively analyzing external and internal factors and participants who are relevant to the company, collect and process quality related data and information, and ensure proper communication of this relevant data to employees [12]. Next, employee training and employee commitment are two important quality practices that includes the development of new skills, motivation, and professional development opportunities [13]. Information analysis or quality information systems refer to distribution of crucial information that contributes to achieving the desired level of quality for products and services [14]. Continuous support is among managers and employees is necessary in order to control and maintain a stable level of desired quality. This includes periodic evaluation, control, and reporting critical data [11]. Furthermore, quality system improvement and organization for quality are key factors for creating a productive and efficient environment where quality results can be obtained through input-output processes [15]. The inputs may include various financial resources, materials, knowledge, employees, and data information while outputs may be products or services and other elements that may be wanted (secondary raw material) and unwanted (waste, hazardous materials). Next, statistical techniques and methods are used to analyze and process various data that is collected from the internal and external environment of the organization. Some of the main statistical control techniques are control charts, design of experiments, loss function, and robust design [16].

Furthermore, customer focus drives the company forward. This process has an internal and external part. The internal part addresses the quality of products and services, while the external part includes quality from the aspect of people and the environment [17]. Finally, supplier quality management addresses the quality of materials and other resources from suppliers, as well as the procedures done by the suppliers that ensure stable quality products [11].

Based on the analyzed literature, it is evident that quality management enhances the processes that occur in the organization. In this paper these quality aspects are analyzed for the improvement process of EEW management. In the next section, EEW management is addressed.

EEW MANAGEMENT

As the quantity of EEW rises, there is an urgent need to develop sustainable solutions for an effective and efficient EEW management system [18]. Certainly, EEW requires special handling and management as it may contain hazardous materials. The situation on a global scale is getting worse by each year as the agreements, procedures, protocols, and overall recycling intensity are not enough to handle the increase in EEW [19]. EEW is often extremely heterogeneous. Besides plastics, it may contain aluminum, copper, and gold. However, the percentage of precious metals in EEW is decreasing every year. This puts big stress on recycling plants as their economic growth and stability depends on the extracted precious metals from EEW [2]. Some of the main issues of EEW management include insufficiency of material reuse, as a large amount of precious metals such as gold, platinum, aluminum, silver, and palladium are incinerated or buried in a landfill [20]. In the same study a multi-level taxonomy is proposed. Here, the first level includes categories such as strategic system planning, system design, and system management. Further, the second level includes sub-categories that are part of the first-level categories. Thus, under strategic system planning there are social liability assessments, organizational systems, and waste prevention. System design includes recovery process design and secondary market development. Finally, the system management includes waste generation, end-of-life scenario and network configuration. The third level includes ten tools/techniques/models. These are survey analysis, review analysis, policy assessment, field study, experimental study, multi-criteria decision making, simulations, mathematical programming, life cycle analysis, and material flow analysis [20]. Other studies proposed closed-loop supply chains (CLSC) that reduce the environmental impact of supply chains. EEW supply chains are prone to releasing hazardous materials into the environment. Through closed-loop supply chains, EEW management is improved and raw materials are used more efficiently thus reducing its environmental impact [21].

Through the Waste of Electrical and Electronic Equipment (WEEE) directive, Denmark implemented various models for an efficient EEW management system. This model included collective schemes where consumers deliver waste to the collection points. This way municipalities have significantly lower administrative burden and lowering cost in the long-term [22].

For comparison, in Switzerland EEW is managed through the Ordinance on the Return, Taking back and Disposal of Electrical and Electronic Equipment (ORDEE) form. This includes product take back programs, regulatory approaches, voluntary industry practices, and economic instruments [23]. There are many more studies that propose extended producer responsibility [24]; reverse logistics which incorporate design of logistics network, planning the disassembly processes, and organizing the reverse supply chain [25]; effective system of monitoring the shipment and transportation of EEW [26]. It is evident that EEW management can incorporate various models, and various levels of regulation. For example, in Europe the main emphasis for EEW management is on non-state/non-government actors, while in China EEW is managed by traditional approaches by the government [27]. Surely, EEW is a big concern to the vast majority of developing and developed countries. As mentioned above, there are many models that address this issue.

Now, in this paper a model for EEW management improvement is suggested through the aspects of quality management. The main idea is that if quality is the priority, then results will follow. This may lead to increased extraction rates of precious metals, and lower recycling costs. The proposed theoretical model is presented in the next section.

A MODEL FOR EEW MANAGEMENT IMPROVEMENT

The EEW management improvement process is presented in the form of a developed EEW management model where every element of the model is labeled with numbers and a capitalized "Q" letter (ex. 1Q, 2Q, 3Q...). This type of labeling is used to explain in detail the possible application and procedure of various aspects of quality with the goal to improve the whole EEW management model/system. On Figure 1, the EEW management model is depicted. This model is based on other models presented and suggested in similar studies [21], [27], [28], [29], [22], [30].

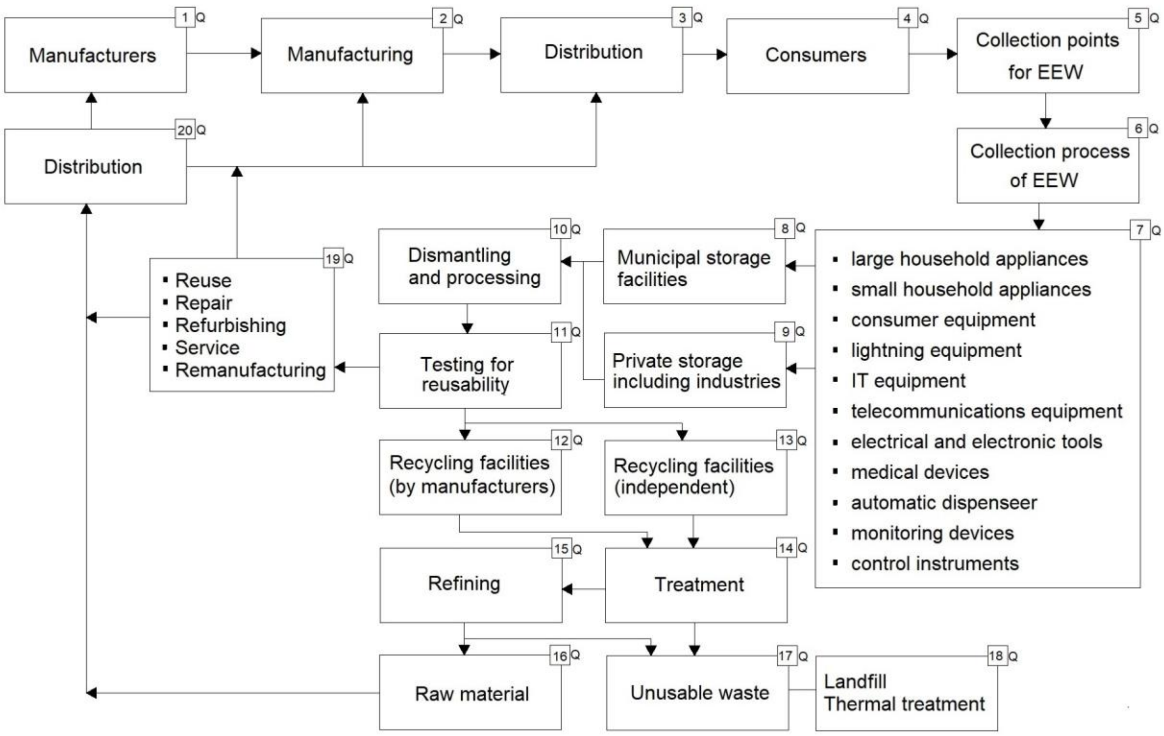

Figure 1. EEW management model

As mentioned before the labels (1Q, 2Q... etc.) for each element of the model are used to give detail on the improvement of the EEW management process through the various aspects of quality. The meaning behind the labels are presented in Table 1.

Table 1. Label description

Label	Meaning/process/procedure	Label	Meaning/process/procedure
1Q	Manufacturers are encouraged to implement various quality management standards (in accordance with the industry, products and services). Some of the quality practices that should be implemented are supplier quality management and organization for quality. This can improve the overall quality of products and reduce waste and production costs.	11Q	As mentioned in the previous section, employee training is also necessary to create a quality driven atmosphere where strict procedures are implemented to ensure that reliable parts are selected for repair, reuse, service, refurbishment, or remanufacturing.
2Q	In the manufacturing process, employee training, management commitment and support are crucial for achieving high standards of quality thus increasing the exploitation period of products (in this case electrical and electronic devices).	12Q	Recycling facilities owned and managed by product manufacturers should consider quality management system standards such as ISO 9001 and ISO 14001. This would lower costs and increase productivity.
3Q	Here, quality can be involved through information and analysis of orders, and achieving a high level of consistency of delivery times and sticking to predefined schedules.	13Q	Similarly to the recycling facilities owned by manufacturers, independent recycling plants should also consider implementing some of the mentioned ISO standards and to focus on quality system improvement.
4Q	Consumers should be informed about the importance of proper EEW disposal. Here, customer focus has to be involved in order to make the customer feel respected rather than instructed.	14Q	The treatment process can include the focus on customers (in this case customers are manufacturers that buy raw material from the processed EEW). In addition employee training can increase the quality and extraction rates of raw materials (precious metals, plastics, glass etc.)

5Q	Collection points have to “enjoy” continuous support from manufacturers and the government. This would increase the volume of collected EEW.	15Q	The refining process should integrate statistical techniques that will help increase the “pureness” of certain raw materials (especially precious metals).
6Q	The collection process has to integrate statistical techniques through which significant data can be obtained and used for future optimization of the EEW management process.	16Q	The extracted raw material should be thoroughly inspected for quality, homogeneity and consistency of quality between batches.
7Q	For effective collection of EEW, it has to be categorized and clearly defined in order to increase the efficiency of the whole process.	17Q	Unusable waste has to be handled carefully, and the ISO 14001 standard is a necessity at this point.
8Q	These storage facilities have to develop information analysis techniques and to implement an effective distribution system.	18Q	Landfills and thermal treatment can be extremely hazardous for the environment, thus ISO 14001 is highly recommended. This way the negative impact of these hazardous materials can be kept at a minimum.
9Q	Similarly to municipal storage facilities, private storage facilities are also encouraged to implement quality systems that will ensure an efficient flow of EEW.	19Q	In the repair, reuse, service and refurbishment processes ensuring high quality end-products is important for future reduction of EEW.
10Q	At this stage EEW is dismantled and processed. Here, employee training can significantly improve the productivity of dismantling and preparing it for testing.	20Q	Finally, closing the loop-based model of EEW management, distribution of raw material to the manufacturers, and refurbished/repaired/serviced products to consumers is addressed. Here, continuous support, information analysis and supplier quality management should be used to ensure reduced EEW waste in the future.

Through these quality-based improvements, the goal is to reduce the amount of EEW that is treated as unusable waste, and to increase the volume of EEW that goes through the collection points. This can lead to reduced EEW that end up along the roads, and among organic waste. This could further reduce recycling costs and distribution costs, and increase the amount of precious metals that are extracted. The depiction of this model has its limitations. Certainly, this is just a theoretical model and the quality aspects of improvement could be presented in more detail. However, the paper doesn’t focus on particular manufacturers, or markets, but rater EEW management as a whole. This way a more generic approach was seemed fit for this paper. The model takes into consideration the before mentioned findings in the domain of EEW management and quality management. It is suggested that this approach can increase productivity of every participant in the EEW management cycle. This includes manufacturers, recycling plants, storage facilities, and distribution channels. Certainly, implementing quality manage systems is an imperative for a modern EEW management system.

CONCLUSION

In this paper the improvement of EEW management through quality practices was addressed. After thorough analysis of relevant literature in the domain of quality management systems and EEW management systems, it can be concluded that certain aspects of quality practices can contribute to the effectiveness and efficiency of EEW management systems. An EEW management system model was developed in order to present where quality practices could be implemented and used to reduce costs, to increase productivity, and most importantly to increase the percentage of extracted precious metals. As mentioned before in this paper, numerous recycling facilities have economic stagnation or hardship due to inadequate precious metal extraction. If process quality and overall organization quality would be priority, there is a good chance that the extraction and refinement processes of EEW would result in a higher percentage of extracted precious metals.

Now, in this paper the EEW management model presented twenty (20) elements. Every element was labeled (1Q, 2Q, 3Q...20Q). Furthermore, these labels were described as quality practices/aspects through which the EEW management process could be improved. The theoretical model, and theoretical improvements through quality practices are based on credible research in this domain. It can be concluded that this type of approach can indeed improve the overall EEW management system, as the goal of high quality products/service/processes may result in lower costs, higher productivity, and less waste.

The contribution of this paper to the existing body of literature is moderate. It depicts a model that is based on other EEW management models. The quality practices proposed are generic, and moderately defined. This is a major limitation. However, given the nature of this paper, this limitation is not severe. The goal was to present the possibility and framework of EEW management improvement through quality practices. For future research it is recommended to address specific quality techniques for specific segment of the EEW management system. If possible, several studies are necessary to address and research the proposed theoretical model and the possibility of quality practices use for EEW management improvement.

ACKNOWLEDGEMENT

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ANALYSIS AND OPTIMISATION OF ENERGY PERFORMANCE IN RESIDENTIAL BUILDINGS WITH SUNSPACES

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Abstract: The design of passive solar houses with a sunspace can be improved if the method of energy performance simulation is accompanied by optimization algorithms. Building optimization can include a variety of goals, such as energy, environmental, economic, etc. Optimization parameters include building geometry, environmental conditions, structural elements of the thermal envelope, thermal mass, glazing, and others. This paper discusses the thermal behaviour of a residential building with a sunspace and attempts to optimize the orientation of a passive solar building with a sunspace and the percentage and type of glazing. The obtained results form a part of a more extensive research of passive sunspace systems from an energy-efficiency and environmental perspective. The aim of the study is to highlight the possibilities of utilizing this type of passive system in an ongoing crisis in the energy-generation product market, and also to emphasize the environmental impact of emissions from fossil fuel combustion.
Key words: sunspaces, residential buildings, energy performance, optimization

INTRODUCTION

The design of passive solar and bioclimatic buildings is based on a number of principles and recommendations established in the 1980s. Use of passive systems in residential buildings can provide a substantial portion of passive solar heating, but the degree of efficiency of sunlight depends on numerous parameters, such as climatic parameters of the site, urban planning, as well as the structural properties of a building (building envelope shape, thermal properties of used materials, etc.).

REVIEW OF PREVIOUS RESEARCH ON PASSIVE SUNSPACE SYSTEMS

Sunspaces are passive systems that can easily be integrated into the structure of a building, whether it is under construction or already completed. The primary role of passive sunspace systems is to collect solar energy, accumulate it inside, and transfer it to other living areas. In addition, sunspaces also serve as buffer zones, protecting the indoor space from excessive heat loss. Passive sunspace systems work in the way represented in Figure 1: sunlight penetrates the outer glazed portion of the sunspace and the glazed partition between the sunspace and the living area, and is accumulated within the building structure (thermal mass, e.g. floors and walls), which results in the heating of the sunspace itself and the adjacent rooms [1].
According to Olivetti et. al (2012), the thermal balance of a sunspace can be expressed with the following equation:

$$Q_{as} + Q_{ai} + Q_{ae} + Q_w + Q_f = \Delta E_w + \Delta E_{f,} \qquad (1)$$

where Q_{as} is the energy absorbed in the sunspace structure, Q_{ai} is the energy the indoor surface exchange with indoor air, Q_{ae} is the energy exchanged with the external environment, Q_w is the energy exchanged with the indoor room, Q_f is the energy exchanges via the floor, and ΔE_w and ΔE_f are changes of the internal energy of the wall and the floor, respectively [2].

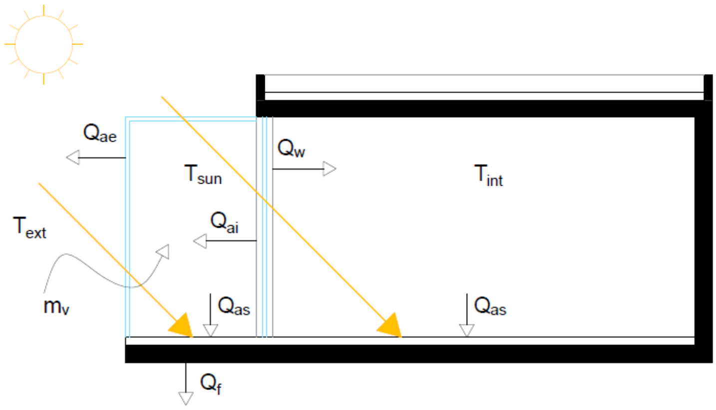

Figure 1. Heat exchange between the sunspace and the external environment (adapted from Olivetti et al., 2012): T_{int} – indoor air temperature, T_{sun} – sunspace air temperature, T_{ext} – outdoor air temperature, m_v – air infiltration (adapted from [2])

Climate factors can be vital for sunspace thermal behaviour. Chiesa et al. (2107) studied the impact of sunspaces on the reduction of energy required for heating, for different climate conditions at 50 different locations in Europe. They established that the heating degree day parameter (HDD_{20}) is directly associated with the heating share achieved by sunspaces [3].
The impact of sunspaces on passive heating and cooling in Belgrade, Serbia was discussed in Ignjatovic et al. (2015). The study was conducted on a model building using the IES Virtual Environment software. The results showed that energy savings for heating of the portion of the building adjacent to the sunspace were between 8 and 12%, with 30% of ventilation openings open and with a medium glazing quality [4].
Energy performance of sunspaces in the climate conditions of Portugal was analyzed by Aelenei et al. (2014). The study was conducted using dynamic simulation in EnergyPlus software. Four variants of a model sunspace were included at six different locations in Portugal, and the installation of a sunspace was shown to reduce energy consumption at each location. The biggest energy savings were observed in a south-oriented sunspace, which was fully integrated into the primary building with natural ventilation between them and an indoor curtain for protection against overheating [5].
The role of thermal mass in passive sunspace systems is to store heat, which is later distributed to the various rooms during periods without sunlight. Suarez et al. (2018) analyzed the thermal behaviour of sunspaces during the day using numerical simulation. The analyzed thermal mass comprised a floor construction with 0.20 m thick sand filling. The results showed that the amount of energy the floor thermal mass transfers to the environment is actually the highest in the spring and in the autumn, 8.3 kWh in March, 2.8 kWh in June, 7.5 kWh in September, and 5.7 kWh in December [6].
Phase change materials (PCMs) are being used in passive heating systems for latent heat storage. Guarino et al. (2017) studied the use of PCMs in sunspaces in the cold climate of Montreal, Canada. The study showed that the used PCM had a significant impact on indoor temperature fluctuations. In case of mild weather (10°C), indoor temperature will not drop below 18°C. In addition, the PCM examined in this study enabled a temporal latency of heat transfer into the room from 5 to 8 hours. Since the phase change of the used PCM ranged from 18 to 24°C, it was determined that the material is inefficient for cooling during the summer, because it was constantly in its liquid phase at higher temperatures [7].
Sunspaces can be used for energy renovation of existing buildings, as it has been established that they positively affect indoor heating. Fotopoulou et al. (2018) examine the possibilities of energy savings through energy renovation of existing buildings, which involves interventions on the building envelope and the addition of a sunspace. The study was conducted by means of creating the basic model and additional models of façade reconstruction through different levels of intervention. In the analyzed case, which involved window replacement, the addition of thermal insulation and a sunspace to the façade resulted in heating energy savings of 79% in the climate of Bologna, Italy [8].

Grudzinska (2016) investigated the use of sunspaces and consumption of heating and cooling energy at five different locations in Poland. Heating and cooling needs were calculated using BSim software dynamic simulation for two types of sunspace with different thermal insulation properties. A model of a flat with the surface area of 74 m^2 was created and three thermal zones were designated. The analysis of obtained results for the heating energy required revealed that the biggest reduction was achieved in the zone directly connected to the sunspace, and it ranged from 70 to 90%. Reduction of heating energy for the entire flat depends on climate conditions and amounts up to 30%. Since the study did not consider overheating protection during the summer, there was an increase in cooling energy consumption form 43 to 96%, so the authors recommend that any design of passive systems should consider a cooling strategy during summer months using some kind of mechanical ventilation [9].
Among the more recent studies of passive sunspace systems, the one conducted by Ulpiani et al. (2017), involving energy savings analysis of a low-energy-consumption building with an integrated sunspace in the Mediterranean climate. The created simulation models comprise various sunspace constructions, in terms of glazing percentage (0%, 30%, and 50%), glazing type (single or double), width of the sunspace base (1.5 m; 2 m; 2.2 m; 2.5 m), and openings in the partition wall (with or without them). Simulations were performed using EnergyPlus software, and the results showed that the most favourable sunspace configuration was the one with a 1.5 m base and a configuration that involves a convective glass sunspace with double glazing and mechanical air circulation, which had 30% better performance than a configuration without circulation [10].
Previous research dedicated to sunspaces in residential buildings, the primary focus was on energy savings achieved through sunspace use and on examining the impact of thermal mass on the energy efficiency of a sunspace building for different climate conditions. The aim of this paper is not only to analyze the energy efficiency of the said buildings but also to investigate and analyze the conditions of thermal comfort in the room adjacent to the sunspace. Another aim is to examine the impact of glazing orientation, percentage, and type on energy consumption for the climate of Niš, Serbia.

METHODS AND MODEL DESCRIPTION

Calculation of energy performance of buildings with a sunspace relies on stationary and dynamic methods. The best known stationary methods, such as those used in the EN ISO 13790 standard [11] do not yield sufficiently accurate results. Dynamic simulation methods that can determine energy needs of buildings more precisely require computer support and more time for the simulation to be performed. In this paper, the EnergyPlus software is used to determine the energy properties of a model residential building with a sunspace using dynamic modelling, for the climate of the city of Niš, Serbia, which is located in a humid continental climate area, typical of the entire country of Serbia. Meteorological data considered in the model represent a typical meteorological year.
For the purpose of this study, a basic model residential building with a sunspace was created with only the ground floor (P) and with a 92.16 m^2 floor area. The ratio of the floor area sides is 1.25:1. Sunspace with a depth of 2.4 m is attached across the entire length of the longer primary building façade, and it represents an independent thermal zone. The passive solar building model consists of two thermal zones: the sunspace and the rest of the building.

Table 1. Thermal envelope properties of the model building

Construction type	Structural assembly elements	U [W/m^2K]
Façade wall	mortar 2cm, brick wall 25cm, thermal insulation 12cm, mortar 1cm	0.287
Floor	parquet flooring 2.2 cm, cement screed 3cm, thermal insulation 10cm, hydro insulation 1cm, lean concrete 15cm, gravel 10cm	0.300
Flat roof	cement screed 4cm, hydro insulation, thermal insulation 15cm, sloping concrete 5cm, thermal insulation 5cm, RC slab 14cm, mortar 2cm	0.155
Glazing	Double glazed aluminium frame 6+6mm	1.1

Table 1 shows the properties of the thermal envelope of the model. The sunspace in the basic model is completely glazed, as is the partition between the sunspace and the primary building.

RESULTS

EnergyPlus simulation was used to calculate the main parameters of energy performance of the model residential building with a sunspace (air temperature, radiant temperature, operative temperature, heating and cooling load, etc.). Some of the results are shown in Figures 2 and 3.

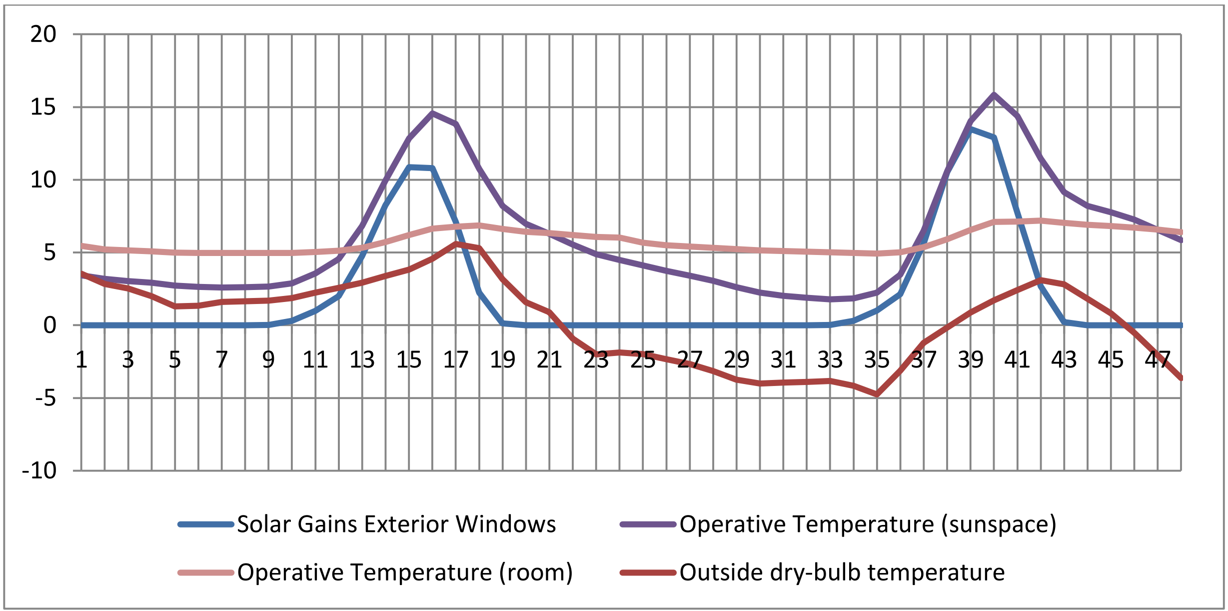

Figure 2. Operative temperature in the sunspace and the room for 22 and 23 January

Figure 2 shows the operative temperatures in the sunspace and the adjacent room, as well as solar gains simulated for winter conditions (22 and 23 January). The data indicate that during the day, when sunlight (direct and diffuse) is present, the operative temperature within the sunspace increases, reaching its maximum at 4pm. The room interior is heated with a latency of one to two hours after the sunspace, and it is noticeable that the presence of the sunspace diminishes the operative temperature fluctuations in the primary building. Figure 3 shows the annual energy needs for heating and cooling of the model residential building with a sunspace, for a typical meteorological year according to the climate conditions in Niš.

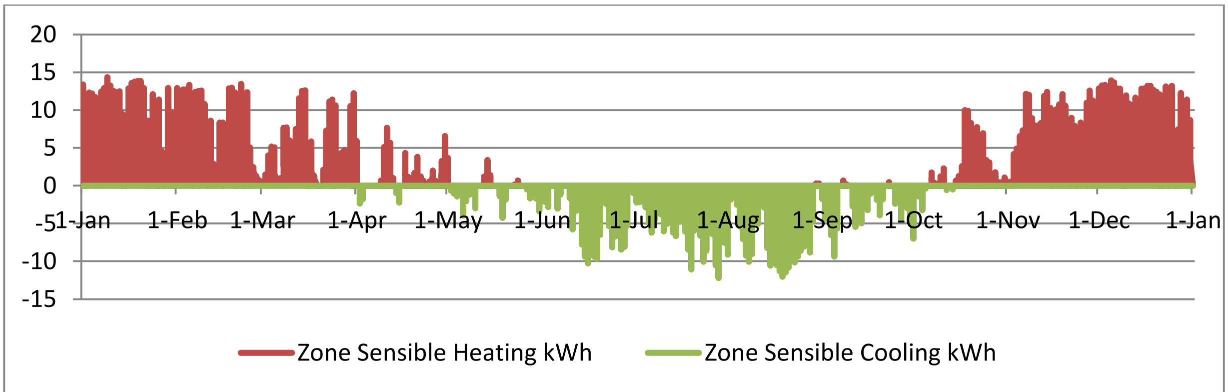

Figure 3. Analysis of annual energy needs for heating and cooling of the model residential building with a sunspace

Optimization of building orientation and glazing of a residential building with a sunspace

Using the model defined for the climate conditions in Niš, optimization of a building with a sunspace was performed using a genetic algorithm (GA). Genetic algorithms are metaheuristics used to generate solutions for optimization of functions, which are particularly successful with functions with multiple local maxima and minima. Genetic algorithms utilize iterative procedures to create a population of solutions, whereby a "natural" selection determines the solutions that are close to optimal. An objective function is introduced as a criterion for the selection of individuals, which guarantees that the selected individual is the optimal solution to the problem. When searching for the minimum value of the function, the lowest value in the population is the best. The parameters involved in genetic algorithms include population size, number of generations, and mutation probability.

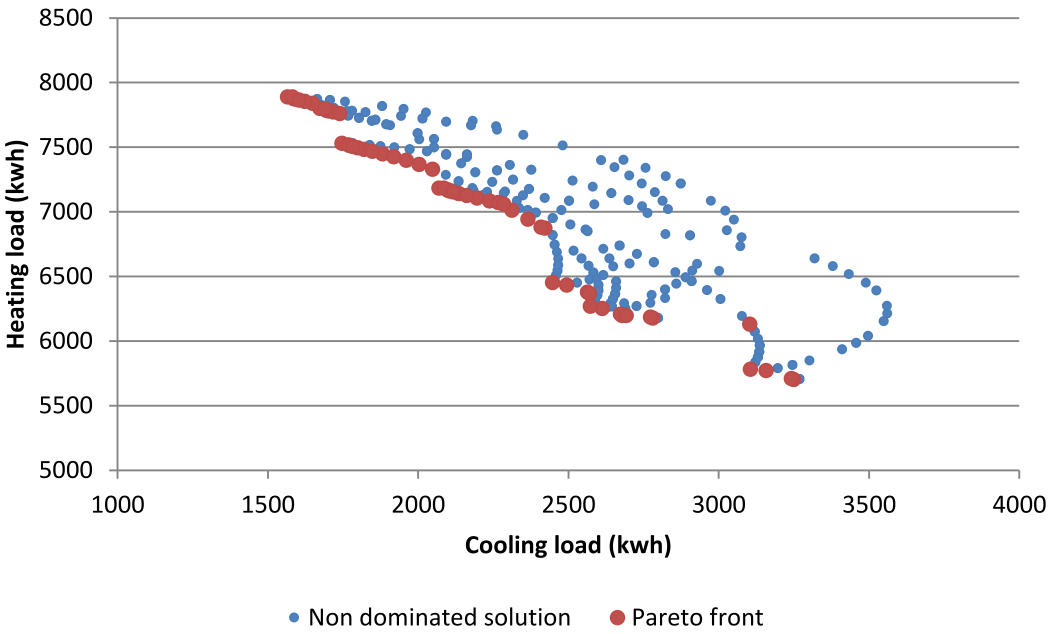

Figure 4. Distribution of building variants in relation to heating load and cooling load (kWh) with a formed Pareto front in relation to optimization parameters

For the purpose of optimization of a passive solar residential building with a sunspace, the maximum number of generations was set at 100, the base population size at 20, the maximum population size at 200, and the mutation probability at 0.4. The optimization was performed with two objectives in mind – to reduce the heating load and the cooling load. The object of optimization is the said passive solar building and the variable parameters used in the optimization include building orientation, sunspace glazing percentage, internal glazing percentage, and glazing type. Building orientation has the values ranging from 0° to 360°, with a 5° step. Glazing percentage of the sunspace and the internal partition ranges from 0 to 100%, with a 5% step. Four glazing types were selected: single glazing with 6mm clear glass; single glazing with 5mm clear glass; double glazing, 6mm clear glass with air-filled gap; and double glazing, 5x13mm clear glass with argon-filled gap. The result of optimization with a formed Pareto front is shown in Figure 4.

DISCUSSION

Analysis of the data obtained from the optimization for cases forming the Pareto front leads to a conclusion that in the fifteen most favourable cases the building orientation is either southward or moved maximally 10° eastward or westward (Table 2). For a better indoor heating effect, the partition between the sunspace and the adjacent room should have a lower glazing percentage (20-25%), while the sunspace glazing percentage should be around 60%. Lower glazing percentage for both the sunspace and the partition together with single glazing are the best options for cooling. This paper did not consider protection from overheating during the summer, which might reduce the energy required for cooling. After the analysis of glazing types, the recommendation is to use double glazing with clear low-emission glass and argon-filled gap.

Table 2. Top fifteen favourable solutions of a residential building with a sunspace for the defined variable parameters (building orientation, glazing percentage, and glazing type)

Building orientation (°)	% Internal glazing	% Sunspace glazing	Glazing type	Cooling load (kWh)	Heating load (kWh)	Cooling and Heating load (kWh)
15	70	55	Dbl Clr 6mm/6mm Air	2573.10	6269.36	8842.47
355	90	50	Dbl Clr 6mm/6mm Air	2612.36	6252.06	8864.43
5	20	50	Dbl Clr 6mm/6mm Air	2678.26	6198.79	8877.06
10	10	20	Dbl Clr 6mm/6mm Air	2672.90	6206.79	8879.69
15	20	60	Dbl Clr Low 5mm/13mm Arg	3105.52	5782.15	8887.68
0	30	50	Dbl Clr 6mm/6mm Air	2692.36	6197.89	8890.26
15	10	85	Sgl Clr 6mm	2446.65	6451.97	8898.63
355	50	90	Sgl Clr 6mm	2494.47	6433.06	8927.54
355	80	40	Dbl Clr Low 5mm/13mm Arg	3157.77	5770.48	8928.25
5	25	20	Sgl Clr 6mm	2569.76	6368.63	8938.40
10	70	25	Sgl Clr 6mm	2563.14	6378.82	8941.97
10	20	60	Dbl Clr Low 5mm/13mm Arg	3241.89	5709.18	8951.08
5	25	65	Dbl Clr Low 5mm/13mm Arg	3248.75	5702.71	8951.47
5	10	50	Sgl Clr Low 5mm	2780.33	6177.83	8958.17
10	100	40	Sgl Clr Low 5mm	2772.70	6185.50	8958.21

CONCLUSION

This paper presented an analysis and optimization of a passive solar building with a sunspace by means of numerical simulation using the EnergyPlus software and a genetic algorithm. Minimal energy consumption for cooling during the summer and minimal energy consumption for heating during the winter were set as the objectives of optimization. Variants of the created model residential building with a sunspace had different building orientations, sunspace glazing percentages, internal partition glazing percentages, and glazing types. Further research into the optimization of passive sunspace systems should also include the optimization of thermal mass as well as the optimization of systems for protection against excessive solar radiation during the summer.

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CALCULATING DAILY VIBRATION EXPOSURES AND WORKED EXAMPLES IN CASE HAND-ARM VIBRATION

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Abstract: The purpose of the hand-arm vibration risk assessment is to enable you as the employer to make a valid decision about the measures necessary to prevent or adequately control the risks from exposure of workers to hand-arm vibration. The daily vibration exposure, for a worker carrying out one process or operating one tool can be calculated from a magnitude and exposure time. If a person is exposed to more than one source of vibration then partial vibration exposures are calculated from the magnitude and duration for each source.
Key words: Hand-arm vibration, daily vibration exposure

INTRODUCTION

Vibrations arise when a body oscillates due to external and internal forces. In the case of hand-arm vibration, the handle of a machine or the surface of a work piece vibrates rapidly, and this motion is transmitted into the hand and arm. Hand-arm vibration (HAV) is vibration transmitted to the hand and arm during the operation of hand-held power tools and hand-guided plant, or while holding materials being processed by plant. HAV is commonly experienced by workers (Fig.1.) who regularly use power tools including jackhammers, chainsaws, grinders, drills, riveters and impact wrenches [1], [4].
The risks from hand-arm vibration affect people across many industries and occupations. The risks are greatly increased with use of higher vibration equipment and with prolonged and regular use of the equipment. However, investigations have shown that vibration hazards can be controlled and risks reduced by good management. They have also shown that the costs of such controls need not be high and can usually be offset by the benefits of keeping workers healthy. Additionally, the vibration control measures have, in many cases, led to improved efficiency. Before the *daily vibration exposure*, *A*(8), can be estimated, you need to know the total daily duration of exposure to the vibration from each tool or process being used.
You should be careful to count only the time that the worker is exposed to vibration; a period when a worker has put the equipment down or is holding it but not operating it should not be counted.
It is important to keep workers and their representatives involved and informed in the assessment of vibration risk. An effective partnership with workers will help to ensure the information used for the risk assessment is based on realistic assessments of the work being carried out and the time taken to do that work.

Figure 1. Hand-arm-vibration [4]

WHAT VIBRATION PARAMETERS ARE USED FOR EXPOSURE ASSESSMENT

Hand-arm vibration is caused by vibration transmitted into the hand and arms through the palm and fingers. Vibrations arise when a body oscillates due to external and internal forces Figure 1. In the case of hand-arm vibration, the handle of a machine or the surface of a work piece vibrates rapidly, and this motion is transmitted into the hand and arm[1], [3].

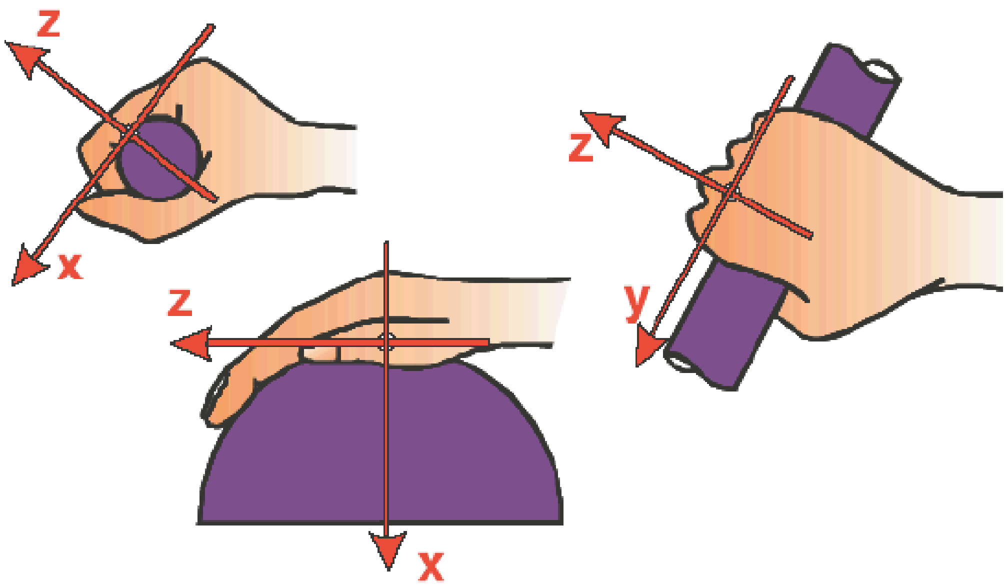

Figure 2. Axes of hand-arm vibration measurement [1]

Vibration is defined by its magnitude and frequency. The magnitude of vibration could be expressed as the vibration displacement (in meters), the vibration velocity (in meters per second) or the vibration acceleration (in meters per second per second or m/s^2). Most vibration transducers produce an output that is related to acceleration; so acceleration has traditionally been used to describe vibration.
Frequency is the number of times per second the vibrating body moves back and forth. It is expressed as a value in cycles per second, more usually known as hertz (abbreviated to Hz). For rotating tools the dominant frequency is usually determined by the speed at which the tool rotates (usually expressed as the number of revolutions per minute or rpm; dividing the rpm by 60 gives the frequency in Hz). For hand-arm vibration, the frequencies thought to be important range from about 8 Hz to 1000 Hz. However, because the risk of damage to the hand is not equal at all frequencies a *frequency-weighting* is used to represent the likelihood of damage from the different frequencies. As a result, the weighted acceleration decreases when the frequency increases. For hand-arm vibration, only one frequency weighting curve is used for all three axes [1],[3].
The risks from hand-arm vibration affect people across many industries and occupations. The risks are greatly increased with use of higher vibration equipment and with prolonged and regular use of the equipment. However, investigations have shown that vibration hazards can be controlled and risks reduced by good management. They have also shown that the costs of such controls need not be high and can usually be offset by the benefits of keeping workers healthy. Additionally, the vibration control measures have, in many cases, led to improved efficiency[1],[3].
From each vibration axis a frequency-weighted root-mean-square average acceleration is measured. This is referred to as *a*hw. The value used for assessment of exposure is the *vibration total value*, which combines the three *a*hw values for the axes x, y and z, using:

$$a_{hv} = \sqrt{a_{hvx}^2 + a_{hvy}^2 + a_{hvz}^2} \qquad (1)$$

WORKED EXAMPLES

Where just one machine is used

The *daily vibration exposure*, *A*(8), for a worker carrying out one process or operating one tool can be calculated from a magnitude and exposure time, using the equation:

$$A(8) = a_{hv}\sqrt{\frac{T}{T_0}} \qquad (2)$$

where *a*hv is the vibration magnitude (in m/s^2), *T* is the daily duration of exposure to the vibration magnitude *a*hv and *T*0 is the reference duration of eight hours. Like vibration magnitude, the daily vibration exposure has units of metres per second squared (m/s^2)[1],[3].

Example

A forest worker uses a brush cutter for a total of 4½ hours a day. The vibration on the brush cutter when in use is $4 m/s^2$. The daily exposure *A*(8) is:

$$A\,(8) = 4\sqrt{\frac{4.5}{8}} = 3\ m/s^2 \qquad (3)$$

This daily exposure of $3 m/s^2$ is above the exposure action value but below the exposure limit value [3].

Where more than one machine is used

If a person is exposed to more than one source of vibration then *partial vibration exposures* are calculated from the magnitude and duration for each source. The overall daily vibration exposure can be calculated from the partial vibration exposure values, using:

$$A(8) = \sqrt{A_1(8)^2 + A_2(8)^2 + A_3(8)^2 + \cdots} \quad (4)$$

where $A1(8)$, $A2(8)$, $A3(8)$, etc. are the partial vibration exosure values for the different vibration sources[1].

Example

A fettler uses three tools during a working day:
1. An angle grinder: 4m/s² for 2½ hours
2. An angle cutter for 3 m/s² for 1 hour
3. A chipping hammer 20 m/s² for 15 minutes

The partial vibration exposures for the three tasks are:

Grinder: $A_{Grind}(8) = 4\sqrt{\frac{2.5}{8}} = 2.2\ m/s^2$

Cutter: $A_{Cut}(8) = 3\sqrt{\frac{1}{8}} = 1.1\ m/s^2$

Chipper: $A_{Chip}(8) = 20\sqrt{\frac{8}{8\times 60}} = 3.5\ m/s^2$

The daily vibration exposure is then:

$$A(8) = \sqrt{A_{Grind}(8)^2 + A_{Cut}(8)^2 + A_{Chip}(8)^2} \quad (5)$$

This daily exposure of 4.3m/s² is above the exposure action value but below the exposure limit value [1],[3].

Your risk assessment should enable methods for controlling exposure to be identified. While you are assessing the vibration exposures, you should be thinking about the work processes that cause them. Understanding why workers are exposed to vibration will help identify methods for reducing or eliminating them.
The approach you take to reduce risks from hand-arm vibration will depend on the practical aspects of your particular processes and on the current levels of exposure.

HOW CAN HAV RISKS BE MANAGED?

The following steps should be used to ensure, so far as is reasonably practicable, workers and other people are not harmed by exposure to HAV in the workplace:

Find out what could cause harm

The following can help you identify potential vibration hazards:
•Observe the workplace, and work tasks to identify areas where exposure to HAV can occur and how workers interact with the plant.
•Visually inspect the plant before and during operation.

•Ask your workers about problems they encounter at your workplace when interacting with plant– consider operation, inspection, maintenance, repair, transport and storage requirements.
•Review your incident and injury records including reports of indicative behaviour e.g. dropping tools or difficulty climbing a ladder due to inability to maintain strong grip [9].

Assess the risk.

When you have identified the hazards at your workplace you need to think about the risks—the likelihood of somebody being harmed by the hazard and how serious the harm could be. You also need to think about how incidents could happen and who might be harmed. The most important factors when considering the risk of health effects for HAV are:
•the vibration emission of the tool, and
•the duration for which the worker is exposed to the vibration, both on a day to day, and long term basis.
The main factors influencing harmful HAV exposures are:
•Tool and task characteristics – high vibration emission, poor tool maintenance, minimal handle insulation, increased weight of tool, increased surface area of hand in contact with tool, harder material being contacted.

•Individual characteristics – gripping of handle more tightly than needed, low operator skill, poor technique, individual lifestyle factors (e.g. smoking), an individual's medical history (e.g. disease or prior injury to fingers, hands or wrists).
A risk assessment can help you determine what action you should take to control the risk and how urgently the action needs to be taken.
In some circumstances it may be necessary to engage a vibration specialist to assess your workers' vibration exposures [9].

Take action to control the risk.

The WHS laws require a business or undertaking do all that is reasonably practicable to eliminate or minimise risks
The ways of controlling risks are ranked from the highest level of protection and reliability to the lowest. This ranking is known as the hierarchy of risk control. You must work through this hierarchy to manage risks.
If possible consider whether risks from using the vibrating plant can be completely removed from the workplace, for example replacing hand operated jack hammers with backhoe or other mobile plant mounted breaking tools, substituting manual fettling using hand-held grinders with robotic fettling machines, or jig mounted grinders.
If it is not reasonably practicable to completely eliminate the risk then consider the following options in the order they appear below to minimise risks, so far as is reasonably practicable:
•Substituting high-vibration tools with ones with lower vibration emissions levels and replacing older equipment with new vibration-reduced equipment.
•Using engineering controls e.g. modifying existing tools to either minimise the vibration or prevent the vibration from moving into the handle of the tool, directing cold air from the exhaust of air powered tools away from the worker's hand, and maintaining plant and tools regularly to minimise vibration.
If after implementing the above control measures a risk still remains, consider the following controls in the order below to minimise the remaining risk, so far as is reasonably practicable:
•Using personal protective equipment (PPE) e.g. gloves to protect hands from cold and/or wet surfaces or working conditions which increase the likelihood of finger blanching. The use of 'anti-vibration' gloves as a control measure to minimise transmission of vibration to the hands is of limited effectiveness and, depending on the frequency of the vibration, may even increase transmission. Thick gloves should also be avoided as the lack of 'feel' can lead to workers gripping tools more firmly than necessary leading to increased vibration transmission and rapid fatigue.

A combination of the controls set out above may be used if a single control is not enough to minimise the risks.
You should consider all possible control measures and make a decision about which are reasonably practicable for your workplace. Deciding what is reasonably practicable includes the availability and suitability of control measures, with a preference for using substitution, isolation or engineering controls to minimise risks before using administrative controls or PPE. Cost may also be relevant, but you can only consider this after all other factors have been taken into account [9].

CONCLUSION

The evaluation and assessment of risks arising from exposure to vibration and the implementation of protection measures can be complicated. The risks from hand-arm vibration affect people across many industries and occupations. The risks are greatly increased with use of higher vibration equipment and with prolonged and regular use of the equipment. However, investigations have shown that vibration hazards can be controlled and risks reduced by good management. A daily vibration exposure assessment depends on both the level of vibration and the duration of exposure. In this paper we look at how daily vibration exposure is calculated from vibration magnitude information and exposure times.

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CALCULATING DAILY VIBRATION EXPOSURES AND WORKED EXAMPLES IN WHOLE-BODY VIBRATION

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Abstract: Whole-body vibration magnitude is the frequency-weighted acceleration value in the highest of three orthogonal axes for a seated or standing worker. To assess the daily vibration exposure of workers, we need an estimate of the time machine operators are exposed to the vibration source. In this paper given examples daily exposure where there is just one task and daily exposure where there is more than one task.
Key words: Whole-bode vibration, daily vibration exposure

INTRODUCTION

Human vibration is defined as the effect of mechanical vibration on the human body. During our normal daily lives we are exposed to vibrations of one or other sort e.g. in buses, trains and cars. Many people are also exposed to other vibrations during their working day, for example vibrations produced by hand-tools, machinery, or heavy vehicles. Just as sound can be either music to the ear or irritating noise, human vibrations can either be pleasant or unpleasant [1]. We enjoy, and even create pleasant vibrations when we run, dance or take a trip on the merry-go-round, but we try to avoid exposing ourselves to unpleasant vibrations such as travelling on a bumpy road or operating hand-held power tools. A good deal of research has been done in studying the effect of exposure to vibration on man, especially in his working environment. Some of the early research involved a study of people such as aircraft pilots, operators of heavy work vehicles and hand-tool operators. Their ability to perform complex tasks under adverse vibrational conditions formed part of the first investigations. Nowadays, human vibration research is also carried out in working environments and the results used to establish International Standards which allow human exposure to vibration to be evaluated. [1]. Regular exposure to Whole-Body Vibration (WBV) can in some cases be responsible for reducing operator comfort, performance and health. Defining any such health effects is difficult as many symptoms are indistinguishable from other causes. Long term exposure to whole-body vibration (WBV) particularly to repeated large jolts and jars are however linked to back pain. Employees who operate mobile machines or other vehicles over poor surfaces as a main part of their job are particularly at risk.
If employees are at risk, employers and equipment manufacturers must consider what action is needed to reduce the risk so far as is reasonably practicable. This must meet the requirements of general legislation including the Health and Safety at Work.
This procedure is intended to help managers and others decide whether there is a risk of excess exposure to Whole-body Vibration and what kind of action might help to reduce it, such as:
• elimination of the risk altogether;
• evaluation of the levels of risk;
• prioritising action required according to risk;
• introduction of control measures such as purchasing requirements; health monitoring;
instruction of employees.The subject of vibration is surrounded with technical information and terms but as far as possible, a non-technical language has been used in this document [6].

Figure 1. Jobs which cause whole body vibration

DETERMINING EXPOSURE DURATION

Before the daily vibration exposure $A(8)$ can be estimated, you need to know the total daily duration of exposure to the vibration from the vehicles or machines used. You should be careful to use data that is compatible with your vibration magnitude data, for example, if your vibration magnitude data is based on measurements when the machine was working, then count only the time that the worker is exposed to vibration. Machine or vehicle operators questioned on their typical daily duration of vibration exposure usually state a value containing periods without vibration exposure, e.g. truck loading and waiting times [3].
Usually, the vibration that occurs when the vehicle is travelling will dominate vibration exposures. However, some exposures are dominated by operations being performed while the vehicle is static, such as excavators and tree harvesters.
Work patterns need careful consideration. For example some workers may only operate machines for certain periods in a day. Typical usage patterns should be established, as these will be an important factor in calculating a person's likely vibration exposure [3].

DETERMINING VIBRATION MAGNITUDE

The *root-mean-square* (*r.m.s) vibration magnitude* is expressed in terms of the frequency-weighted acceleration at the seat of a seated person or the feet of a standing person (Fig 2), it is expressed in units of *metres per second squared* (m/s^2). The *r.m.s vibration magnitude* represents the average acceleration over a measurement period. It is the highest of three orthogonal axes values ($1.4a_{wx}$, $1.4a_{wy}$ or a_{wz}) that is used for the exposure assessment.

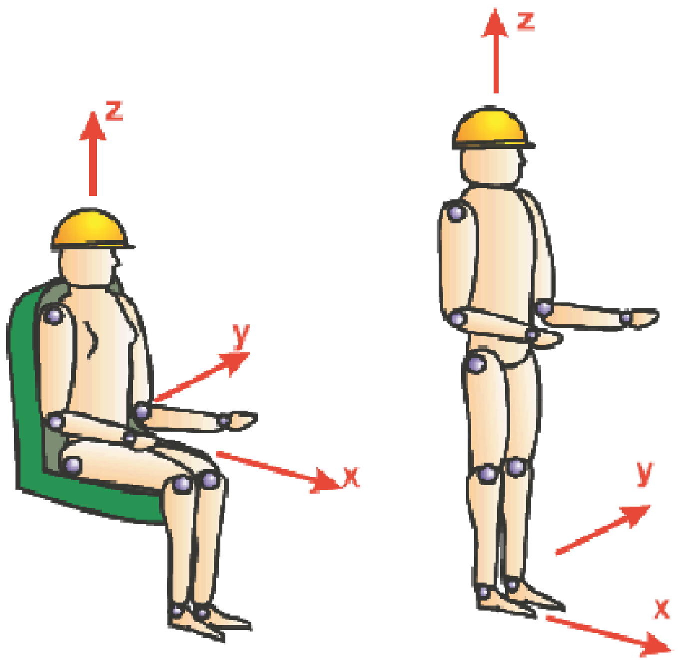

Figure 2. Vibration measurement axes[3]

Daily exposure: A(8), where there is just one task

Step 1: Determine the three frequency weighted r.m.s acceleration values *a*wx, *a*wy and *a*wz., from manufacturer's data, other sources, or measurement.
Step 2: Find the daily exposures in the three directions, x, y and z from:

$$A_x(8) = 1.4a_{wx}\sqrt{\frac{T_{exp}}{T_0}} \tag{1}$$

$$A_y(8) = 1.4a_{wy}\sqrt{\frac{T_{exp}}{T_0}} \tag{2}$$

$$A_z(8) = a_{wz}\sqrt{\frac{T_{exp}}{T_0}} \tag{3}$$

Where:
Texp is the daily duration of exposure to the vibration, and
*T*0 is the reference duration of eight hours.

Step 3: The highest value of *Ax*(8), *Ay*(8) and *Az*(8) is the daily vibration exposure.

Example
A tree harvester driver operates the vehicle for 6½ hours a day.
Step 1: The vibration values on the seat are:
• x-axis: 0.2 m/s²

• y-axis: 0.4 m/s²
• z-axis: 0.25 m/s²

Step 2: The x, y and z axis daily exposures are then:

$$A_x(8) = 1.4 \times 0.2\sqrt{\frac{6.5}{8}} = 0.25\ m/s \qquad (4)$$

$$A_y(8) = 1.4 \times 0.4\sqrt{\frac{6.5}{8}} = 0.5\ m/s \qquad (5)$$

$$A_z(8) = 0.25\sqrt{\frac{6.5}{8}} = 0.23\ m/s \qquad (6)$$

Step 3: Daily vibration exposure, A(8) is the highest of these values. In this case it is the y-axis: 0.5m/s² (i.e. at the exposure action value) [3]

Daily exposure: A(8), where there is more than one task

If a person is exposed to more than one source of vibration (perhaps because they use two or more different machines or activities during the day) then a *partial vibration exposure* is calculated from the magnitude and duration for each axis and for each exposure. The partial vibration values are combined to give the overall daily exposure value, *A*(8), for that person, for each axis. The daily vibration exposure is then the highest of the three single axis values.

Step 1: Determine the three frequency weighted r.m.s acceleration values *a*wx, *a*wy and *a*wz, for each task or vehicle, from manufacturer's data, other sources, or measurement.

Step 2: For each vehicle or task, find the partial daily exposures in the three directions, x, y and z using:

$$A_{x,i}(8) = 1.4a_{wx}\sqrt{\frac{T_{exp}}{T_0}} \qquad (7)$$

$$A_{y,i}(8) = 1.4a_{wy}\sqrt{\frac{T_{exp}}{T_0}} \qquad (8)$$

$$A_{z,i}(8) = a_{wz}\sqrt{\frac{T_{exp}}{T_0}} \qquad (9)$$

Where
Texp is the daily duration of exposure to the vibration and
*T*0 is the reference duration of eight hours.

Each partial vibration exposure represents the contribution of a particular source of vibration (machine or activity) to the worker's total daily exposure. Knowledge of the partial exposure values will help you decide on your priorities: the machines or activities or processes with the highest partial vibration exposure values are those that should be given priority for control measures.

Step 3: For each axis (*j*), the overall daily vibration exposure can be calculated from the partial vibration exposure values, using:

$$A_j(8) = \sqrt{A_{j1}(8)^2 + A_{j2}(8)^2 + A_{j3}(8)^2 + \cdots} \qquad (10)$$

where $Aj1(8)$, $Aj2(8)$, $Aj3(8)$, etc. are the partial vibration exposure values for the different vibration sources [3].

Example

A delivery driver spends 1 hour loading his lorry using a small forklift truck, followed by 6 hours driving the delivery lorry each day.

Step 1: The vibration values on the seat are:

Forklift truck	Delivery lorry
x-axis: 0.5 m/s^2 y-axis: 0.3 m/s^2 z-axis: 0.9 m/s^2	y-axis: 0.3 m/s^2 z-axis: 0.3 m/s^2 x-axis: 0.2 m/s^2

Step 2: The x, y and z axis daily exposures are then:

Forklift truck	Delivery lorry
$A_{x,forklift}(8) = 1.4 \times 0.5\sqrt{\frac{1}{8}} = 0.25\ m/s^2$	$A_{x,lorry}(8) = 1.4 \times 0.2\sqrt{\frac{6}{8}} = 0.24\ m/s^2$
$A_{y,forklift}(8) = 1.4 \times 0.3\sqrt{\frac{1}{8}} = 0.15\ m/s^2$	$A_{y,lorry}(8) = 1.4 \times 0.3\sqrt{\frac{6}{8}} = 0.36\ m/s^2$
$A_{z,forklift}(8) = 0.9\sqrt{\frac{1}{8}} = 0.32\ m/s^2$	$A_{z,lorry}(8) = 0.3\sqrt{\frac{6}{8}} = 0.26\ m/s^2$

Step 3: Daily vibration exposure, for each axis are:

$$A_x(8) = \sqrt{0.25^2 + 0.24^2} = 0.3\ m/s^2 \qquad (11)$$
$$A_y(8) = \sqrt{0.15^2 + 0.36^2} = 0.4\ m/s^2 \qquad (12)$$
$$A_z(8) = \sqrt{0.32^2 + 0.26^2} = 0.4\ m/s^2 \qquad (13)$$

Step 4: The driver's daily whole-body vibration exposure is the highest axis A(8) value, in this case the value for the y or z-axes: 0.4 m/s^2, i.e. just below the exposure action value [3].

A risk assessment should enable methods for controlling exposure to be identified. While you are assessing the vibration exposures, you should be thinking about the work processes that cause them. Understanding why workers are exposed to high vibrations and ergonomic risks will help identify methods for reducing or eliminating the risks.

CONCLUSION

Work that involves exposure to whole-body vibration occurs commonly in off-road work, such as farming, construction and quarrying, but it can occur elsewhere, for example on the road in lorries and trucks, at sea in small fast boats and in the air in some helicopters. Whole-body vibration is not restricted to seated workers such as drivers, but may also be experienced during standing operations such as standing on a concrete crushing machine. The purpose of the whole-body vibration risk assessment is to enable you as the employer to make a valid decision about the measures necessary to prevent or adequately control the exposure of workers to whole-body vibration.

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Session 7.

Environmental Management

SUNSPACES AS PASSIVE DESIGN ELEMENTS FOR ENERGY EFFICIENT AND ENVIRONMENTALLY SUSTAINABLE HOUSING

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Abstract: Building design and construction consumes nearly 40% of primary energy. Environmental issues, such as higher atmospheric CO_2 concentrations due to combustion of fossil fuels used for energy production, necessitate increased use of renewable energy sources in buildings. Solar energy is used in building design and construction through active and passive systems. This paper highlights the advantages of exploiting solar energy passively, using passive sunspace systems, which is one way to reduce energy consumption in residential buildings, but only with a thorough knowledge of passive sunspace systems. The paper defines the typology of passive sunspace systems and provides an overview of basic types including their advantages and disadvantages. The presented typology pertains to the functioning of passive sunspace systems, mechanisms of heat accumulation and transfer, and their position and shape.

Key words: passive solar buildings, sunspace, typology

INTRODUCTION

In Europe, about 40% of energy is spent in building design and construction, while two thirds of that energy is spent in residential buildings. Energy consumption will keep being the main topic of research because it is associated with greenhouse gas (GHG) emissions. Increased concentrations of atmospheric CO_2, which is a greenhouse gas, will be even more prominent in the near future. [1,2] Lower energy consumption and better energy efficiency in building design and construction are the chief goals to be reached if emissions of atmospheric pollutants are to be reduced. Therefore, it is necessary to improve the design of passive solar and bioclimatic buildings, which provide a comfortable interior environment using passive means in conjunction with external climate conditions.

PASSIVE SOLAR BUILDINGS

As early as the days of Ancient Rome (50 AD), it was observed that the use of glass in buildings traps the heat inside, creating the now well-known “greenhouse effect”. Roman upper classes added sunspaces (*heliocaminus*) to their villas, which were then used to grow fruits and vegetables throughout the year. In 17th century Europe, glasshouses, better known as *conservatories*, were used to grow plants and were attached to buildings to improve heating during wintertime. In the 1920s, Walter Gropius advocated more extensive use of passive solar buildings in Europe. In the US, the first significant passive solar building was *The Jacobs II House*, designed by Frank Lloyd Wright in a style that he aptly named “the solar hemicycle” [3].

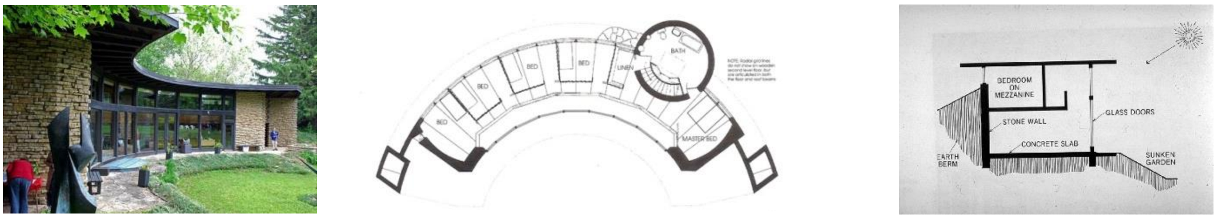

Figure 1. *The Jacobs II House* by Frank Lloyd Wright (appearance, layout, and cross-section)

Passive solar buildings fit within their wider environment and usually have an elongated base, with a west-east orientation lengthwise and a large glazed surface on the south-facing façade, which also allows a visual connection between people and the external environment. In a sense, they imitate nature as they are opened in the winter to collect as much sunlight as possible while offering protection from overheating in the summer by means of overhangs, curtains, or shades.

In passive solar buildings, the function of passive receivers of sunlight is performed either by the entire structure or by parts of the structure that accumulate, store, and transfer a portion of solar energy to other parts of the building if required. With passive solar systems, solar energy is converted into heat; heat accumulation and air circulation in certain parts of the building are required to provide optimal and comfortable conditions in the various rooms [4]. These systems also necessitate heat loss control as well as optimal sizing of thermal mass in the building, in order to provide maximum heat gain in the winter and minimum overheating in the summer. The efficiency of passive solar houses also depends on the local bioclimatic conditions, such as the weather, the relief of the terrain on which the house is situated, the proximity of other buildings in the area, the presence of trees and vegetation that potentially block the sunlight, etc.

Passive solar systems for sunlight collection include direct systems with windows, Trombe wall systems, sunspace systems, and others. This paper focuses on the sunspace passive system as one of the most efficient passive systems, which is easily installed both in buildings under construction and in finished residential buildings.

PASSIVE SOLAR BUILDINGS WITH A SUNSPACE

A passive solar system with a sunspace comprises a glazed portion of the structure adjacent to other living areas. Sunspaces (also called *sunrooms*, *solariums*, or *passive greenhouses*) are among the most popular passive solar systems. They are usually designed as independent thermal zones within a building, attached to rooms in which people are expected to spend more time (e.g. the living room, the dining room, etc.). During a clear day, owing to large transparent surfaces, sunspaces collect sunlight and accumulate it in a thermal mass – in the walls or in the floor. During the night, the passive system serves as a buffer zone preventing excessive heat loss. Sunspaces are often non-heated rooms in which high day-night temperature oscillations are expected, but most of the time they provide a comfortable place to stay and can be used to expand other living areas.

SUNSPACE TYPOLOGY ACCORDING TO PARTITION TYPE

Depending on how sunlight energy is collected, accumulated, and transferred to the adjacent room, there are several types of sunspace. The basic classification is made according to the type of partition that separates the sunspace from the adjacent room, as shown in Figure 2.

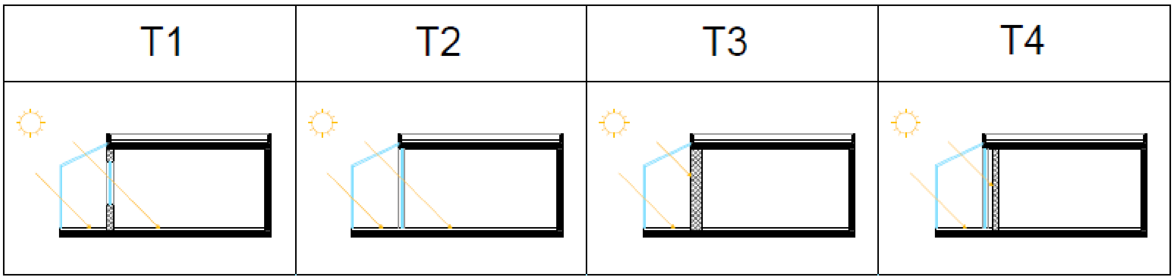

Figure 2. Sunspace types according to the type of partition between the sunspace and the adjacent room: T1 – sunspace with a thermal storage wall and a direct system; T2 – sunspace with a transparent partition; T3 – sunspace with a thick thermal storage wall; T4 – sunspace with a Trombe wall (Source: the authors, adapted according to [5])

Type T1 is a passive sunspace system with a partially glazed partition, which allows direct penetration of sunlight, while the rest of it is made of opaque materials and can constitute thermal mass. With this type, it is possible to take advantage of both the direct and indirect system, as the portion of solar energy will be directly transferred to the adjacent room, while the portion accumulated within the sunspace will be available for later use. The partial glazing of the partition can also enable direct exchange of air between the sunspace and the adjacent room.

Type T2 passive sunspace system has a glazed partition. The second, inner, glazing allows direct penetration of sunlight to the thermal mass in the floors, walls, and other construction elements, protecting the indoor space from excessive heat loss. Due to large glazed surfaces, the design of this sunspace type should include some form of protection from overheating during the summer.

Type T3 has a thick partition wall, which acts as the thermal storage mass. With this passive system type, sunlight penetrates the outer glazing and reaches the thick wall, where it is partially reflected, but mostly absorbed by the wall. Solar radiation increases the temperature inside the sunspace, and the absorbed heat is transferred to the adjacent room by means of conduction. The chief advantage of this passive sunspace type is the reduction of heat loss during wintertime and the mitigation of the effects the external environment has on indoor heated space.

Type T4 is a combination of a passive sunspace system and Trombe wall, which could be considered an improvement over type T3 in terms of higher heat gain.

It should be stressed that each type has the option of installing a mechanical system of air exchange between the sunspace and the adjacent room for the purpose of achieving a better heating effect and reaching appropriate indoor temperatures according to the residents' needs.

SUNSPACE TYPOLOGY ACCORDING TO ITS POSITION IN THE BUILDING

Position of the sunspace in relation to the entire building can vary, and some positioning and shape options are shown in Figure 3.

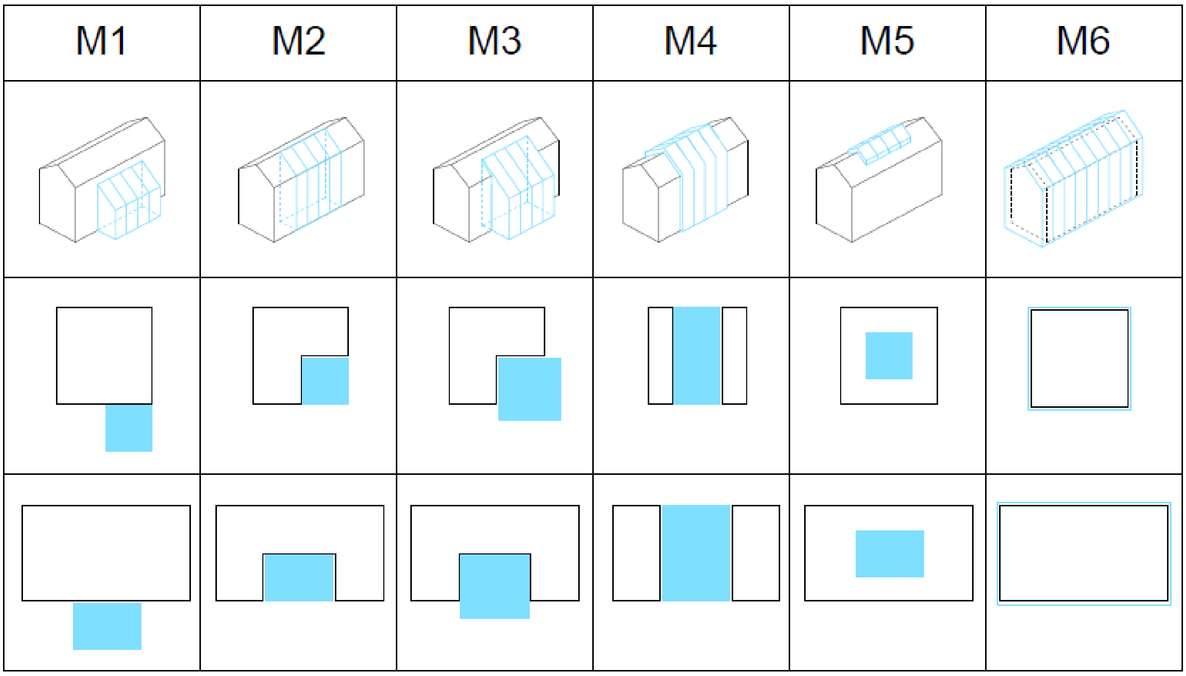

Figure 3. Main sunspace types according to position in relation to the building and shape: M1 – attached sunspace; M2 – fully integrated sunspace; M3 – partially integrated sunspace; M4 – laterally integrated sunspace; M5 – atrium sunspace; M6 – sunspace envelope around the primary building

Attached sunspace (Type M1, Figure 3) is constructed along the outer layer of the primary building, either a façade or the roof surface. Such manner of construction changes both the aesthetic and energy properties of the building itself. In terms of energy efficiency, the attached sunspace helps reduce the transmission losses of the building envelope, but, depending on its position long the façade, size, and material, it can significantly influence the accumulation of heat [6]. One side of the attached sunspace is connected to the primary building, while the other sides are exposed to sunlight and they can be completely or partially glazed. Figure 3 shows variants of the attached sunspace with a square and rectangle basis; however, depending on the desired effect on the façade, the basis can be triangular, hexagonal, or another geometric form.

Figure 3 also shows variants in which the sunspace is fully or partially integrated into the primary building (Types M2 and M3) or between two opposing façades (Type M4). The advantage of a passive system with a fully or partially integrated sunspace is a larger contact surface with the building interior than with the exterior, which makes it more comfortable than type M1 (attached sunspace) during wintertime. In addition, during the summer the surface exposed to excessive heating is smaller, so less protection from overheating is needed [5].

Type M5 is obtained by glazing the atrium. The atrium can be a heated or non-heated space. If the atrium is non-heated, during wintertime the temperature inside it will nonetheless be higher than the ambient temperature. If the atrium is turned into a heated space after glazing, the intervention involves the altering of the building shape factor – by changing the ratio between the building capacity and the area of the thermal envelope, significant amounts of energy can be saved [6].

The sunspace enveloping the primary building (Type M6) is a borderline case, whereby the glazed portion of the façade envelops the entire primary building and constitutes a protective layer, which creates new microclimatic conditions in relation to the primary building. It is often used in the restoration of architectural heritage buildings or for protected historical buildings [7]. If the glazed portion is close to the building façade (0.25 – 2.0 m), it constitutes a “double-skin façade”, which is often used in office buildings, whereby the space between the building’s façade and the glazed façade can be utilized for the placement of overheating protection and mechanical ventilation devices or as maintenance space.

M1 M2 M3 M4 M5 M6

Figure 4. Examples of sunspace houses according to the typology shown in Figure 2

Figure 4 shows examples of individual houses with a sunspace according to the typology pertaining to their shape and position (M1-M6).

TYPOLOGY ACCORDING TO THE POSITION AND SIZE OF THE THERMAL MASS

Thermal mass or heat storage in passive sunspace systems refers to sunspace floor, living area floors, ceilings, or thick indoor walls, especially the wall separating the sunspace from the living area (Figure 5).

The role of thermal mass in sunspace houses is to store heat distributed to the various rooms during diurnal periods without sunlight or during the night. The materials used as thermal mass need to have a high volumetric heat capacity. The best materials for heat storage are water, concrete, gravel, compressed earth blocks, bricks, etc. Mobile elements within the sunspace or other rooms, e.g. water tanks, can also serve as thermal mass.

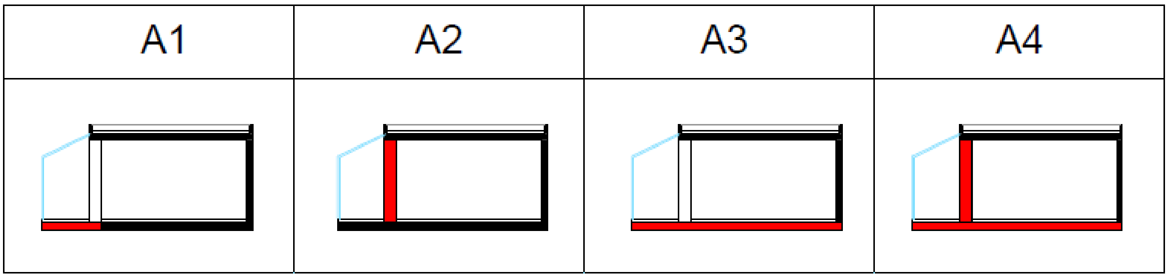

Figure 5. Basic sunspace types according to thermal mass position: A1 – thermal mass in the sunspace floor; A2 – thermal mass in the thick wall between the sunspace and the living area; A3 – thermal mass in the sunspace and living area floors; A4 – thermal mass in the sunspace and living area floors, as well as in the thick partition wall

Bastien and Athienitis (2016) studied the size of thermal mass in sunspaces and glasshouses. They examined the most common sunspace configurations in terms of thermal mass position (floors, wall, or both) and glazing percentage. Their key observations were that thermal mass in sunspaces and glasshouses significantly impacts the time when heat is distributed, minimum indoor temperatures, and daily temperature variations. An increase in thickness of thermal mass within a sunspace from 0.1m to 1m can increase the temperature by 3 to 5°C. If the goal is to increase heating during the evening, a minimum of 0.06 of thermal mass needs to be placed in the floor and as much thermal mass as possible in the wall [8].
Sanchez-Ostiz et al. (2014) studied the energy properties of sunspace buildings in cases when thermal mass is horizontal and when it is vertical. Water enclosed in an aluminium frame was used as the heat storage material. The following is the most relevant results of the study: use of a sunspace with thermal mass allows more stable indoor conditions than in houses without a sunspace or thermal mass; in case of a sunspace without thermal mass, energy consumption is 12.9% lower than in cases without a sunspace, while it is 16.7% lower in sunspaces with thermal mass than in those without thermal mass; sunspaces with thermal mass increase the indoor thermal comfort through increased lowest and reduced highest temperatures [9].
Formation of thermal mass requires the design of massive construction elements, such as walls or floors, whose heat-storing abilities increase with their thickness. In case of buildings under construction, this is feasible in the early design stage; however, in completed buildings there are limited options to change the structure thickness. This is where phase change materials (PCM) come into play as heat storage replacements for thermal mass. The PCMs used in building design and construction should have their melting point in the temperature range between 25°C and 35°C. They can provide significant heat storage, as they absorb sunlight while melting. During cooler periods, PCMs harden and give off heat to the room. The PCMs used in buildings include various types of paraffin, hydrated salt solutions, etc.
A study conducted by Lu et al. (2018) concerns the use of PCMs for latent passive heat storage. Paraffin whose phase change temperature range is 35-40°C was placed in the floor and the wall in order to increase the building's thermal inertia. Data analysis revealed that the use of PCMs allows passive heating of the building that is 7.15°C higher than in a building without PCMs and that it is possible to conserve 54.27% in heating energy [10].
During the summer, in order to prevent increased thermal load of buildings, it is necessary to shade the building, specifically the thermal mass. One way to do that is to build overhangs. When designating the position and dimensions of the overhang, it is crucial to enable unobstructed penetration of sunlight during wintertime, when the angle is smaller. Another way to prevent overheating during the summer is to use deciduous trees, whose treetops would provide shade in the summer and allow sunlight to pass through in the winter, after they have shed their leaves.

CONCLUSION

In order to better understand the thermal behaviour of passive sunspace systems and the main possibilities of this heat collection and storage system, it is necessary to establish their basic typology. This paper presented typologies of passive sunspace systems according to the size, shape, and position in relation to the primary building; the type and structure of the partition separating the sunspace from the living area; and the position and type of thermal mass. In addition, the paper analyzed the manner of heat collection and transfer for certain sunspace types, highlighting their constructional and technical advantages and disadvantages. Sunspaces are passive systems often used in residential buildings due to their considerable energy conservation capability. They cannot provide ideal indoor conditions, but they can significantly conserve the energy-generating products used for heating and cooling. One option for further research is to determine the optimal construction properties of sunspaces (position in relation to the Sun, size, glazed surface area, glazing type, thermal mass dimensions and materials, etc.), depending on climate conditions.

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ENVIRONMENTAL IMPACT ASSESSMENT OF SLOVENIAN MOUNTAIN HUT WITHIN THE SCOPE OF SUSTAINABLE MOUNTAIN HUTS IN EUROPE

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Abstract: Remote off-grid mountain huts are specific micro-grid systems which are usually located in sounder environment. As they are not connected to utility grids they require own energy supply for both heat and electricity. While heat is typically provided by fossil fuels and/or biomass, electricity is usually provided by diesel fuelled generators. These types of power generation inevitably cause a lot of environmental impact. The environmental impact assessment for one Slovenian Pogačnikov Dom hut was made. Specifically CO_2 emissions as global warming potential (GWP) and NO_x emissions were analysed before and after implementation action.
Results shown that with basic investments for installation of additional PV panels and some optimization procedures of the transport, the reductions of 64 % in CO_2 and 54 % NO_x are possible. These results confirm main objective of Life+ Sustain Huts EU project to reduce emissions, producing energy based on renewables and to make mountain huts more sustainable and friendly.
Key words: mountain hut, environmental impact assessment, electricity, heat, renewables

INTRODUCTION

Climate change has been for years one of the most important tasks to be taken into high consideration, both in EU and internationally. In this sense, in order to keep the increase of the global temperature below 2 ºC by 2050, the EU has established the objective of reducing greenhouse gases emissions (GHG) by 80 % taking as reference GHG levels from 1999, by 2050. The targets for 2020 are also in this line (reducing greenhouse gas emissions by 20 %, increasing the share of renewable energies to 20 % and achieving the 20 % energy efficiency target), [1].
A mountain hut is usually an isolated construction in the mountains, where not only the access to utilities is complicated, but also it is difficult to transport purveyances or fuel supplies. Then, other solutions instead of the usual electricity and gas companies must be considered. Nowadays, the systems providing energy to these facilities are fossil fuel-based, which implies the installation of a diesel generator in order to produce electricity and heat for the heating system and hot water. Moreover, the fuel to be supplied to the generator and other needs to be transported by helicopter in many cases.
Furthermore, Europe depends strongly on imports from foreign countries, which are 80 % of their petroleum reserves. These reserves are usually in unstable regions at political level. Then, this dependence is a clear weakness for Europe´s economy and a major problem to be solved. As it has been stated in the EU document: ‘’the electricity may play the most important role in order to reach the zero emissions by 2050, contributing to replace fossil fuels in transport and heating’’, [2]. In this sense, almost all the electricity and heat that is being consumed nowadays in isolated huts is generated based on diesel consumption. By including the pioneering systems that EU project Life+ Sustain Huts presents, it will be demonstrated how to reduce the dependence of the huts from fuel from foreign countries, promoting renewable generation with almost zero emission as a way of achieving energy independence, sounder environment and making stronger economy, [3].
Mountain huts are mainly located in natural parks where pollution is a critical factor and the different authorities look for the best measures to prevent deterioration, contamination and conservation of natural habitats of wild fauna and flora. To maintain that environment the integration of zero emission solutions for providing electricity and heat to the remote located huts it’s necessary in the future. In order to evaluate the implementation of these effective solutions the Life Cycle Assessment (LCA) should be applied before and after implementation actions, [4,5].
As the core of the project Life+ Sustain Huts, innovative climate change adaptation technologies are going to be developed in 9 huts from four different countries (Italy, France, Slovenia and Spain),

which will demonstrate that can be easily replicated and transferred to other places independently of the climate, latitude or country. The technologies to be applied will be based on photovoltaic, micro hydro power and wind energy generation, fuel cells, electrolysers, hydrogen storage as well as new insulated materials which will be installed in the huts in order to demonstrate, show and educated in the climate change adaptation.

In present study identification of all technologies used in mountain huts are evaluated in terms of Life Cycle Inventory (LCI) analysis that will serve as a basis to set up a general LCA numerical model for mountain hut and specific LCA numerical models for each mountain hut with all specific inputs. In this paper the detail information for energy and mass balances for Pogačnikov Dom hut will be presented. Data included are fossil fuel consumption, electricity consumption and generation, biomass consumption, transportation type and distances covered which contribute to the environmental impacts of mountain hut operation during one year (3,5 months/ one season). One implementation action which is planned for Pogačnikov Dom in the future will be calculated for transportation and operation phase following comparison of the CO_2 and NO_x emissions before and after implementation.

METHODOLOGY IN THE STUDY

In the first part of the study the basic methodology used to collect all the data is the survey based on specific questionnaires and interviews of huts owners. In the second part the basic LCA numerical model will be set up to general overview of all possible inputs and outputs. In the numerical model all processes, virgin materials, transport types and distances and other flows important for mountain huts in the LCA study are included.

On the basis of data provided with LCI tables for Slovenian hut (Pogačnikov Dom) LCA numerical model with all mass and energy balances are set up. Furthermore the CO_2 and NO_X emissions are calculated for transportation and operation phase of the Pogačnikov Dom. This preliminary calculation study will serve as a data source for more detailed LCA study later in the project.

Technologies reviewed in the study are just currently used technologies and energy carrier in the mountain hut. From operational point of view just the integral data (average working hours, yearly fuel consumption, number of transportations of the fuel to the huts, etc.) for one year average is important as an input data for further LCA study. At this point the operation dynamics is not needed. This study will deliver the basic list with the type and power of technology used, main energy carriers, and basic operational characteristics.

Huts involved in the study

Life+ Sustain Huts is a demonstrative project which aims to reduce environmental impacts in natural habitats by implementing novel and original renewable energy based solutions in mountain huts. The mountain huts within the project are located in 4 different European countries. Particularly, there are 2, which are located in Slovenia (Kocbekov Dom and Pogačnikov Dom); 5 mountain huts located in Spain, four involved in the project (Bachimaña, Llauset, Lizara and Estós) and another one will be included proximately (Montfalcó); 1 in Italy (Refugio de Torino) and the most recent one in France (Refuge D'Ayous). In this study we will analyse Slovenian mountain hut Pogačnikov Dom.

The Pogačnikov Dom (Figure 1) is located in Triglav National Park to 4 km from Slovenia's highest mountain Triglav, it is perched on a small hilltop at the altitude of 2050 m on the peak of Kriški podi Kriški podi and also is surrounded by other six peaks: Bovški Gamsovec, Križ, Stenar, Razor, Planja and Pihavec. There are marked routes in order to can access to all of them. In the Figure 2 is shown the location of the hut. Latitude of the hut is 46,401965 and longitude is 13,800577. The hut was built during 1948 and 1951, though it was renovated and extended in 1973. After that, a cargo ropeway was constructed (nowadays is upgraded since 2003), while in 2004 the roof of the hut was renovated. Pogačnikov Dom is located in Slovenian Alps and it is usually open 3 months per year, from mid-June to mid-September.

Figure 1. Pogačnikov Dom, Slovenian hut

Dimensions of the hut are 15.5x11.5x7.5 m and capacity is for nearly 80 people, but the average accommodation per day is 28, besides 3 people work there. Pogačnikov Dom has diesel and gasoline generator, PV panels with batteries for electricity generation and wood stove for heat generation. Wood burning oven is use for cooking.

Figure 2. Location of Pogačnikov Dom in Slovenian Alps

ENVIROMENTAL IMPACT ASSESSMENT

Environmental impact assessment in this study was done with the life cycle assessment (LCA) methodology, which follows the ISO 14040 and 14044 standards, [6,7]. The environmental impacts have been evaluated according to the CML 2001 method for global warming indicator (GWP), [8].

The goal and the scope of the LCA study

The one of the goals of Life+ Sustain Huts project and also this study is to make detailed life cycle inventory (LCI) tables for all mountain huts (Pogačnikov Dom in this study). The scope of the study are ‘’gate to gate’’ which include all emissions to air, soil and water during operation with included transportation of the fuel. Functional unit used will be 1kWh of energy generated (electricity, heat) that will enable relative comparison of different huts separately for electricity and heat production. Furthermore the main goal of this study was to analyse possibility of the CO_2 and NO_x emissions reduction before and after the implementation action which are planned for Pogačnikov Dom. This implementation action are: Non-operational diesel and gasoline generators, installation of additional 5,5 kW PV panels and transport optimization (20% reduction of diesel consumption).

Life cycle inventory (LCI): mass and energy balance

Below it is detailed specification for Pogačnikov Dom with all information in tables, where operational characteristics are summarized. The aim is to reach the maximum information about the technologies installed on/in the hut, and the current state of hut, such as dimensions, average of visits per day, capacity of accommodation, as well as the surroundings, where the hut is located in order to analyse the possibility to install new technologies or improve current ones. All data are for 1 year operation (3.5 months – Jun- Sep).
The technologies for electricity generation are gasoline and diesel generator with 1,37 kW PV system with batteries (storage) and converters (Table 1). For the heat generation is wood stove and for cooking they use wood burning oven (Table 2). The fuel consumption for hut operation is 733.82 kg of diesel, 74.88 kg of gasoline and 20 m^3 of biomass per year (Table 3).

Table 1. Technologies used for electricity generation in Pogačnikov Dom

Electricity sources	Brand / type	Time	m^2	Installed power	Max efficiency	Electricity generation
Diesel generator	Nutool NDGS5000T	401 h	/	4.2 kW	19 %	1684.2 kWh/year
Petrol generator	Honda EC60002k	45 h	/	4.5 kW	22 %	202.5 kWh/year
PV panels	BP 255	/	4.32	1.37 kW	15 %	1347 kWh/year
Batteries storage	TAB 8 OPzS 800 Ah (2V*8)	/	/	115.2 kWh ~19200	/	/
Electricity consumption						**3233.7 kWh/y**

Table 2. Technologies used for heat generation in Pogačnikov Dom

Heat sources	Installed power	m^3	Efficiency	Energy generation in 1 year/kWh
Wood stove	8	8	/	36167 kWh
Wood-burning oven	5	/	70 %	
Energy consumption				**36167 kWh**

Table 3. Fuels consumption per year in Pogačnikov Dom

Fuels – consumption per year	Type of fuel	Used for	m^3	Mass kg
Liquid fuel	diesel	Electricity	0.882	733.82
Liquid fuel	Petrol 95	Electricity	0.09	74.88
Biomass	firewood	Heat	20	/

For accessing to the hut the only way for the visitors and employees is by foot. While for transporting the goods and fuel they use their own cargo ropeway (500l of diesel per year) and van (1920 km/year and avg. consumption: 15l/100km). Helicopter transport is hired only for heavier cargo, such as renovations or modification of the hut. Helicopter transport is excluded in this study.
According to all LCI analysis information a general LCA model for mountain huts are set up with all possible inputs/outputs. The general LCA model developed within a task C5.2 [9] of Life+ Sustain Huts project and is divided in two parts: one for electricity production (presented in Figure 3) and other for heat production (presented in Figure 4). This approach with separated models for heat and electricity will be used because of easier comparison of environmental impacts before and after different interventions and changes in technologies for specific hut. Data used in the model are for the period of 1 year. In the case of environmental impacts before and after the project for specific hut, the overall energy generation will be included that will provide absolute results useful just in the case of single hut impacts evaluation as is in this study.
One of the goals of this assessment is to see if it is possible with the implementation of new technologies achieve lower or almost zero environmental impact and more sustainable operation of mountain huts.

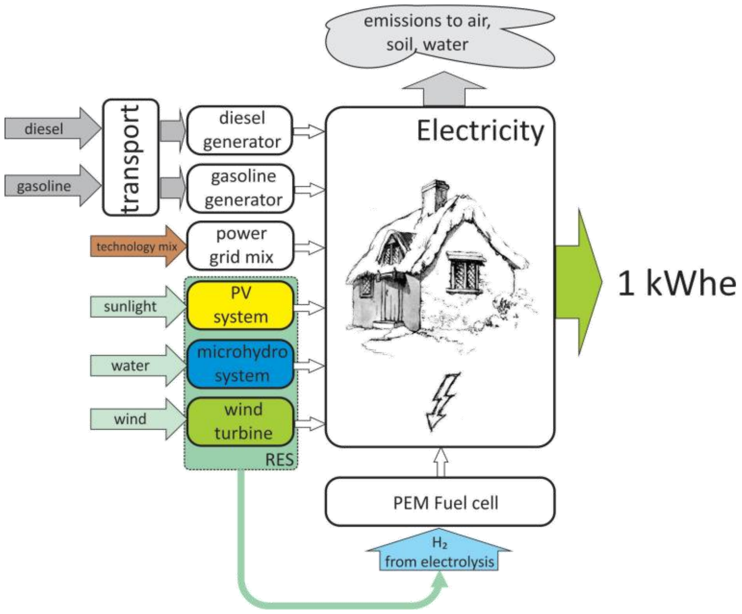

Figure 3. General LCA model for electricity production

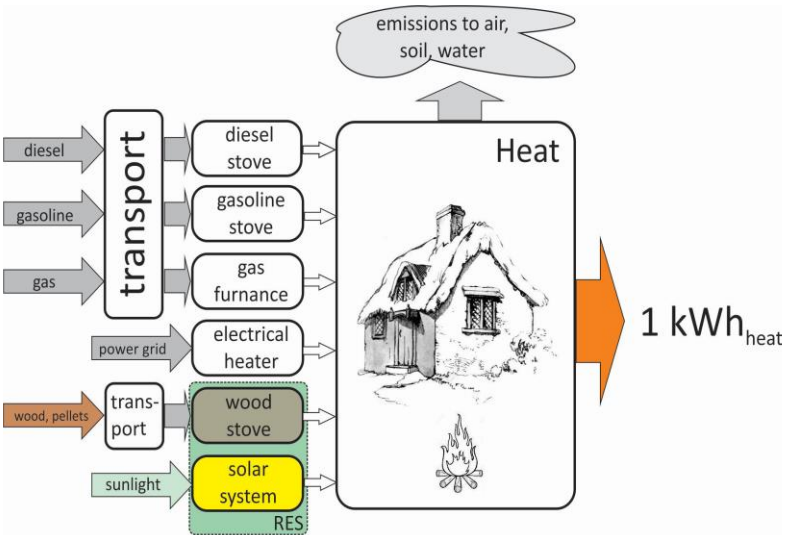

Figure 4. General LCA model for heat production

For Pogačnikov Dom the installation of new PV panels (5.5 kW) and elimination of diesel and petrol generator are considered in this study. Boundary conditions are:

- Transportation: van and cargo ropeway.
- Operation (electricity generation with diesel and gasoline generators).
- Operation (heat generation with wood burning oven).

Life cycle impact assessment methodology (LCIA)

After goal and scope has been determined, data has been collected, an inventory result is calculated. This inventory result is usually a very long list of emissions, consumed resources and sometimes other items. The interpretation of this list is difficult. An LCIA procedure is designed to help with this interpretation. According to the CML2001 LCIA method the Global Warming Potential (GWP [kg CO_2 eq.]) midpoint indicator was used to compare CO_2 emissions per 1kWh of produced electricity/heat for different fuel sources, which will be used in the future.
Values for CO_2 emissions was gathered from CO_2 emissions factors of German Environment Agency and International Energy agency [10,11] per 1kg of fuel and for NO_x emission data for transportation

(helicopter, van and cargo ropeway), electricity and heat generation was gathered from estimation of NOx emissions from fossil fuel combustion [12,13]. Used values for emissions per 1 kg of fuel are:

- Diesel: 3,162 kg CO_2/kg 0,0392g NOx/kg
- Gasoline: 3,189 kg CO_2/kg 0,0342g NOx/kg
- Biomass: 0 kg CO_2/kg – biomass are considered as CO_2 neutral, 0,009g NOx/kg

According to all mass and energy balances for Pogačnikov Dom calculation was done according to methodology described above for different fuels (diesel, gasoline and biomass) and phases of the hut life cycle.

RESULTS AND DISCUSSION

The observed hut in this analysis relies on fossil fuels as main energy source for electricity and heat generation. The case study presented here is performed for Pogačnikov Dom in Slovenia with 3233 kWh of electricity and 36166 kWh of heat consumption per year (from mid-June to mid-September). Electricity is generated from PV system, diesel and gasoline generators and heat from firewood. Operation of the hut requires transportation of food, energy carriers, staff and in some cases also water to the hut. In the case of Pogačnikov Dom cargo ropeway driven by diesel engine is used for transportation and the consumption is 420 kg of diesel per year. The transportation with the van is also included and it is in average 1920km per year (15l of diesel per 100km). All mass and energy balances are presented in Figure 5 below as LCA model for Pogačnikov Dom before implementation actions (current status).

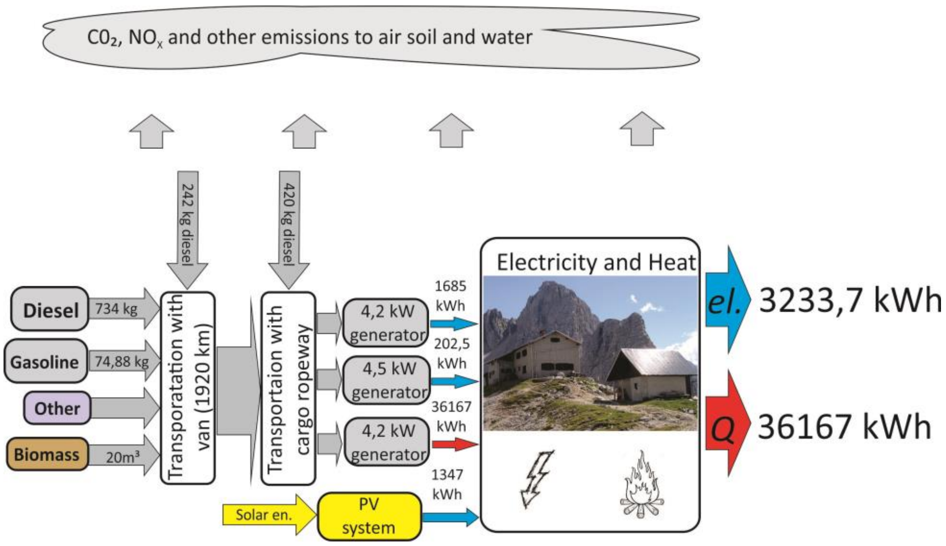

Figure 5. LCA model with mass and energy balances for Pogačnikov Dom before actions

According to current status and used fuels for 1 season (3,5months) hut emits during operation with included transport 4678 kg of CO_2 and 65,9 kg of NO_x per year. The main contributors to the environmental impact are diesel generator and cargo ropeway. Gasoline generator has small environmental impact because of lower consumption of the fuel and less operational time. Emissions caused by transportation are 2118 kg of CO_2 which represents 45,3 % of all emitted emissions in this study, the rest belongs to operation due to electricity generation (54,7 %). Similar ratios are for NO_x emissions where the highest value comes from diesel generator and cargo ropeway. Heat generation contribute 15,8 % to NO_x emissions, transportation 38,4% and electricity generation 45,8%.
From these results we can conclude that the highest environmental impact for CO_2 and NO_x emissions for Pogačnikov Dom comes from electricity generation and transportation. Calculation of emissions after the implementation action, installation of additional 5.5 kW PV panels, removing diesel and gasoline generator and optimizing the transport, shows high reduction of CO_2 and NO_x emissions in Figure 6 and 7 respectively.

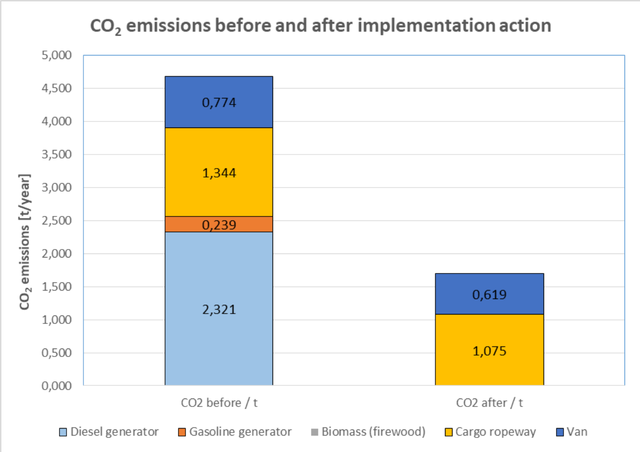

Figure 6. CO_2 emissions emitted during one season of operation for Pogačnikov Dom

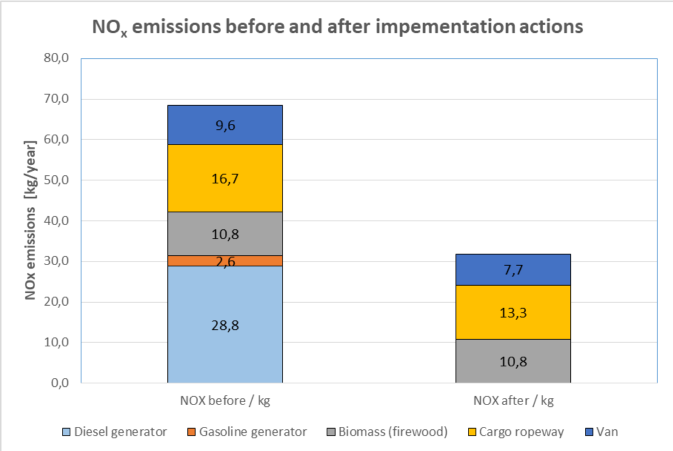

Figure 7. NO_x emissions emitted during one season of operation for Pogačnikov Dom

From this assessment of the emissions the results show just below 3 t of CO_2 emissions reduction which represents 64% and reduction of NO_x for 36,6 kg or 54% of all emissions for operation phase of 3.5 months (one season operation). With the investment that is planned for Pogačnikov Dom, additional PV installed and fossil fuel driven generators will be put out of operation, a great reduction of emissions is expected.
Due to the goal to achieved almost zero greenhouse gas (GHG) emission mountain hut the analysis for global warming potential (GWP, kg CO_2/eq.) was analysed for 1kWh of generated electricity and heat for different fuel sources for entire life cycle.

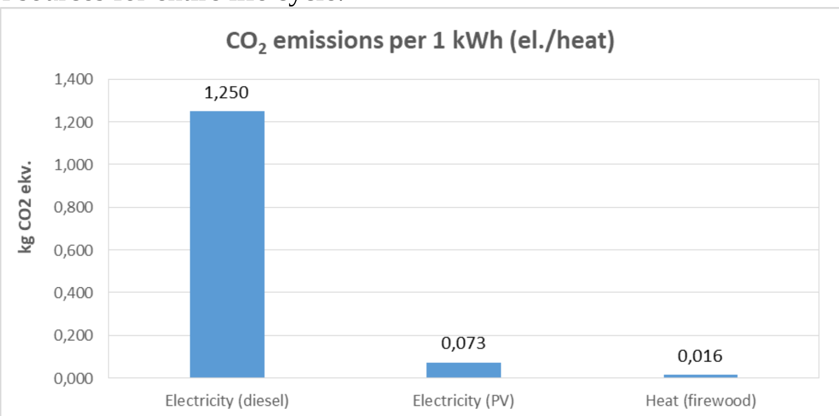

Figure 8. GWP (CO_2 eq.) for produced 1kWh of electricity (PV, Diesel generator) and heat (firewood)

Results show that replacement of fossil fuels with renewable energy technologies for heat and electricity generation is sensible but they also have some environmental impact during the whole life cycle. The impact of RES are almost negligible compared with fossil fuels but it's questionable if we could achieved 100% zero free emission mountain hut (considering different environmental impact indicators) in the whole life cycle.

CONCLUSION

It the case of mountain huts operation big improvements is possible in terms of emissions reduction (CO_2, NO_x) because all huts currently generate electricity/heat from fossil fuels. This reduction is of great importance since mountain huts are located mainly in very sensitive parts of nature. For the study case of Pogačnikov Dom is located in Natura 2000 protected region. Results show that the main impact comes from electricity generation, due to the high use of fossil fuels. It is shown that with basic investments, some optimization procedures of the transport and with additional education of the staff working in the hut, reductions higher than 50 % in CO_2 and NO_x are possible.

ACKNOWLEDGMENT

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BUILDINGS FROM RECYCLABLE MATERIALS

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Abstract: Waste prevention and the use of waste as a resource is becoming increasingly important for shaping not only environmental policy but also industrial and raw materials policy. Rapid industrial development and disregard toward the environment have led to the generation of excessive amounts of waste, which in turn has become one of the biggest issues of our time. Recycling is the much needed solution for the lack of space for storing waste on the one hand and the limited natural resources on the other hand. Over the past decade, many new recycling procedures for all types of materials have been developed, while waste management has become a growing concern worldwide. Recyclable materials such as plastics, glass, metal, and rubber can be used in the construction of buildings of various purposes. This paper presents several examples of the use of said recyclables as building materials.
Key words: recycling, construction, glass, plastic packaging, rubber

INTRODUCTION

Recycling is the process of converting waste materials into new materials and objects. It is an alternative to "conventional" waste disposal that can save material and help reduce greenhouse gas emissions. Recycling can prevent the waste of potentially useful materials and reduce the consumption of fresh raw materials, thereby reducing energy usage, air pollution (from incineration), and water pollution (from landfilling). Recyclable materials include many kinds of glass, paper, cardboard, metal, plastic, tires, textiles, and electronics.
Large amounts of waste generated daily are a major environmental issue for both urban and rural areas. According to an EEA (*European Environment Agency*) study, municipal waste consists of 35% paper, 25% organic materials, 11% plastics, 6% glass, 2% textile, 2% iron, and 1% aluminium.
Plastics are inexpensive, lightweight, and durable materials, which can readily be moulded into a variety of products that find use in a wide range of applications. As a consequence, the production of plastics has considerably increased over the last 70 years. Current levels of their usage and disposal generate several environmental problems. Around 4 % of world oil and gas production, a non-renewable resource, is used as feedstock for plastics and a further 3–4% is expended to provide energy for their manufacture. A major portion of plastic produced each year is used to make disposable items of packaging or other short-lived products that are discarded within a year of manufacture. In addition, because of the durability of the polymers involved, substantial quantities of discarded end-of-life plastics are accumulating as debris in landfills and in natural habitats worldwide.
Recycling is one of the most important actions currently available to reduce these impacts and it represents one of the most dynamic areas in the plastics industry today. Recycling provides opportunities to reduce oil usage, carbon dioxide emissions, and the quantities of waste requiring disposal.
While plastics have been recycled since the 1970s, the quantities that are recycled vary geographically, according to plastic type and application. Recycling of packaging materials has seen rapid expansion over the last decades in a number of countries. Advances in technologies and systems for the collection, sorting, and reprocessing of recyclable plastics are creating new opportunities for recycling; therefore, it may be possible to divert the majority of plastic waste from landfills to recycling.
One of the ways to reuse plastic bottles is their use as building materials for the construction of residential buildings.
Polymers, including synthetic rubber, comprise about 10% of total waste, and their recycling is important for several reasons. One is that polymers are low-density and high-viscosity materials, so

polymer-based products occupy large spaces in landfills; for instance, 1 tonne of car tyres occupies about $6m^3$.
Car tyre manufacture has been on the rise throughout the world over the last several years, with an annual increase of 6.7% between 2004 and 2008 [5]. In 2004 and 2005 almost 1 million tonnes of car and truck tyres were recycled in Europe. From 1992 to 2005, tyre recycling saw a stable increase – in 1992 62% of tyres were deposited in landfills and only 5% recycled, whereas in 2005 62% were recycled or used to generate energy. In the same period, the amount of generated waste from tyres also increased, from 2 million tonnes in 12 countries, to 3.1 million tonnes in 25 countries. Today, only 12% of whole tyres go through minimal processing, such as baling, removal of wires and sidewalls, or simple cutting, whereas c. 76% of tyres collected for recycling are processed into three categories of material: shreds, granulate, and powder [5].
End-of-life tyres (ELTs) constitute a specific type of waste. Large amounts of ELTs are either stored or deposited in landfills. ELTs are often uncontrollably disposed of in the environment, thus exposing it to potential wildfire risk. They can be processed, recycled, and used as an important alternative material in the manufacture of certain rubber products or in energy production. There are different methods of recycling and processing ELTs, the most common of which are crushing and pyrolysis.
ELTs are non-toxic non-biodegradable, and their shape, weight, and elasticity make them suitable for a variety of products, either as granulate or powder. Extensive research has made available numerous new products that incorporate recycled tyres.
In construction, recycled ELTs are being used as aggregate in concrete and additions to asphalts used in roads. Since concrete with added rubber granulates (crumb rubber) is an excellent noise and vibration absorber and has lower sensitivity to temperature change, recycled tyres are also used in roof insulation, construction noise barriers, waterproof membranes, porous bitumen binders, rubber piping, turfs for sports or children’s playgrounds, pavements, gardens, areas around swimming pools, etc. Whole ELTs filled with earth are being used to build walls of residential buildings.
If recycled glass is used to make new bottles and jars, the energy needed in the furnace is greatly reduced. Every 1,000 kg of waste glass recycled into new items saves 315 kg of carbon dioxide from being released into the atmosphere during the creation of new glass. For every tonne of recycled glass used, 1.2 tonnes of raw materials are preserved.
The use of recycled glass as aggregate in concrete has become popular in modern times. This greatly enhances the aesthetic appeal of the concrete. Recent research findings have shown that concrete made with recycled glass aggregates exhibits better long term strength and better thermal insulation due to the thermal properties of the glass aggregates [4].
Glass aggregate, a mix of colours crushed to a small size, is substituted for pea gravel or crushed rock in many construction projects.
Recycled glass has the following applications: glassware manufacture, glassphalt (asphalt with added crushed glass used for asphalt paving), manufacture of construction materials (glass bricks and elements, insulation foams and panels, etc.), reflective road marking colours, glass wool, moisture drainage for landscaping, decorative sand in restaurants, glass fibres, abrasives, etc.

A HOUSE BUILT ENTIRELY FROM RECYCLED MATERIALS – DENMARK

Architecture studio *Lendager Arkitekter* **from Denmark designed a house completely built from recycled materials. The house has an area of 130m²** and is located in the Danish city of Nyborg**.**

Figure 1. House built out of recycled materials,
Architecture Studio *Lendager Arkitekter*, Denmark

The loadbearing structure of the house comprises two prefabricated shipping containers with insulated exteriors. The roof and the façade are built out of aluminium soda cans. Façade panels contain pressed and heat-treated granulated paper. The kitchen floor consists of used bottle corks, while the bath tiles are made from recycled glass. Walls and floors are covered with OSB-panels containing pressed wood-chips. House design is based on the principle of passive solar architecture in terms of house orientation, temperature zoning, natural lighting optimization, shading, and natural ventilation. The built was built exclusively from recycled materials. The end result of this project was a house with a modern design, which looks as if it were built out of more expensive materials.

A PLASTIC BOTTLE HOUSE – BOLIVIA

Ingrid Vaca Diez from Bolivia built a house out of plastic bottles. The walls are made of discarded bottles filled with mud and sand. Ingrid thought that such construction could solve both the homelessness and the recycling problems in Bolivia. So far, Ingrid's houses became home to several families who had previously been left homeless.

Figure 2. Plastic bottle house in Bolivia

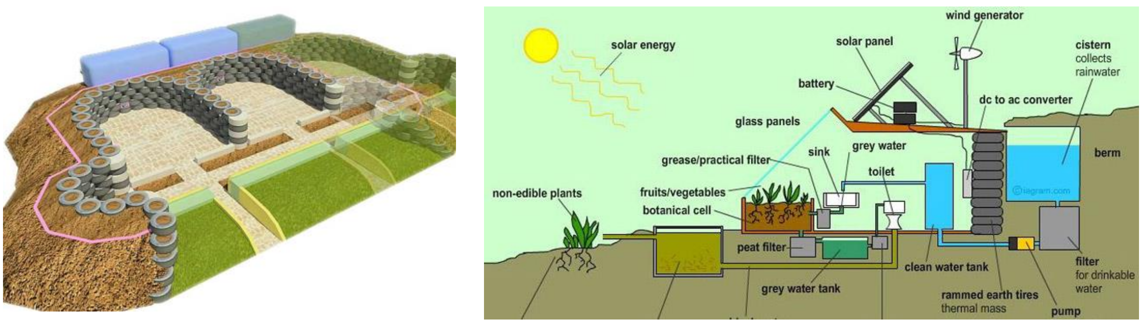
A BUDDHIST TEMPLE MADE OUT OF BEER BOTTLES – THAILAND

Beer bottles have become a primary material in green building. In addition to being cheap and easy to build with, they also provide the building with natural lighting and good insulation. One of the best examples of beer bottle buildings is a Buddhist temple in Thailand. Its construction required around 1.5 million brown and green beer bottles. The bottles were used to build an entire complex of 20 buildings, including the temple, bungalows for monks, bathrooms, and a crematorium, with various beer bottle decorations throughout.

Figure 3. Beer bottle Buddhist temple

PASSIVE SOLAR HOUSE WITH WALLS MADE OF TYRES

Earthship is a passive solar house with earth-rammed tyres used as walls. It is a special type of eco-construction using natural, discarded, and recycled materials. Earthship buildings are autonomous. Earth-packed tyres are used as loadbearing walls as they provide excellent thermal insulation. They are simultaneously the thermal mass of the building. Partition walls are made out of glass and plastic bottles bound with concrete. Through exclusive use of natural and waste materials from the surrounding, such houses significantly reduce negative environmental impact.
The houses are built so as to utilize local resources, especially solar power. The southern façade contains glass panels and faces the Sun, which provides natural lighting and thermal energy for heating. The southern facade is mostly used as a greenhouse where fruits and vegetables are grown. Earthship houses are usually built in the shape of a horseshoe in order to take full advantage of the natural lighting and insolation during winter months. They are designed in such a way as to maintain an indoor temperature of 22°C. Electricity is generated by solar panels and wind generators.



a) b)

c)

Figure 4. Earthship house; a) foundation; b) cross-section; c) outside appearance

CAR TYRE HOUSE IN BRUSNICA, SERBIA

An example of a car tyre house built according to the Earthship method can also be found in Serbia, in the village of Brusnica, 3 km from Gornji Milanovac. In addition to car tyres, about 300 of them, the house also consists of glass bottles, aluminium cans, earth mortar, straw, wood, concrete, and bricks. The tyre wall, which is 25 m long and 2 m tall, took one month to build. Old glass will be used to build the greenhouse. This Earthship house has a green roof and a composting toilet, i.e. a toilet bowl without a flushing system and without a cesspit. All household waste water is purified naturally.

Figure 5. Car tyre house in the village of Brusnica near Gornji Milanovac

CONCLUSION

Recycling has the following results:
- conservation of raw material resources
- conservation of energy
- environmental protection
- provision of new jobs.

There are many materials that can be recycled: paper, cardboard, plastic, glass, aluminium, copper, iron, ceramics, tyres, electronics, etc. This paper presented the possibilities for using recyclable materials in construction. The materials can be used to build loadbearing or partition walls, façades, floors, and other elements.

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Session 8.

Occupational Safety

PREVENTION OF CHEMICAL ACCIDENTS IN THE LEGISLATION OF THE REPUBLIC OF SERBIA

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Abstract: This work represents a review of legal prevention of chemical accidents in the legislation of the Republic of Serbia. The Republic of Serbia is in the process of legal approximation with the EU. The Law on Environmental Protection, with amendments from 2009, contains recommendations from Seveso-II (Directive 96/82/EC). However, only the subordinate legislation will enable complete implementation of Seveso-II (Directive 96/82/EC) which enables prevention, preparedness and quick response to a chemical accident. The historical legal approach and the normative legal approach were used in this paper. The authors conclude that it is necessary to continue the approximation of legal precepts in this area with the Seveso-Directives, considering that they have been a role model for legislation in many countries worldwide.

Keywords: chemical accident, European Union law, legal protection, Serbia.

INTRODUCTION

Major accidents involving dangerous chemicals pose a significant threat to humans and the environment. "Chemical incidents involving the release of substances hazardous to human health may carry the risk of serious adverse health and economic effects due to its nature and frequently unpredictable consequences."[1] However, the use of large amounts of dangerous chemicals is unavoidable in some industry sectors which are vital for a modern industrialised society [2]. In particular, environmental accidents can have implications for human health (e.g., drinking water contamination), economic well-being (fish kills and contamination of fish habitat) and social well-being (e.g. contamination of recreation areas such as beaches, recreational fishing grounds, and rivers along community parks) [3]. To minimise the associated risks, measures are necessary to prevent major accidents and to ensure appropriate preparedness and response should such accidents nevertheless happen [2]. *Major accident* is also defined as an "unexpected, sudden occurrence including, in particular, a major emission, fire or explosion, resulting from abnormal developments in the course of an industrial activity, leading to a serious danger to workers, the public or the environment, be it in immediate or delayed, inside or outside the installation and involving one or more hazardous substances" [4]. At many stages during the production, transportation, storage and use of many of these chemicals there is a risk that accidents will occur, both the possibility of occurrence and the severity of possible accidents depending on the chemicals concerned. [5].
In Europe, the catastrophic accident in the Italian town of Seveso in 1976 prompted the adoption of legislation on the prevention and control of such accidents. The so-called Seveso-Directive (Directive 82/501/EEC) [6] was later amended in view of the lessons learned from later accidents such as Bhopal, Toulouse or Enschede resulting into Seveso-II (Directive 96/82/EC) [7]. Council Directive 96/82/EC1 on the control of major-accident hazards involving dangerous substances, the so-called Seveso II Directive, aims at the prevention of major-accident hazards involving dangerous substances and at the limitation of the consequences of such accidents for man and the environment [8]. In 2012 Seveso-III (Directive 2012/18/EU) was adopted taking into account, amongst others, the changes in the Union legislation on the classification of chemicals and increased rights for citizens to access information and justice [9]. The Seveso experience illustrates many different types of uncertainty that are mobilized by industrial disasters and suggests a new interpretive model [10].
This Directive applies to more than 12,000 industrial establishments in the European Union where dangerous substances are used or stored in large quantities, mainly in the chemical and petrochemical industry, as well as in fuel whole sale and storage sectors [11]. Considering the very high rate of industrialisation in the European Union the Seveso Directive has contributed to achieving a low

frequency of major accidents. The Directive is widely considered as a benchmark for industrial accident policy and has been a role model for legislation in many countries worldwide [3].
In the Republic of Serbia, there is an ongoing process of harmonization with EU regulations. In last few years the Republic of Serbia has rendered several laws with which it took over or established the legal basis for taking over the standards of the quality of environmental from EU directives. In that way, legal norms compatible with European norms were adopted and their objects, standards and requirements can be applied directly or applied through envisaged procedure of decision rendering in connection with plans, programs and projects which may have a significant influence on the environment and through the procedure of issuing integrated licenses, which have ensured *modus operandi* in compliance with European [12].

LEGAL FRAMEWORK OF PROTECTION FROM CHEMICAL ACCIDENTS IN THE REPUBLIC OF SERBIA

The Law on amendments to the Law on Environmental Protection (hereinafter: LEP) [13], passed by the National Assembly of Serbia in May 2009, contains recommendations from Seveso-II (Directive 96/82/EC). The *Seveso installation* was defined as an installation for activities that involve and can involve dangerous substances in quantities equal to or in excess of the quantities allowed. Also, the Directive defines the duties of the Seveso installation operator, who must deliver a *Notification* and draw up a *Major Accident Prevention Policy (MAPP)*, or a *Safety Report* and an *Emergency Plan.*
The Ministry of Environmental Protection of the Republic of Serbia has identified the installations that submit to the requirements from Seveso-II (Directive 96/82/EC) and published a Preliminary List of Installations (14 May 2009). Subordinate legislation will enable complete implementation of this directive that enables prevention, preparedness and quick response to a chemical accident.

Protection from Chemical Accidents

The operator of the Seveso installation, or establishment for activities that involve or can involve one or more dangerous substances, in quantities equal to or in excess of the quantities allowed, shall deliver a Notification, that is, draw up a *MAPP* or a *Safety Report* and *an Emergency Plan*, depending on the quantity of dangerous substances which are used during the activities, and take measures to prevent chemical accidents and limit their consequences for man and the environment. The Minister draws up a list of dangerous substances and their quantities, and criteria for determining the type of document that the operator draws up.
The accident risk is estimated based on the likelihood of accident occurrence and possible consequences.
The chemical accident risk can be: trivial, minor, moderate, substantial, and priority, according to the criteria shown in the following table:

Table 1. Risk criteria based on the likelihood of accident occurrence and possible consequences [9]

	C o n s e q u e n c e				
Likelihood of occurrence	minor	appreciable	severe	very severe	catastrophic
small	trivial risk	minor risk	moderate risk	substantial risk	priority risk*
medium	minor risk	moderate risk	substantial risk	priority risk*	priority risk*
high	moderate risk	substantial risk	priority risk*	priority risk*	priority risk*

* unacceptable risk

The risk is acceptable if it has been estimated as: trivial risk, minor risk, moderate risk and substantial risk.
The risk is unacceptable if it has been estimated as priority risk.

A *MAPP* consists of the goals and operating principles of the operator, in order to control chemical accident hazards. The MAPP must contain enough elements which are proportionate to accident hazards. Based on these elements, the operator can guarantee a high level of prevention of chemical accidents to the man and the environment. The operator is required to draw up a MAPP no later than six months after the Notification has been delivered. The Minister prescribes the content of the MAPP in greater detail.

The operator who is required to draw up the MAPP shall, before drawing up the MAPP, deliver to the Ministry a Notification about:

- the new Seveso installation or establishment, at least three months prior to the start of operation;
- the existing Seveso installation or establishment, no later than six months after the date of entry into force of this legislation;
- the existing Seveso installation or establishment, that carried out activities during which dangerous substances were involved in quantities lower than the quantities allowed in case quantities of dangerous substances increased and reached the allowed quantities, no later than three months from the date of the change;
- permanent shutdown of the Seveso installation or establishment, or modification of the Seveso installation or establishment, or any change that can affect the likelihood of chemical accident occurrence.

  The Minister prescribes the content of the Notification.

The Safety Report and the Accident Protection Plan are drawn up by the *operator*. A different legal person or company can be hired to draw up the documents, provided that they are listed in the relevant register for design, engineering, studies and analyses. In case a different legal person or company is hired, the drawing up of documents must involve a person who is a permanent employee of the operator.

The operator shall exchange information and adjust the Emergency Plan to the Emergency Plan that is drawn up by the competent authorities of the local self-government, Autonomous Province and Republic of Serbia. The Minister prescribes the content and methodology of the Safety Report and the Emergency Plan in greater detail.

The operator shall also draw up and deliver to the Ministry a *Safety Report* and an *Emergency Plan*:

- for a new Seveso installation or establishment, at least three months prior to the start of operation;
- for the existing Seveso installation or establishment, no later than eighteen months from the date of entry into force of this legislation;
- for the existing Seveso installation or establishment that carried out activities during which dangerous substances were involved in quantities lower than the quantities allowed in case quantities of dangerous substances increased and reached the allowed quantities, no later than six months from the day of the change.

The operator submits a request for consent to the Safety Report and Emergency Plan, along with those documents.

The operator shall periodically review and update the Safety Report where necessary:

1) at least every five years;
2) at any other time at the initiative of the operator or the request of the Ministry, where justified by new facts arising from analysis of other chemical accidents or near misses.

In the event of the modification of the process, or the nature or quantity of dangerous substances, or other changes which could have significant repercussions on chemical accident hazards, the operator shall immediately revise the Safety Report and the Emergency Plan and deliver them to the Ministry, and if the changes are related to modification of the installation or establishment, this shall be done before the modification is implemented.

The operator shall review, test, and where necessary update the Safety Report at least every three years.

The operator shall ensure that information on safety measures and on the requisite behaviour in the event of a chemical accident from the Emergency Plan is supplied to all legal persons and all establishments serving the public (schools, hospitals, etc.), as well as natural persons liable to be affected by the consequences of a chemical accident. The information shall be updated every three years. The updated information must be accessible to the public. The maximum period between the repetitions of the information to the public shall be no longer than five years.
The operator shall ensure that the Safety Report and the list of dangerous substances that are present in the Seveso installation or establishment are available to the *public*. The competent authority shall ensure the public inquiry, organise a presentation and conduct a public discussion about the Safety Report in the process of deciding on consent to the Safety Report. The public discussion can be held no sooner than twenty days from the date of public notice. The applicant of the Safety Report participates in the presentation and the public discussion.
In the *Safety Report* the operator shall demonstrate that:

1) an adequate policy and a safety management system for implementing it have been put into effect;
2) chemical accident hazards have been identified and the necessary measures have been taken to prevent such accidents and to limit their consequences for man and the environment;
3) adequate safety and reliability have been incorporated into the design, construction, operation and maintenance of any installation, storage facility, equipment and infrastructure which are linked to accident hazards;
4) any justified objections and suggestions from the public have been accepted and incorporated into the Safety Report.

In the *Emergency Plan* the operator shall demonstrate that:

1) all necessary measures for containing and controlling chemical accidents so as to minimize the consequences of the accident for man, the environment and property have been foreseen and taken;
2) the ways of communicating the necessary information to the competent authorities and to the public have been foreseen and implemented;
3) necessary measures for the clean-up, restoration and recultivation of the environment following a chemical accident have been foreseen;
4) enough data for drawing up the emergency plans at the level of the Republic of Serbia, the Autonomous Province, or local self-government unit, has been processed (hereinafter: external plans).

The Ministry gives consent to the Safety Report and the Emergency Plan after the demands have been met. The Ministry can ask for revisions and amendments of the documents if they ascertain that they do not contain the necessary data.
In the event that conditions for consent to the documents have not been met, the Minister issues a decision which forbids the operation or the start of operation of the Seveso installation, establishment or part of the installation, and the establishment and storage facility. An appeal can be filed against the decision. The appeal does not delay the implementation of the decision. The Government decides on the appeal against the first-instance decision.
In order to evaluate the Safety Report and Emergency Plan, the Minister, in accordance with the regulations which govern the public administration, can decide to name a special task force – a *technical committee*. The technical committee delivers their opinion on whether the demands have been met to the Ministry without delay.
Based on the Safety Report and the Notification, the Ministry ascertains and compiles a *registry of* the operators and Seveso installations or establishments with increased likelihood of chemical accident occurrence or increased consequences of that occurrence due to their location, proximity to similar installations or the type of the stored dangerous substances.
The operators shall exchange information necessary for drawing up the Safety Report and Emergency Plan, in order to mind the nature and range of mutual chemical accident hazards.
Based on the *Safety Report* and the Notification, the Ministry compiles the *registry* of the installations, as well as the registry of reported accidents.

In the event of a *chemical accident*, the operator shall immediately notify the Ministry, the local self-government unit and the competent authorities concerned in the area of emergency conduct, in accordance with the regulations that govern protection and aid, of:

- the circumstances of the accident,
- the dangerous substances involved, the data available for assessing the effects of the accident on man and the environment and the emergency measures taken.

The operator shall as soon as practicable inform the competent authorities of the steps envisaged to alleviate the medium- and long-term effects of the accident and to prevent any recurrence of such an accident. The operator shall ensure that any urgent, medium- and long-term measures to eliminate the consequences of the chemical accident are taken, as well as, after conducted analysis of all aspects of the chemical accident, recommend future preventive measures. The Ministry shall supervise and control the implementation of the operator's duties.
State authorities, authorities related to the Autonomous Province and local self-government units, based on the jurisdiction from the regulations of protection and aid, draws up external plans, which are an integral part of emergency response plans.
Based on the Safety Report, the Ministry ascertains the operators and Seveso installations or establishments that are concerned with activities which can cause a chemical accident capable of transboundary effects, and notifies the competent authorities in the country that can be affected by the consequences of that accident as soon as possible, and no later than notifying the domestic public. The Ministry notifies the competent authorities of the other country of all important facts from the Safety Report on the Seveso installation or establishment concerned with activities which can cause a chemical accident capable of transboundary effects, as well as of all important facts from the Emergency Plan of that installation or establishment.
The provisions of the LEP shall not apply to the following:

- military installations;
- accidents created by ionising radiation;
- the transport of dangerous substances by road, rail, internal waterways, sea or air, i.e. transport outside the establishments covered by this law, including loading and unloading and transport to and from another means of transport at docks, wharves or marshalling yards;
- the transport of dangerous substances in pipelines, including pumping stations, outside Seveso installations or establishments covered by this law;
- accidents during the exploration or exploitation of minerals, unless the minerals are chemically and thermically processed or stored, if they contain dangerous substances within their allowed quantities;
- waste land-fill sites, with the exception of operational tailings disposal facilities including artificial lakes, dikes and dams, containing dangerous substances, in particular when originating in the chemical and thermal processing of minerals.

In the event of an accident, depending on its scope, within or without the installation, and the estimates of the consequences that can cause direct or delayed danger to human health and the environment, a *state of environmental endangerment* is declared, and *the public is notified* of the measures taken. The state of environmental endangerment is declared by the Ministry, or the competent authorities of the Autonomous Province, or the local self-government unit authorities. As for accidents with transboundary effects, the state of environmental endangerment is declared by the Government.
In order to prevent the further spreading of the pollution caused by the accident, the legal and natural person shall immediately take measures of restoration according to the Emergency Plans, at their own expense. If the polluter responsible for the accident is subsequently identified, the authorities that bore the expenses of removal of pollution consequences demand reimbursement.

CONCLUSION

The Republic of Serbia is in the process of legal approximation with the EU. The harmonization of regulations in the area of environmental protection in our country with the regulations of EU entails the adoption and implementation of European and worldwide standards.
The LEP from 2009 along with its amendments contains the recommendations from Seveso-II (Directive 96/82/EC). The *Seveso installation* was defined as an installation for activities that involve and can involve dangerous substances in quantities equal to or in excess of the quantities allowed. Also, the Directive defines the duties of the Seveso installation operator, who must deliver a *Notification* and draw up a *MAPP* or a *Safety Report* and an *Emergency Plan.* Subordinate legislation will enable complete implementation of this directive that enables prevention, preparedness and quick response to a chemical accident. That is why, within the framework of the Negotiating Chapter 27 in our country, further synchronization with the EU policies related to chemical accident protection is necessary.
In the field of environmental protection, the Republic of Serbia has until now achieved the most when it comes to approximation of its regulations with European regulations, however, maximum engagement is necessary from all subjects when it comes to regulation implementation, from the Republic and Autonomous Province to local self-governments, non-governmental organisations, and others.

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Students Session

IMPROVING THE PALLETIZATION PROCESS IN INDUSTRY BY USING THE FANUC ROBOT

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Abstract: The application of robots in the nowadays is been determined primarily by technical and economic aspects of production. The market has growing requirements and increasingly stringent quality standards that companies need to achieve in order to be competitive in the market. Advanced technologies brings to companies increased productivity, increasing the level of uniformity of quality, higher level of security and many other advantages which actually helps companies to be competitive in the market and gain a competitive edge. The introduction of robots in the production directly satisfy market requirements and achieves a complete modernization of the production chain respectively industry in which that system is introduced, which includes the highest quality standards.
Key words: robot, safety, economic aspects.

INTRODUCTION

At the present time we are faced with the fast development of science as well as with the fast development of technology. The phase in which we are now has its name and it is named the phase of revolutionary changes. At this stage is dominated by automated systems which are in an essential meaning actually the robotic systems. Such rapid development of technology creates the industry's growing need for such systems. As a continuation of the improvement of technical solutions in the field of automation of technological processes in various industries is based on the introduction of robots. The aim of introducing these solutions is for upgrading and improvement of production processes. [1]
The application of robots is primarily determined by technical as well as economic aspects of production. The key and most important reasons for the introduction of the robot are: [2]

- increasing the quality of finished products;
- reduction of bad production of products;
- increasing the degree of uniformity - constancy of the quality (in all the processes which are connected with a repeatability of robot action);
- increasing the level of security of the work as a whole;
- reducing the necessary manpower for routine repeatable process;
- reducing the cost of production and maintenance as a whole;
- meeting the requirements imposed by competition and stringent quality standards.

In addition to the technical advantages of introducing and using robots, it is necessary to emphasize the rational side of the introduction of robots into specific industrial drives, which are primarily due to the volume of production and the nature of the operations that the robot (or more robots) should implement.
These advantages are mostly relate to serial production processes where there is a large number of repetitions of the same operation or series of operations. And in those cases, the advantages of introducing robots are almost obvious. [2] The type of industry in which such a robot is introduced plays a big role, because of the humanization of labor. If in a particular industry the workforce carries out very heavy and physically demanding jobs, the need for robots is more than necessary. Robots are effective tools that can completely replace a man in performing tough and single jobs and thus free him from harder and easier efforts. Some of the industries also have hazardous working environments of toxicological character, which can have major consequences on human health and in this case it is necessary to introduce a robot and thus protect man from the impact of the toxic environment.

The most commonly used robots and robotic lines in the industry are those related to packaging or palletizing operations. These are, in principle, also operations in which are the same operation is repeated continuously, so they are also suitable for the introduction of robots. [4]

METHODS OF IMPLEMENTING ROBOT IN INDUSTRY

The decision to introduce robots into production should first be re-examined. Economic reasons are certainly the primary ones for the introduction of robots or robotic lines, because that is the meaning of the share of automation in the development of productive forces. The purpose is to lead to the decreasing of production costs using such systems. Accordingly, the basic question posed before the introduction of robots into industrial processes, regardless of the complexity of the given system and the nature of the system itself, is the profitability of such a step. It is most important to determine the main reason for introducing such a system. When you feel the need for introducing a robot into a particular production process, it's important to look at some important aspects, such as: [2,5]

- Determining key points in the technological process where robot should be introduced;
- Determining the required technical characteristics of the robot based on the requirements imposed from the production;
- Precise defining of technological requirements and operations that the robot should perform;
- Defining the changes to be made in the technology of work and equipment in the existing plant.

However, when designing each production line which would have robots in its composition it is necessary to perform individual and selective considerations, such as[4,8]:

- Assessment of the needfor the introduction of robots in technical, technological and economic terms;
- Determining the key points in the technological process where the robots should be introduced in;
- Determining the required technical characteristics of the robot based on the requirements imposed by the production.

FANUC – ROBOT FOR PALLETIZATION

The robot of the company Fanuc type M410iC / 185 is the world's first designed robot specifically for palletizing. This series improves and increases the performance of application handling and improves the palletization process. It is suitable for all types of industries in which it is necessary to achieve high capacity of packaging. This robot belongs to a group of flexible robots because it is adapted for the particular type of packaging or palletization based on the gripper that is placed on it. In addition, using this robot in industries that produce products which are packaging in high-weight formats also leads to the humanization of work. Soon due to the entry into force of the law on the humanization of labor, any company that, within the scope of its production implies packaging or palletization of heavy goods which is performed by a man, must possess one robot like FANUC [3].

This four-axis model present the system of high speed palletizing, assembly, processing and transmission of parts. The maximum load capacity of the robot is 185 kilograms. This type of robot can very easily handle large fluids and heavy loads at maximum speed thanks to high permitted joint movements and inertia. The narrow arm and wrist allow the robot to access and maneuver even in a limited work space. Regarding the servo drive with this device is available in the following format. A servo hand can be 100% integrated into the robot thanks to the hollow wrist, making for efficient, cost saving cable routing. Also, the 6-axis servo amplifier controls the servo hand as the 5th axis.In this way, the efficiency of the installation is achieved and it is obtained to save the costs for the cables that are not needed in this case. In Table 1 there are given the basic characteristics of the FANUC robot, type M410iC / 185. [3,4]

Table 1. Basic characteristics of robot FANUC type M410iC/185 [3,4]

Number of controlled axis		4	
Controller		R- 30iB	
Load capacity (kg)		185	
Repeatability (mm)		±0,5	
Mechanical weight (kg)		1600	
Max.reach (mm)		3143	
Motion range (°)	**J1**	360	
	J2	144	
	J3	136	
	J4	720	
	J5	-	
	J6	-	
Max. speed (°/s)	**J1**	140	
	J2	140	
	J3	140	
	J4	305	
	J5	-	
	J6	-	
Moment /inertia (Nm/kgm^2)	**J4**	88	
	J5	-	
	J6	-	
IP protection			For axis J1 and J2 is IP54 protection; and for axis J3, J4 is IP67.

In Table 2, the factory and standard characteristics that can be obtained with this robot and also some basic characteristics are shown. In addition, here are some of examples that are possible and available on the request of customers are presented.

FANUC, above all else, takes care of safety. The safety of the operator is the most critical component of the design of robotic cells. FANUC provides a variety of smart security solutions that keep minimal costs and, in addition, keep operators, robots and tools extremely secure. All the robots of this company and the M410iC / 185 have a DCS system which represents a smart and integrated system that keeps safe operators, as well as robots and tools [3,7].

Table 2. Characteristics of robot FANUC type M410iC/185[3]

Robot	**M-410*i*C/185**
Robot footprint [mm]	1094 x 945 (806 x 610)
Mounting position Floor	•
Mounting position Upside down	-
Mounting position Angle	-
Controller	**R30*i*B**
Open air cabinet	-
Mate cabinet	-
A-cabinet	•
B-cabinet	o
*i*Pendant Touch	•
Electrical connections	
Voltage 50/60Hz 3phase [V]	380-575
Voltage 50/60Hz 1phase [V]	-
Average power consumption [kW]	1
Integrated services	
Integrated signals on upper arm In/Out	8/8
Integrated air supply	1
Environment	
Acoustic noise level [dB]	75.3
Ambient temperature [° C]	0-45
Protection	
Body standard/optional	IP54
Wrist & J3 arm standard/optional	IP54

• standard o on request - not available ( ) with hardware and/or software option

CONCLUSION

By introducing robots into production, the production process improves in many ways. The robot improves the production and decrease the production and maintenance costs, also increases the quality of production and it is important to say that the payback period for invested funds for such technology is very fast.

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THE IMPORTANCE OF HUMAN RESOURCES IN THE FUNCTIONING OF TECHNICAL SYSTEMS IN AIMS OF RELIABILITY

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Abstract: The modern world of business requires constant improvement of all business processes in enterprises. In a continuous process, create innovative business ideas. Using different methods with new radical solutions, higher efficiency and productivity of business are achieved, and therefore profitability. In this way, it is possible to make greater and more efficient use of all necessary resources for doing business. Methods of applying the maintenance system in production processes are of great importance. The aim of the research is to measure the importance of human resources in business and their impact on the reliability of technical systems.
Key words: reliability, technical system, economy, maintenance, human resources, modern business processes, radical changes

INTRODUCTION

The modern world of business becomes more and more demanding than companies are expected to largely operate based on efficient and effective processes. In each organization, it is very important to ensure a high-quality system operation and thus enable the production system to function reliably. Each technological system requires in a single continuous process the application of the maintenance concept as well as control. Depending on the complexity of the organization, the maintenance system is more complex. The maintenance technology is applied in the company in different ways and with different degree of equipment. Maintenance procedures represent the activities and operations to be carried out in order to restore the system from the failed state to the operating state, or to prevent the sudden failure occurrence. Determining the state of the system is one of the key problems in the process of its maintenance. It is necessary to monitor the change in the state of individual parameters of the circuits and elements that lead to weakening over time, and if nothing is done to the malfunction or the interruption of work. It is also very important that in the event of a sudden malfunction, the cause is detected, what is the malfunction and how to remove it. work failures are reduced to a minimum. By applying regular control of production processes, the lifetime of machines in the technical sense can be extended, which implies a lifetime of its proper operation. In all branches of industry, control of the security system is of utmost importance, as well as the introduction of a concrete strategy. It is considered that every successful organization is working on the principle of applying the standard. With the application of leadership on all new things, one achieves a certain goal and in this way the company moves towards achieving success [1-4]. It is necessary to enable undisturbed operation of the entire drive infrastructure. Human resources are one of the key factors that significantly affect the reliability of machines in the industry.

CONCEPT OF MAINTENANCE OF TECHNICAL SYSTEMS WITH THE TARGET OF EFFICIENCY AND EFFICIENCY OF PRODUCTION

The future brings with it the application of new and innovative technologies in business. Production processes are becoming more and more demanding, which is why there is a need for constant maintenance and application of new methods of maintenance of technical systems. There are many ways to apply the maintenance concept. Most companies use combined maintenance of technical systems in their business. By implementing various activities related to maintenance of the technological system, a number of different results are desired. It is considered that the objectives are different for which the maintenance implementation system has been launched, although in each situation there is a common idea to form some sort of improvement. In most cases, the main goals are:

increasing the quality of finished products, increasing productivity, increasing the efficiency of business processes, increasing the employee's motivation, saving time, effective production, reducing the number of scrapes, applying adequate maintenance methods to increase the safety at the work of all employees. The suitability of the system refers to adapting to external conditions in order to minimize costs. One of the basic and very important tasks of implementing a maintenance system is to align the available resources of human resources, material resources, equipment, spare parts, and to solve the problem that arises during the operation of the system. In each organization, the manager is one of the key people. Each department requires adequate organization of production processes. Its main task is to direct and coordinate production processes in order to increase efficiency and effectiveness of production. Although it is possible to implement an uninterrupted maintenance system in some cases, it may happen that the technical system fails, regardless of the application of maintenance methods. Figure 1 gives a schematic diagram of the cause of the cancellation.

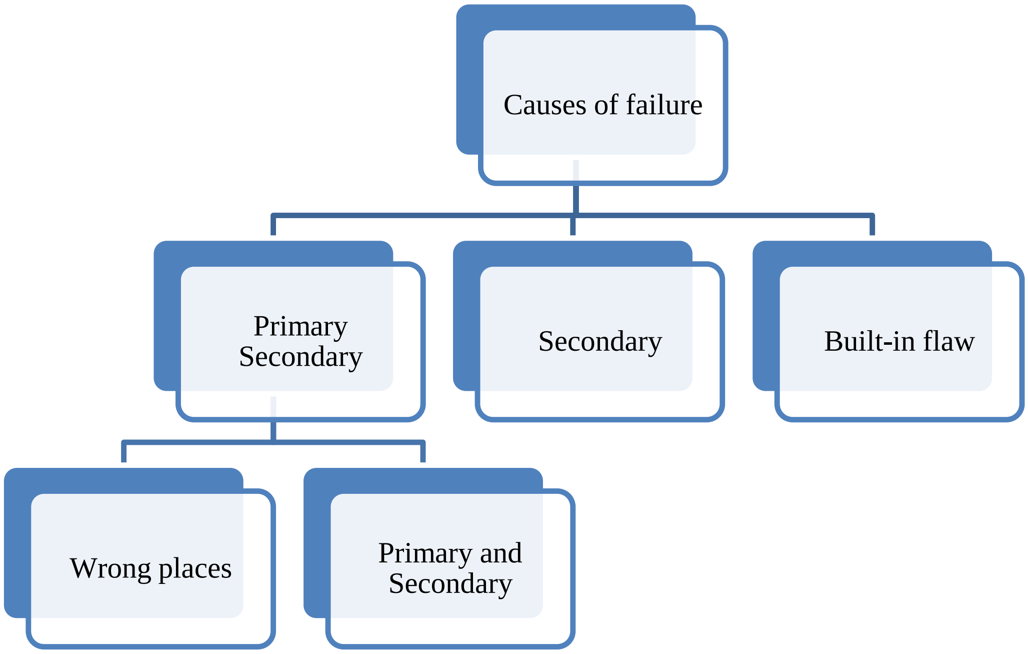

Figure 1. Causes of failure

TECHNICAL PREPARATION AND TECHNICAL DIAGNOSTICS IN PRODUCTION PROCESSES

When determining production preparation, it is necessary to apply the first planning dimension. Define a specific business plan and strategy whether it is specifically about short-term or long-term planning. Diagnostics are measuring instruments, pressure and temperature measurement, sound and visual. This drive works well because the number of downtime is minimal. The process of validation occurs in this drive. This is a procedure where it is proven that the machine works properly. Pre-requisite planning and preparation of spare parts based on stock situation and planned activities are planned for ordering and procurement. This is described in the procedure "Procurement, acceptance and commissioning of new equipment and spare parts", code 15 05 (Annex 1). Then the planning and preparation of small and consumable materials for small and consumable material must be delivered in writing to the warehouse department in writing about the minimum stock. Based on the situation in the warehouse and the planned activities, it is planned to order materials above the minimum supplies. Ordering the material is done in writing, on the order that is handed over to the independent procurement officer. During the procurement process, it must be contacted for any additional explanations, information on the delivery date, etc. Filled orders are stored in a three-to-five-year timeframe for the production reference officer. It is also very important to prepare equipment and conditions for carrying out preventive maintenance where it is necessary to pay attention to the safety of the maintenance workers and other potential participants in the interventions must be maximized, the work on the equipment must not affect the production process that may occur in the environment of this equipment, every type of pollution of the environment must be avoided, equipment must be provided before performing the work at the site of the intervention, all necessary energy connections necessary for their execution (electricity, compressed air and water ...), the greater part of the accessories or tools necessary for the intervention must be provided from unauthorized handling.

Technological development brings with it a constant need for constant improvement of quality. When it comes to improving the quality, we need to focus on improving all business processes in order to achieve business excellence. Quality management according to the concept of Juran, involves the dissemination of quality through the organization and is based on three key interrelated aspects: planning, control and improvement. Quality assurance as a continuous process, according to Deming, is achieved through certain phases: increasing quality, reducing costs, increasing productivity, conquering the market, securing jobs. Modern technologies with their tools provide support to 212 mentioned factors of successful business, appropriate integration and implementation into an integral information system. [3]. It is considered that the process in which organizations reacts quickly with drastic changes is one of the most effective in today's world of business. The reengineering of managerial processes implies radical changes in the goals, strategies and policies of the organization. It refers to the key changes in business architecture that must be aligned with changes in the environment and management's efforts to ensure that the organization provides its survival and development [4]

International governing standards published by ISO, such as ISO 9000, ISO 14000, ISO 18000, contain elements relating to social responsibility [6]. Many companies base their business on the application of standards. They introduce integrated management systems and send their employees to seminars on the revision of ISO standards 9000 and 14000, which was conducted in September 2015.

THE CHARACTER OF HUMAN RESOURCES FOR THE RELIABILITY OF TECHNICAL SYSTEMS

The role of management in business processes is of great importance for business. Adequate management ensures greater efficiency of business processes and consequently leads to higher profitability. The basis for carrying out maintenance and proper management is to have the necessary information that can be reached at a certain point and the disposal of useful knowledge. Information plays a very important role in business management. In order to carry out the work in a planned and accurate manner, it is necessary to dispose of certain information, and more importantly, it is necessary to know how to apply the information in the right way and at the right time. In the management of the business, information is exchanged where success can depend on the manner in which these knowledge is applied and on whether certain information is available at a particular point in a particular place to certain individuals. It is always necessary to be in the first place and at the right time. There are different factors that have stimulated the development of many activities and thus increase competitiveness and become the apolitical leader in the market. Modern business requires also the application of new and modern technologies for the application of information systems. The development of information technology has been used to support the deployment and control of stock, transport or warehouse design of various facilities, which greatly facilitates the execution of business processes. It is necessary that all key business resources of the company be implemented in the entire work system in order to achieve greater efficiency of the entire technical system. Every organization should be viewed as a network of interconnected processes. Adequate management of individual processes in the organization achieves a competitive advantage on the market. Any drastic change in business activities, norms, behaviors, employees and the business environment is of great importance for the business of one company. Reengineering has emerged as a response to the Japanese quality management concept that represents a programmatic approach to change in accordance with the amaric way of business thinking [7]. Domestic enterprises are of great importance for the country's economy. Increased exports of goods to foreign markets result in increased gross domestic product. The state operates profitable and, therefore, the company as a whole has been successfully and developed in all segments. The management phase represents the direction of resources in a particular direction in order to achieve the goal. It is necessary to know the potentials of all resources and direct them towards a common goal. In all processes, the last stage is to control until then arranged. At this stage, it comes to knowing whether the process is taking place in accordance with the plan and it is possible to spot the potential mistakes and shortcomings in the plan. The goal of the control is to correct the error in time and to make improvements as needed. The introduction of drastic changes in the organization of management requires the creation of a certain transition process. It is necessary to create adequate conditions for radical changes to be made. It is considered that it is necessary first of all to analyze whether the organization really needs to drastically redesign the business processes, then determine the plan for implementing the changes, set certain goals and start with the realization. Prior to the implementation of the change, management must undergo certain training and education in order to improve the business in the best way, and on the other hand in order to prepare its staff. Employees must be educated but also encouraged, create a positive climate for accepting new changes, involve employees in decision making. It is important that the leaders as well as the department managers in order to successfully redeem the rewards of each employee's success in the organization. When defining the necessary changes, management must set up a business strategy. It is necessary to set high goals for this is an ideal business strategy "Be the first and at the same time the best" in the domain of business. All business activities must be monitored and monitored, errors must be perceived in time, processes must change from root, but must start from the most basic ones. Leaders for business efficiency must constantly motivate their employees, create a positive business environment. Reliability has always been a significant aspect in the assessment of industrial products and / or equipment. Good product design is of course essential for products with high reliability. However, no matter how product design is good, products worsen over time as they operate under certain stress or load in the real environment, often including coincidence. Maintenance has therefore been introduced as an effective way of ensuring a satisfactory level of reliability during the useful life of physical assets [8]. Since reliability has always been considered as a significant aspect in the assessment of a particular technology system, it has an increasing importance in modern enterprises, bearing in mind that the need for higher quality is constantly increasing, which at the same time requires the possession of reliable machines. In order for a system to be considered reliable, from the very beginning of the creation of the system it is necessary to implement the characteristics that will ensure the reliability of the machines.

Problem and subject of research

The realization of this work stems from the project Summer Professional Practice and the Project of Employers' Union - Employers of Zrenjanin. Companies that are part of this association develop their innovations in their business and base their business on new ideas and projects. The idea is to find out to what extent the human factor affects the reliability of the technical systems. The area of reliability of technical systems as well as human resources as one of the important factors in the territory of the city of Zrenjanin is not sufficiently emphasized. There is very little research on this topic. Both employees and management organizations give us a clear picture of the importance of human resources on the functioning of the company's technical systems.

Research Area

The research was conducted in the territory of the city of Zrenjanin, the administrative center of the Central Banat District, which has a population of 76,511 in the territory of the city, and 123,362 in the municipality. The total area of the municipality is 1324 $[km]^2$.

Method of research

The research involved two groups of opponents. The first group of respondents were managers in the management sector, while the other group of respondents made the management of the company. The first part of the paper is based on the theoretical part of the application of the maintenance concept while the other part of the paper is based on research work. Data collection was carried out in two ways. The first way involved an employee interview as well as a department manager, while the other way of collecting data was a questionnaire survey, where it was pointed out that the questionnaire was anonymous and that the obtained results would be used exclusively for research work in this territory.

Research hypotheses

Main hypothesis: There is a positive attitude about the application of methods of maintenance of technical systems and their visibility in the territory of the Central Banat
Hypothesis 1: Human resources represent a significant factor of reliability of the function of the technical systems in the enterprise
Hypothesis 2: Adequate management of human resources in the sector of maintenance of technical systems in the company achieves higher efficiency and profitability of the company

The aim of the research

The research aims to demonstrate the impact of the application of methods of maintaining technical systems as well as the impact of human resources on the reliability of technical systems, and hence on the success of business operations. Increasingly, the market is becoming saturated sufficiently to show the need for constant innovation by introducing innovations in order to achieve competitiveness. The future brings with it the need for constant improvement of both the employees themselves and the overall management, but also the improvement and modification of business processes. It is considered that in order to achieve success, it is necessary to create a satisfied collective that performs its work tasks in a sufficiently efficient and productive way, using different innovative solutions.

Research results

The research involved two groups of respondents. One group of respondents covered the employees in the management sector while the other group of respondents comprised the management of the company. The main hypothesis has been proven through subhipodes. The survey showed that the largest application of the maintenance system is small, followed by medium and large enterprises. The survey is boldly assuming that employees have a positive attitude about the application of methods of maintaining technical systems in production 37% fully agreed, 13% of respondents agreed while 15% were undecided. The structure of the response is shown in Figure 4. The obtained results show that the main assumption is confirmed by this research. The research has shown that companies that are in the phase of development and are new on the market are not sufficiently informed about the application of modern business methods. Most of these respondents were not sufficiently familiar with the application of the maintenance system in business processes. Respondents believe that the role of human resources in the company's business is very important. They consider it of great importance to adequately manage technical systems in this way to reduce production errors, thus increasing the reliability of the technical systems. The key to the success of the company's business is the consequence of the use of the concept of the business process maintenance system. Respondents believe that the implementation of the concept of maintenance of production systems in the business of enterprises in the territory of the city of Zrenjanin absolutely agreed 42% of respondents 23% of respondents agreed, while 9% of respondents were undecided.

CONCLUSION

The ideas for the realization of this work are derived from the project "Summer Professional Practice" implemented by the Employers' Union - Employers of Zrenjanin. Companies that are part of this association develop their innovations in their business and base their business on new ideas and projects. Regarding the concept of the implementation of the system of maintenance of technical systems of companies of the association members in the business processes, they introduce drastic changes related to the implementation of the maintenance system and the reliability of the technical systems. The first part of the paper is based on the theoretical part of the application of the system of maintenance of production processes in order to increase the reliability of the technical systems in the business, while the other part of the work is based on research work. The goal of maintaining a technical system is to enable proper operation of the entire system, with minimization of downtime, failures and maintenance costs. This will at the same time result in increased business efficiency. If one wants to achieve success on the market while using the company in a flexible and economical way to utilize all the resources while developing the high quality of its products, it is necessary to introduce in the course of a radical change the monitoring of a number of specific processes. Research on this topic is of great importance as it draws public attention to Serbia that the implementation of the concept of the maintenance system in production processes as well as human resources that indirectly affect the reliability of technical systems should be an actual topic because it is directly related to the effectiveness of the organization, and indirectly, it has an effect on the business of the whole country.

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ERGONOMY IN AUTOMOBILE INDUSTRY FOR CABLE MANUFACTURE

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Abstract: The paper is dedicated to the ergonomic aspect in the cable industry for automotive serial production. After a brief introduction to the essence of the science of ergonomics, consideration is given to discussing the most common problems that workers in the industry of this type most often encounter. An example of the problem of engineering ergonomics is presented as well as a proposal for its solution. In conclusion, it comes to the realization that ergonomics is not a science for itself, it is closely related to other aspects, such as productivity and economics of production.
Key words: ergonomics, automotive industry, cables, work tables.

INTRODUCTION

Ergonomy is a science that deals with shaping and studying human work, as well as relationships in working with the metallic and physical affinity of people. The essence and purpose of ergonomics is to customize, or adapting tools, work tasks, work environments, according to the worker and his needs, rather than adapting the worker to the needs of the job. Also, ergonomics implies product design, in such a way that they are best adapted to the human body. For this purpose, it implies research of the human organism and behavior, on the basis of which it provides data and information about the suitability of the subject with which a person comes into contact, on the basis of that, it can be concluded that ergonomics studies the anatomical, physiological and other parameters of the human body.

REVIEW OF THE MOST OFTEN TEGOBES IN THE INDUSTRY OF CABLES FOR CARS - MUSICAL AND BONE TEGOBES

NIOSH (The National Institute for Occupational Safety and Health) has developed a questionnaire for evaluating risk factors in various ergonomic studies across the United States. They are mainly used to assess body factors and evaluate the design of the task itself, and in other cases also include psychosocial aspects of work. NIOSH questionnaires contain graphic representations of the body divided into regions (Figure 1), in order to facilitate locating the identified disability or disorder. These impressions differed in individual research. In general, the body is divided into a hundred regions, with the left, right, front and back sides being different. If, according to the nature of the task, it can be assumed that a part of the body will be associated with a disorder, partial body displays are taken [1].

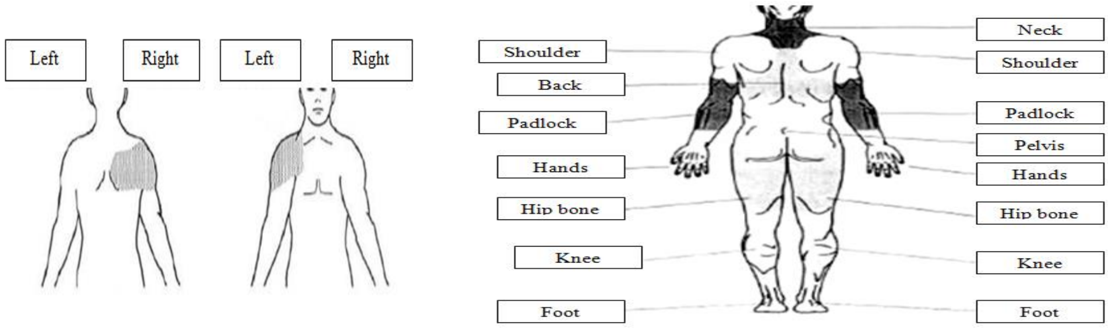

Figure 1. NIOSHs graphic representations of the body divided into regions.

The irregularities that appear are categorized as pain, tegobs, problem or discomfort, and are ranked according to the degree of severity (Table 1). The questionnaire initially seeks to determine the existence of one of the following symptoms: pain, stiffness, anxiety, depression or scurvy, which then determines the severity of the duration, frequency and intensity. This method has no preventive role. How difficult is the psychological structure, it is difficult to objectively measure it. It basically relies on an individual's assessment or comparison with other situations/jobs [2].

Table 1. Ranking of symptoms affects duration, frequency and intensity (NIOSH).

Duration of difficulty	Frequency of the occurrence of the difficulty	Intensity of difficulty
Less than an hour	Almost never (every 6 months)	Without pain
From 1h to 24h	Retouch (every 2 to 3 months)	The blessings of pain
25 hours to one week	Sometimes (once a month)	Moderate pain
From 1 to 2 weeks	Often (once a week)	Serious pain
From 2 weeks to 1 month	Almost continuous (every day)	The worst possible pain
From 1 to 2 months		
More than 3 months		

The method of estimation of muscle fatigue - the technique of functional work analysis is a method developed primarily for application to workers in the automotive industry. Their complaints were not always an obvious cause. Sometimes these are muscular problems that are due to the long repetition of certain patterns of movement, i.e. due to muscle fatigue. This method can be applied to all muscle groups, but only in fatigue assessment. It is also suitable for evaluation of implemented interventions. To calculate the amount of accumulated fatigue grade, duration and frequency of effort are reduced to three categories each. By combining them, there is an overall assessment of the level of fatigue, which may be low, moderate, severe or very strong. This sets the priorities for intervention. It uses Bragg's scale. The method gives the best results.

DISCUSSION AND REVIEW OF ERGONOMIC PROBLEMS IN THE AUTOMOBILE INDUSTRY FOR CABLE PRODUCTION

A very interesting example for considering this topic is in the automotive industry of serial production of cables. Workers carry out the job of keeping the cables in a standing position for 8 hours, the material for the production of cables is located on the work boards in a horizontal position, as shown in the figure (Figure 2). There are many problems with the ergonomic aspect existing in this case, starting from the height of the worktop, which is not the appropriate height of each worker, and it is necessary for a certain number of workers to be placed in a folded body position in order to perform their work steps, besides, on the working table there are too many assembly elements which require maximum concentration in operation, as well as good vision, if the board is overwhelmed, which is often the case (look at the picture), workers lose concentration at stress and damage their eyesight.

Figure 2. Work table and position of the worker's body

Figure 3. The look of the work table

In the figure (Figure 2) shown, one can notice a worker whose back is in a raised position, as can be seen in the position of the hand (marked with red lines), where after 8 hours of daily maintenance of this position, difficulties and problems in the health sense are created, in the form of muscular-bone problems that occur due to the prolonged repetition of certain patterns of movement. In the illustrated figure, a dashboard is displayed, which is saturated with different labels and mounting elements, when the work tables are in a horizontal position, the workers need to lean toward the boards in order to understand the meaning of the labels, where in addition to straining parts of the body like back, hand grip and vision. Observing, in addition to the ergonomic aspect, the economic and productive aspect of such problems, it can be concluded that they are closely related, the health condition of the workers certainly affects the productivity of his work, if his work is hampered by the health situation, it certainly negatively affects the productivity of his work, and thus directly to the economic aspect of the company itself.

Suggestion of the problem presented from the ergonomic aspect

Companies that have recognized the significance of these issues have taken some steps in terms of employing and improving their workplace. Work tables made in a vertical position, which can be adjusted based on the physical predisposition of workers, is the essence of the work tables adapting to the worker, not the workers to the work table [3]. The work table is adjustable in terms of height, can be adjusted to be more or less positioned, as well as set at an angle that corresponds to the worker in the pin of the position it is working on the worksheet. In addition, above each work table there is lighting that makes it easy to spot the signs and mounting elements, the body is in a rhythmical position and the field of vision is wider, since the table can be adjusted to the height of the worker's eyes. How it all looks like can be seen in the following pictures.

Figure 4. Work boards, which are adaptable to the person working on it

Figure 5. All possible positions in which the working table can be adjusted to the worker

The following figure (Figure 6) shows that the position of the worker's body is more correct and more ergonomic with the use of optimized work tables. In an ergonomic aspect, this position of the body is more similar to the worker, muscle and bone pains are suppressed, the worker is not burdened during the execution of work steps, and makes his work easier and more productive [4].

Figure 6. Ergonomic work table and proper position of the worker's body

CONCLUSION

On the basis of everything exposed in the paper, it can be concluded that ergonomics has an impact on several aspects in the production of one industry. In addition to the ergonomic aspect, which facilitates the work and improves the health status of the worker, it also achieves higher productivity, and thus improving the economic aspect of an enterprise. Mud companies have learned the importance of their employees by investing in their employees investing in the company. A healthier and contented worker will do his job more eloquently, more productive and quality, and this will definitely have a positive impact on the company's economy.

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THE INFLUENCE OF TECHNICAL INSPECTION ON THE SAFETY OF MOTOR VEHICLES

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Abstract: Throughout this work, the authors were dealing with the issue of safety of motor vehicles in traffic, that is, with the influence of technical safety checks of active motor vehicles on the overall safety. The conducted research included all the segments of technical safety checks of motor vehicles – from braking and stopping system, steering, light and adhesive systems, to pneumatics. Each of the listed elements represents a part of the motor vehicle assembly and it is pointed out as an important factor for the safety of motor vehicles in traffic.
Key words: safety, motor vehicles, braking system, steering, light system, pneumatics.

INTRODUCTION

Nowadays, in the 21st century, we are witnesses of an increased technical and technological development in all fields. The main reason for that expansion level is the development of modern IT technologies and their overall application through the wide spectrum of industrial branches and fields.
It is almost unimaginable not to have a motor vehicle as means of transport today. According to the data of the Ministry of Internal Affairs, 2.3 million motor vehicles (automobiles) were registered in Serbia in 2017 and if we compare this number to the total population of the Republic of Serbia, we can conclude that around 40% of population has its own vehicle. One of the most influential factors for the vehicle safety is its lifespan/age. According to the previously mentioned data from 2017, it can be clearly seen that the average age of vehicles in the Republic of Serbia is between 13 and 14 years [1], which is really old compared to the European average.
Throughout the work itself, the methods used for testing motor vehicles on technical checks are going to be shown, as well as all the necessary steps ensuring that a motor vehicle is in a fully controlled condition. Also, through the mentioned hypotheses, we will try to prove the importance of technical checks for the vehicle safety in traffic.

THEORETICAL CONSIDERATIONS

Terms of safety and technical check

Safety as a term has a wide meaning, however, every type of safety is directly or indirectly connected to life and human beings, whether it comes to work safety, safety in traffic or some other form of this term. When it comes to traffic, safety nowadays is reduced to a small percentage, so the term could be considered in the opposite sense, that is, unsafety. There are various factors that have an impact on traffic security and safety, starting from the human factor, motor vehicle components (brakes, pneumatics, steering, etc.), to weather conditions at the moment of traffic conduction. One of the main methods for diagnosing the accuracy of the motor vehicle system is the technical check which is carried out once a year during the vehicle registration and during which the safety parameters of the motor vehicle system parts are being controlled. There are two types of technical checks:

1. Regular,
2. Extraordinary.

Regular parameters that should be controlled are:

1. Braking systems,
2. Steering,
3. Pneumatics,
4. Lights.

When talking about a motor vehicle as a factor which has an influence on life safety while participating in traffic, it is necessary to mention that the two essential elements of every vehicle are the braking and the steering system. Considering the overall system reliability during the making of the motor vehicle in production facilities, these two elements are marked as a degree of high importance of the system reliability [2].

$$R_k=0{,}99=99{,}9\%$$
$$R_{up}=0{,}99=99{,}9\%,$$

The reliability extent of any technical system moves in the scale range from 0 to 1, according to the mathematical logic principle [2].

Braking system

Braking system is one of the main parameters when testing motor vehicles on technical checks. Drive part is the essential part of every motor vehicle and without it is impossible to imagine proper functioning of the vehicle and it is the same with the system that enables stopping the movement which is as important as the drive system. Apart from braking, this system has other tasks, above all, to allow controlling the vehicle speed, viz. adjusting the speed to the traffic conditions, together with other systems.
While constructing the braking system, the reliability of the system itself is the main item taken into consideration. According to [3], reliability is calculated as:

$$R(t) = n - \frac{\sum N(\Delta t_i)}{n} \tag{1}$$

In the Figure 1. is shown the influence of the braking coefficient in different road conditions.

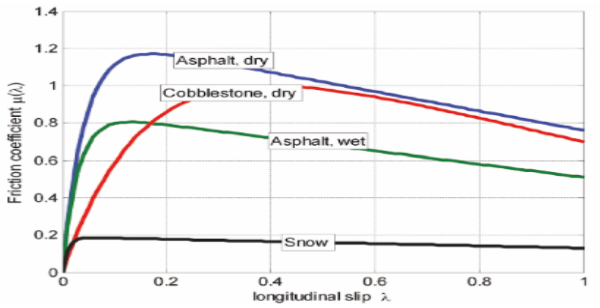

Figure 1. Dependence of the braking coefficient and slipping level [4]

Technical check of braking systems

This is the first step in testing motor vehicle safety on a technical check and if the vehicle does not pass this control segment, it is considered unsafe for participating in traffic.
Both the front and the back braking system are being checked. The braking system is consisted of the main braking cylinder and the auxiliary ones, placed on the front and back wheels.
During the braking device check, safety, speed and efficiency are being controlled and especially:

1. The biggest activation force and braking coefficient of the working and auxiliary brake,
2. Difference in braking force between wheels of the same shaft (the difference must not be more than 30%),
3. Parking brake,
4. Existence of mechanical and other damages,
5. Free movement of commands [5].

Testing the friction coefficient is done by measuring the braking force of the technically correct vehicle with valid registration, mass of the wheel, as well as of the vehicle shaft. Therefore, the coefficient can be calculated mechanically as well, as the ratio of force, wheel mass and gravitational acceleration.

$$\mu = \frac{F}{m*g} \tag{2}$$

Figure 2. Reading the braking coefficient

Figure 3. Testing rollers

Braking coefficients of motor vehicle are shown in the Table 1 [6].

Table 1. Coefficients values K_{fp}

Vehicle type	Prescribed braking distance		Speed v[km/h]	K_{fp}
	Main brake s_r[m]	Auxiliary brake s_p[m]		
Passenger vehicles	$0{,}1 \cdot v + \frac{v^2}{150} = 50{,}65$	$0{,}1 + \frac{2 \cdot v^2}{150} = 85{,}30$	80	0,594
Buses	$0{,}15 \cdot v + \frac{v^2}{130} = 36{,}70$	$0{,}15 \cdot v + \frac{2 \cdot v^2}{130} = 64{,}40$	60	0,570
Freight vehicles up to 3,5t	$0{,}15 \cdot v + \frac{v^2}{115} = 58{,}10$	$0{,}15 \cdot v + \frac{2 \cdot v^2}{115} = 105{,}70$	70	0,550
Freight vehicles up to 12t	$0{,}15 \cdot v + \frac{v^2}{115} = 29{,}20$	$0{,}15 \cdot v + \frac{2 \cdot v^2}{115} = 50{,}90$	50	0,574
Freight vehicles over 12t	$0{,}15 \cdot v + \frac{v^2}{115} = 19{,}90$	$0{,}15 + \frac{2 \cdot v^2}{115} = 33{,}80$	40	0,589

Steering device

The steering device is one of the most important devices in a motor vehicle from the traffic safety point of view. Its purpose is to ensure directing of the steering wheels, to keep them under the certain angle, to maintain the direction during vehicle movement, as well as to enable vehicle maneuvering in a small space. Therefore, the steering device has to be reliable in order for a driver to be able to maneuver easily, quickly and safely.

Steering system can be divided into three main groups:

1. Mechanical steering system,
2. Hydraulic steering system,
3. Electro-hydraulic steering system.

Technical check of the steering system

During the steering device check, it is controlled whether it is possible to change the movement direction of the vehicle easily, quickly and safely and especially:

1. Free movement of the steering wheel,
2. Transmission of the steering wheel rotation onto front wheels; necessary force to move the steering wheel,
3. Power steering accuracy, mechanical damage check [5].

Pneumatics

The main roles of pneumatics are to ensure elastic suspension of the vehicle on the surface, to amortize the dynamic load of the vehicle in order to prevent mechanical damage of certain parts and to ensure the realization of the force of friction with the surface, while making sure that slipping is as low as possible, especially when it comes to traction realization, during braking, passing through a curve, etc. [7]. It is important for a safe drive that the pneumatic has a good tread surface with a sufficient profile depth. Pneumatics can be divided into diagonal and radialones [8].
Passenger vehicles are using low pressure pneumatics (1-3bar).

Technical check and pneumatics condition

Motor vehicle is a set of components which means that the impact of elements' reliability is direct. Apart from the regular control of the oil level in the engine, viz. the engine coolant, it is necessary to check regularly the pneumatics condition of the vehicle. In addition to the air pressure, the attention should be paid to their condition and detrition which are often indicators of suspension or steering system failure [7].
During the technical check, steering system and pneumatics are being tested simultaneously, as in most cases the problem is directly connected, viz. one of the defective elements influences the other element of the motor vehicle.

Light system

A component of every motor vehicle is the light system. In its basic package, it is consisted of low and high beam lights, position lights, taillights and of turning and stopping signalization. If one of the listed elements is not working, the motor vehicle is considered unable to pass the technical check.

Technical check of the light system

During the check of the device for lighting the road and the vehicle and for giving light signals, installation and connection of devices for prescribed commissioning are being controlled and especially:

1. Whether all prescribed devices are installed,
2. Direction and intensity of light,
3. Existence of mechanical or other damage [5].

A display of position light check is shown in the Figure 4. The procedure is called light regulation.

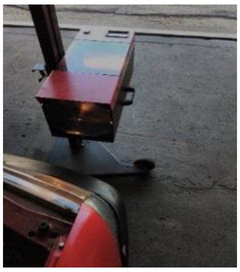

Figure 4. Light regulation

DISCUSSION RESULTS

The research was carried out on the territory of the Republic of Serbia in the period 09/04/2017 – 09/12/2017, by using a survey as a research technique. The sample on which the research is based is consisted only of active drivers who regularly participate in traffic. In the research there was not a target group regarding sex, as both men and women drivers have shared their objective opinion.
The number of examinees for the given period was 56 active drivers, which means that we tested 56 motor vehicles which actively participated in traffic and went through regular technical check processes.
In order to have a clear image of the condition of motor vehicles in traffic, the examinees filled in their vehicle's age. A display of the average age of vehicles is given In the Figure 5.

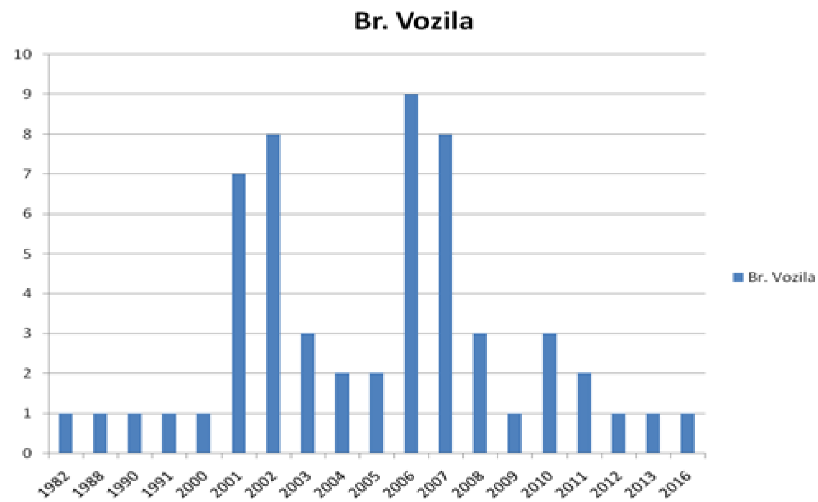

Figure 5. Average age of vehicles

On average, examinees' vehicles have been produced in 2003. This data coincides with the data from the Statistical Office of the Republic of Serbia which indicates that the average age of vehicles on the territory of the Republic of Serbia is between 13 and 14 years old.

In the theoretical consideration are given clear guidelines about the influence of an accurate braking system on reliability of motor vehicles, where the safety in traffic itself is directly affected by reliability. Based on that, the first segment of the survey refers to examining opinions about the impact of accurate braking system on the safety of motor vehicles in traffic. Figure 6 shows the data about the examinees' way of thinking.

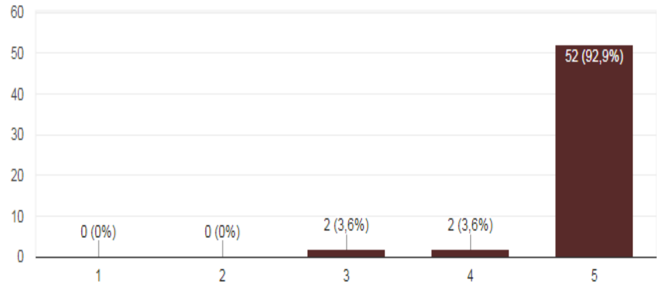

Figure 6. Display of the impact of the braking system on the safety of motor vehicles in traffic

Figure 6 shows the state of examinees' opinions about this segment where 52 examinees (92.9%) answered with the highest grade for the braking system influence, two of them (3.6%) gave a grade 4 which is equal to the very high level of importance, while the remaining two examinees gave a grade 3 which has a mid-importance value.
In order to determine the significance of the technical check in the braking system segment, the survey included a question about the braking system test at the regular technical check.
In the Figure 7 is shown the state of mind about the quality of the motor vehicle braking system check.

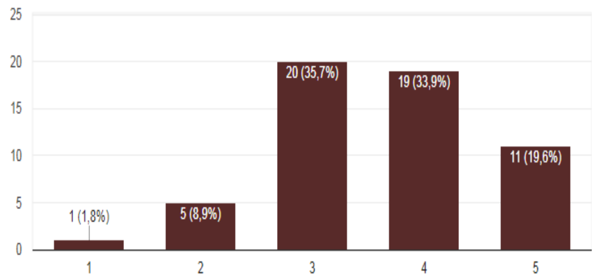

Figure 7. The quality of the motor vehicle braking system check.

In the shown Figure 7 , which is about the level of accuracy check of the braking system, the examinees mostly gave the grade 3 (35,7%), then 19 examinees gave the grade 4 (33,9%), grade 5 (19,6%), grade 2 (8,9%) and finally, grade 1 (1,8%).

Apart from the mentioned braking systems, light systems have a great influence on traffic safety. That is the reason why the survey in its second segment includes examining opinions about the significance and influence of light systems on safety, as well as about light system control at the technical check.
In the Figure 8 is presented a display of drivers' familiarity with the light system check.

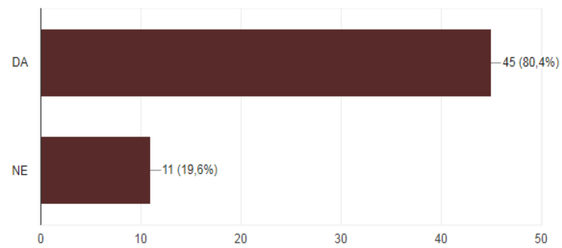

Figure 8. Display of drivers' familiarity with the light system check

In the presented Figure 8, 45 examinees (80.4%) answered with "YES", which means that the majority of drivers is familiar with the fact that accuracy test of light systems is being carried out during the technical check, while a surprising percentage of examinees – 19.6% (11 examinees) answered with "NO", meaning that they are completely unaware of the existence of the light system test.
In the Figure 9 are shown opinions about the extent of light system tests during regular technical checks.

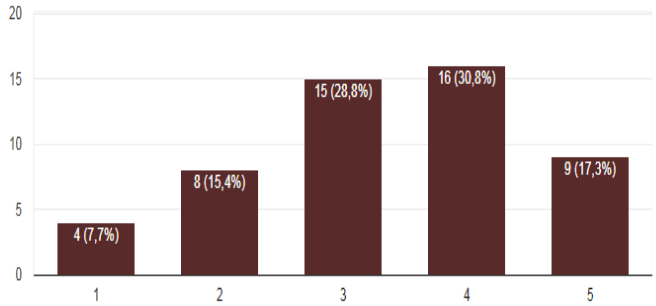

Figure 9. The extent of light system tests during regular technical checks.

According to the Figure 9, it can be seen that the extent of verification in the average range has a grade 4 (30.8%) which satisfies the traffic safety conditions regarding this component, especially taking into consideration that traffic frequency is much higher during the day, while in the nighttime traffic is conducted during 1/3 of the time.

At the beginning of the theoretical consideration it was mentioned that, apart from the braking system, the other essential factor while constructing the vehicle is the steering system, whose reliability has to be one hundred percent. The third part of the survey was referring to the public opinion about the steering system importance for the safety of motor vehicles in traffic, so the question was: „How important and influential is the steering system regarding traffic safety? "

Figure 10 shows the answers on the question about the influence of the steering system.

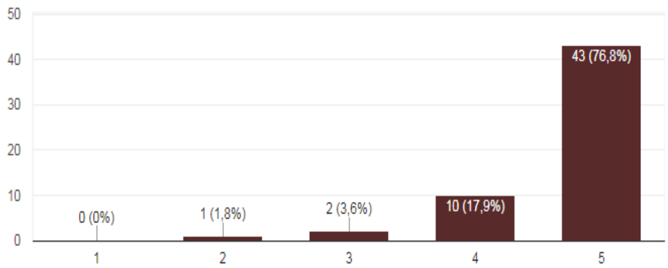

Figure 10. The influence of the steering system.

Most examinees answered to this question with 5 (76.8%) and 4 (17.9%), meaning that the impact of this system has a big role on the safety of motor vehicles in traffic, which is confirmed by the claim that the steering system is one of the two essential motor vehicle systems.
According to the previous diagram, clear conclusions about the system's importance have been drawn out, while in the Figure 11 is presented the answer to the question: "To what extent is the motor vehicle steering system being tested at the technical check?"

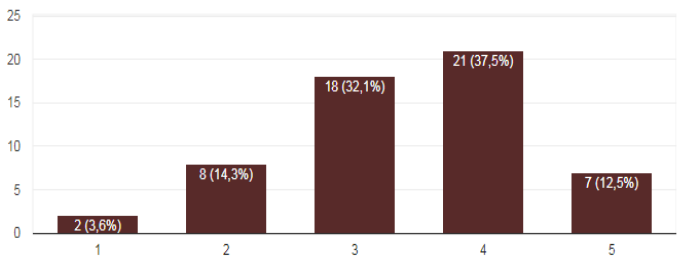

Figure 11. Display of the extent of steering system test at the technical check.

The variety of answers in the Figure 11 is obvious, however, most examinees answered with the *grade 4*(37.5%), while there were 10 negative answers in total (17.9%).

Pneumatics are possibly the factor that receives the least attention during regular technical accuracy checks of motor vehicles. Motor vehicle pneumatics actually belong to a subgroup of the steering system, since both steering and braking coefficient depend on them and that is why this element is of high importance.
Figure 12 shows the question about the influence of pneumatics on the vehicle safety in traffic.

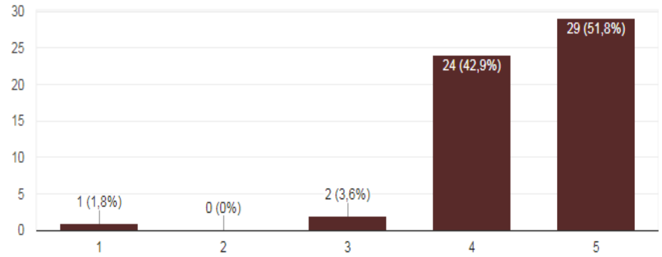

Figure 12. Pneumatics influence display

According to the presented graphic, the biggest number of examinees - 29 (51.8%) and 24 (42.9%) believe that the influence of pneumatics on the vehicle safety in traffic is big, which confirms the fact that both steering and braking system are dependent on pneumatics.

On the basis of this claim, examinees were questioned: "What is the pneumatic testing level during the technical check of your vehicle?“ and the opinions of examinees are presented in the Figure 13.

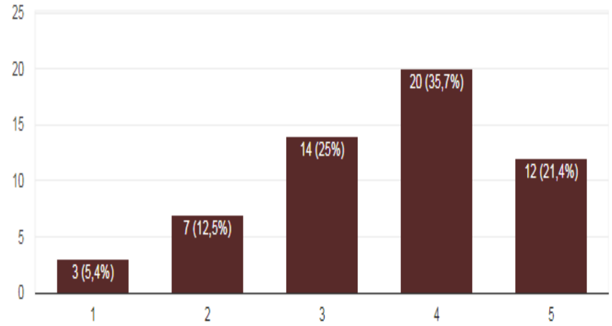

Figure 13. Pneumatic testing level at the technical check

CONCLUSION

Safety as a term has a wide meaning, however, every type of safety is directly or indirectly related to life and human beings, whether it comes to work safety, safety in traffic or some other form of this term. When talking about traffic, safety nowadays is reduced to a small percentage, so the term could be considered in the opposite sense, that is, unsafety. There are various factors that have an influence on traffic security and safety, starting from the human factor, motor vehicle components (brakes, pneumatics, steering, etc.), to weather conditions at the moment of traffic conduction. Two out of three mentioned factors are almost impossible to be affected – human mind is as unchangeable as weather conditions, they are both unpredictable.
When it comes to the overall traffic safety, reliability segment should be taken into consideration the most. In every system it is necessary to pay attention to certain segments that are marked as the most important or the most sensitive system elements. Regarding motor vehicles, those elements are mostly the drive element and the one opposing to it – the braking system for stopping the vehicle and in this type of systems they are classified by ranking in the first group of important elements, from the aspect of system reliability.

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THE ROLE OF KAIZEN IN IMPROVING EMPLOYEES SAFETY AT WORK

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Abstract: The authors of this paper analyze the role of kaizen model to improve the safety of employees at work in the organization. The Kaizen method allows the manager to direct the right moves to managing the company and its management, in order to succeed successfully. Kaizen represents a constant improvement and an endeavor to do the job in the most efficient and effective way. Constantly emphasizing process is another important aspect of Kaizen. Managing the Kaizen method allows the organization to survive, grow and develop faster in the global market. Kaizen is a good example and the key to the success of Japanese companies.
Key words: Kaizen, implementation, organization, safety

INTRODUCTION

In today's business world, each organization's virtue is the ability to develop and improve itself. Also, organizations need to invest in their employees’knowledge in order to increase efficiency and business productivity [6]. The operations of all companies listed in today's business world where there is great competitiveness, must be operational, have good management, be well organized in the company for long-term survival of the business market [7].
The kaizen strategy can be said to have the most important role in the concept of Japanese management - the key to Japanese business success. Kaizen means continuous improvement in the work process. It can be said that Kaizen is the most important concept behind the background of good management. It represents the unifying thread that runs through philosophy, systems and tools for troubleshooting, developed in Japan in the last thirty years [5]. It is also a gradual and continuous improvement of the way an organization works, the quality of products and services, processes, corporate culture, human resources, relationships with customers and suppliers, and everything that concerns the business of one company. This affects not only the internal factors, but also the external factors. A real value of an organization cannot be seen through its long life but in its ability to change itself continuously [8].

KAIZEN CONCEPT

Implementation of the concept of kaizen in the organization

There are many references that deal with successful application of the Kaizen concept in various industries. Introducing Kaizen method resulted in significant performance improvements in two observed companies such as 30% financial growth and 81% productivity improvement [1]. Another research has reported the results of a multiple case study, showing and providing empirical evidence grounded in the application of process innovation and the impact this has on the management of the organization. In this study, the authors found that the application of Kaizen is leading to continuous improvement [10].
A case study showed that a company managed to reduce its operational cost and production lead time significantly by applying Kaizen. A total of RM 31,661.22 per year of saving was targeted to be achieved through the long-term commitment from the Kaizen team and also top management [2]. Kaizen philosophy was applied in a small-sized custom-made furniture industry for continuous improvement in order to develop the products with higher quality and productivity and lower costs to meet the customer requirements [9].

Kaizen Management is a concept of successful business. This business concept increases productivity in the workplace, with the worker maximally dedicated to his workplace. No one knows better his job than the employee himself, and he performs his work task. By this approach, the worker is able to give and initiate improvements in work and working conditions. An example is the Japanese automotive industry that has applied this management concept, a steady advancement is Toyota's world leader in the auto industry. They argued that this change would positively affect productivity and production in the company itself, increase productivity by 50%.[7]

Kaizen focuses on small steps, which lead to great improvements. No idea is considered to be too small, and each, even the smallest change, contributes to the companies' improvement. Kaizen solutions generally do not require large financial investments, they are not risky, and there fore it is expected that it will be more and more present. [7]

Kaizen Management is an element of comprehensive quality management control, and relates to continuous long-term approach to change, while respecting human needs and quality [5].

RESULTS AND DISCUSSION

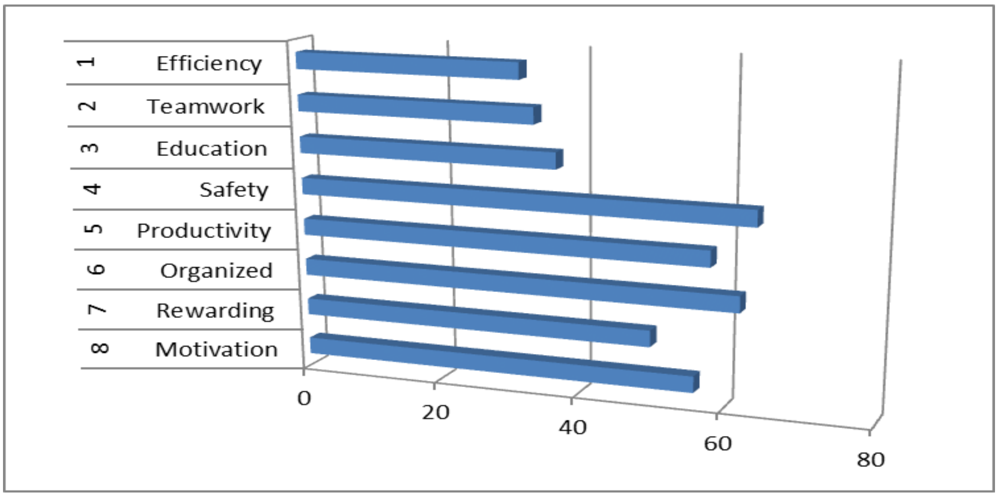

Figure 1. Average grade of employee satisfaction using Kaizen

The results from Figure 1 show that employees have best assessed the factors related to safety, organization and productivity, employees are most satisfied with these factors, while lower grades have factors of efficiency, teamwork and education.

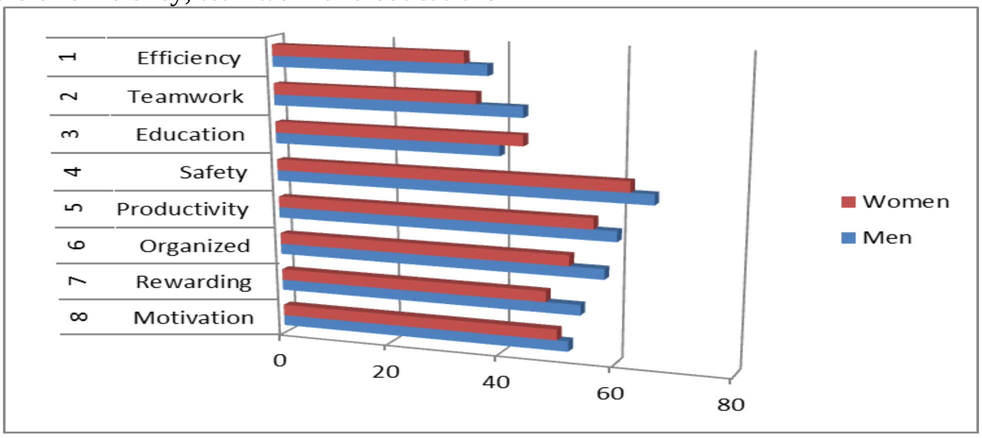

Figure 2. The obtained results of employee satisfaction with Kaizen are shown in both sexes of the respondents

The results from Figure 2 show that employees of both sexes were the best assessors of factors related to safety, organization and productivity, and the respondents of both sexes were most satisfied with these factors. While little assessment, respondents of both sexes have just given factors affecting the efficiency, teamwork and training.

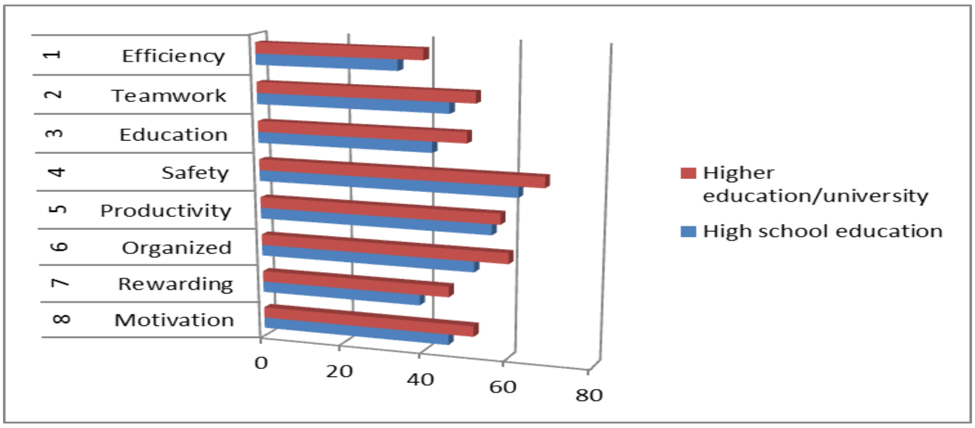

Figure 3. The obtained results of employee satisfaction by using Kaizen according to the professional preparedness of the respondents are presented.

The results from Figure 3. show that employees with HSE and Faculty best assessed the factors related to safety, organization and productivity, employees are most satisfied with these factors. Employees are least satisfied with efficiency and rewarding factors.

Based on the results from Figure 1. it can be concluded that the employees of the company Elitas Ltd. are very satisfied with work and safety at work, which was related to half of the respondents and expert assessment of respondents in the observed company. The highest average grade received is question number 4 "Safety". Employees are obviously satisfied with security in their organization. This is very important for the organization and the whole organization in it. It can be said that issues under number 5 "Productivity" and issue under number 6. "Organization" also received the highest marks for this questionnaire. It can be said that employees are satisfied with their work. For this questionnaire is given a lower assessment question number 1 "Efficiency".

On the basis of the results from Figure 2, the results of the assessments of respondents categorized by sex are presented. One can see that men and women are equally satisfied with the safety at work. The highest grade according to the opinion of men was given issues under number 4 "Safety", 5 "Productivity" and 6 "Organization", while women rated these issues as a lower grade. The lowest grade according to the opinion of both sexes was given the question under number 1 - "Efficiency". It can be said that women are less satisfied with their job than men.

Based on the results from Figure 3, the results of the assessment of the respondents categorized according to the professional qualification are presented. It can be seen that the respondents with secondary education and university are satisfied with safety at work. Also, the respondents in this questionnaire gave the highest score to issue under issue 5 "Productivity" and question 6 "Security". Also, it can be said that respondents with faculty are more satisfied with the job than respondents with high school. The lowest rating of the respondents according to the professional qualification was given to the question 1 "Efficiency" and question 7. "Rewarding, it can be said that the respondents of this group perform quite a lot of tasks, but are not adequately rewarded for them.

It is recommended that they continue to improve the production with the help of Kaizen programs and 5S models that enable the improvement of production and work processes. It can be concluded that the research was successfully carried out and the answers to the research questions were answered, so the hypothesis was confirmed. The management of the company can be satisfied with the obtained results, in terms of safety, productivity and organization in the observed company.

It can be concluded that employees of the company are satisfied with the security, productivity and organization, management attention should be paid to the efficacy, teamwork and remuneration where these factors might significantly improve manufacturing and business processes work in the observed company. It can be concluded that the kaizen method and the 5S model have a major role in improving production and workflow, with this model organizations can improve their safety, productivity, organization, motivation and other important factors that are important for improving business and reducing costs.

CONCLUSION

The Kaizen model points out that a satisfied worker is one hundred percent productive, that's what every company needs, and where Elitas has just recognized the good Japanese practice of the Kaizen model. The business philosophy of Kaizen management is achieved through the application of better and more efficient results reflected primarily self-shots in improving product quality, reducing production time and method of manufacture of the product, in this connection increases the productivity of the company.

The first most visible results were shown in production. Also, besides the minimum financial resources involved in introducing the Kaizen model, on the other hand, it is equivalent to reducing the company-wide costs. Also, this method has shown the simple fact that nothing is perfect and that it should be constantly improved and gradually improved.

This popularity of the Kaizen management model in the organization is achieved thanks to the simplicity and effectiveness of the results it accomplishes. This model has no restrictions on the company's activity and size. Its successful implementation can be found in a variety of industries around the world. The essence of the struggle for competitiveness lies in the acceptance of change [4].

One can simply say, Kaizen is alive method that continuously learns and improves. The implementation of this model for an organization that has no concept of Kaizen, could significantly increase the productivity, conomic efficiency and safety of employees at work. In fact, only those customer-centerd organizations that can deliver value will survive in the modern business arena [3].

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THE ROLE OF IMPLEMENTATION OF THE CONCEPT – TOTAL QUALITY MANAGEMENT IN ORGANIZATIONS

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Abstract: The authors in this paper present the role of the concept of Total Quality Management, its elements and the concept of implementation. Total Quality Managment (TQM) represents a continuous satisfaction of consumer needs, wishes and demands. Quality is and will be the key to improving competitiveness on the global market. TQM is a type of organization management in which all types of cooperation between employees and co-workers are included with the goal to improve the quality of products, services, company activities and work processes. Therefore, the ability of the quality management system to ensure the constant quality of products and services with minimal costs will be the key to the survival and expansion of business activities, that is, the success of each business entity. The goals of modern management include processes that produce goods without errors, satisfying the end users and providing them with competitive market prices.
Key words: Management, Quality, Implementation, Concept, TQM

INTRODUCTION

Total quality management (TQM) is a management approach through which a company can achieve long-term goals. These goals are customer satisfaction, and improved competitiveness on the market [5]. The seven dimensions of TQM are leadership management; employee relationships; reporting, and data quality; training, and skill development of employees; supplier quality management; product, and service design; and process management [12]. The base philosophy of this concept is the utilization in companies regardless of their size, and industry. TQM tools and techniques can improve knowledge gathering from the internal and external environment of the organization [9].
Quality management in the organization plays an important role in the realization of the basic principles of long-term and sustainable development of society. Market changes that have occurred in the last decades of the twentieth century have significantly changed the relationship to quality [1]. When, from the "production market" (excess demand), through the "sales market" (supply surplus) competence markets are reached (excess supply of products of high quality and competitive prices), it led to a completely new approach to quality [11]. Quality management has a significant role in all the activities of today's competitive modern business. Today is the quality in the center of interest of the world's leading corporations [10]. Total Quality Management (TQM), as a kind of philosophy, requires the necessary satisfaction of the needs of all users of services, improving internal processes that increase the profit of the organization and creating conditions for the production of new products and services, and thus increase market share at the global level. Every company, even the best one, has the opportunity to improve [14]. Modern business conditions create huge and unknown changes which every organization faces on daily basis [13].

TOTAL QUALITY MANAGEMENT (TQM)

Model of the concept TQM

Total Quality Management is philosophy, ie. the approach shaped by a set of tools and processes whose outputs bring consumer satisfaction and continuous performance improvements [6]. TQM–Total Quality Management combines the concept of product quality, process control, quality assurance and quality improvement. Total Quality Management is maximally focused on meeting the requirements of both external and internal users [7]. For the successful implementation of total quality management, three key factors must be considered: Effective training, effective implementation and full commitment of top management [17]. Basic concepts [11]:

- Continuous process improvement,
- A focus on the user,
- Prevention of defects,
- Responsibility.

Quality must be permeated through the entire organization. Each working group in the organization must constantly look for ways and ways to improve its own products and services [1]. Total Quality Management is an approach that focuses on defect prevention rather than on dry control that sort defects after they appear. The methods used for the prevention of defects are: Statistical Process Control, Taguchi methods for designing experiments and others [11].

The objectives of total quality are as follows [11]:

- Lower costs,
- Higher income,
- Appropriate authorized employees,
- Satisfied users.

Model of the concept total quality management (TQM) especially focus on employees, man is the most important resource in the organization. The main vector that today creates and consolidates all the changes in the modern business world, technological development and growth was created as a result of the explosion of increasing knowledge. TQM concept is based on knowledge and comprehension [5]:

- Satisfaction of customers as the basic principles of the business process,
- The process of continuous improvement and,
- Long-term growth of the company.

The modern concept of total quality management focuses on man himself, he is the most important resource in the business organization. People are an important organization's potential. Employees in the organization must be the basic, starting and end point in improving the quality of business of the modern organization.

Table 1. Structure of the concept TQM [5].

Acters	Requests	Management Techniques
Society	Integrity of an individual, Environmental Protection, Safety of all in society, Business in accordance with the regulations.	Social marketing, Environmental Protection (ISO 14000).
Consumers	Meeting the needs, Fulfillment requires, Fulfilling the specification, Overcoming customer expectations.	Marketing management, Quality management (ISO 9000).
Partners	Fair relations, Financial results, Growth.	Marketing oriented to building partner relations (relationship marketing).
Shareholders	Financial results, Increasing the value of the company, The growth and development.	Strategic management, Financial management.

Implementation of TQM

Successful implementation of TQM is influenced by a lot of factors. These factors include top management role in defining quality policies; role of the quality department; employee training, and new skills development; product, and service design, and development; quality management of suppliers; process management; product, and service quality reporting; employee relationships; developing good relationships with suppliers; improved communication throughout the organization; customer satisfaction orientation; strategic management; overall quality improvement; and increased productivity [8].
In other articles, it was noted that the main success factors of TQM are systematic approach; process improvement; defining goals and business strategies; quality measuring and analysis; and corrective actions [18]. It can be seen, that processes regarding product quality and human resource management have a major impact of TQM success. If employees are aware of the importance of quality improvement, then TQM is more likely to bring better business performance [3].
The success in implementing total quality management in the company is conditioned by the existence of 8 basic elements [11]: ethics, integrity, trust, training, teamwork, leadership, recognition and communication. According to their function, the following elements are divided into four groups [16]:

- Basic: ethics, integrity, trust;
- Building: training, teamwork. leadership;
- Binding: communication;
- Supreme: recognition.

Total Quality Management is created on the basis of ethical principles, mutual integrity and mutual respect, based on openness, trust and sincerity. Such a combination of elements is the key to the success of its application. Each of the elements gives a unique contribution to the implementation of the principles of this philosophy and its concepts [4].
Quality should be developed starting from the customer's perspective and transmitted as a written policy. Taking a buyer and his requirements for the primary goal of the process, being viewed as the ultimate result, it must have a product that has adequate performance, a competitive price and is distributed at competitive intervals. The value for the customer is in combination with all three elements: quality, price and time [11].

CONCLUSIONS

After carrying out a theoretical analysis in the role of implementation of the TQM concept, it can be concluded that the goal of the concept is to improve the organization's business performance. In order for the organization to improve, it must achieve different business goals such as finance, cost reduction, error reduction, customer satisfaction, product quality and productivity. TQM concept is based on increasing the quality of products, reducing production costs, increasing profit of the organization and customer satisfaction.
The modern era of business requires flexible organizations that can be countered by the constant changes on the market [2]. Organizations tend to satisfy all the needs of their consumers through product quality. Applying the concept of total quality management TQM, increasing product quality, reducing production costs and increasing profit the organizations increase the level of consumer satisfaction. In the future, we should not be guided by the idea that quality in organization is a matter of "quality experts" but that it depends on the performance of each person in the organization [15]. Modern business organization in the future will increasingly depend on the information and knowledge.

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QUALITY MANAGEMENT-BASED MEASURES FOR IMPROVING MAINTENANCE OF PRODUCTION SYSTEMS – EXAMPLES FROM AUTOMOTIVE INDUSTRY

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Abstract: This paper shall present a brief analysis of close interconnection between product quality and maintenance of technical systems (machines) in automotive industry. After an overview of control and maintenance process, their essence and importance, a brief analysis of a production process example is given, also from the perspective of their quality and maintenance.
Key words: quality, maintenance of technical systems, automotive industry

INTRODUCTION

Contemporary business conditions demand quality management which includes not only control and sustaining the constant level of quality, but also the continued improvement of quality, preventing faulty and nonconformity, with the aim to achieve total quality management. To establish quality, it is important to manage and control all its aspects. The quality management function is a part of total organization management, related to management and realized through: quality planning, operational quality management, quality assurance and quality improvement. The quality management function needs to include all quality aspects, from modelling the product (goods or service), during its production and use in practice, i.e. all the activities from the quality circle. Quality management can also be used in maintenance of production systems, which will further be shown through examples of serial automotive production.

CONTROL AND MAINTENANCE PROCESS

Control is in fact a process which enables achieving organizational goals. It is very important if an organization wishes to do their business successfully. Without control, chaos occurs, and stability of any group is impossible [1]. Basically, three phases can be distinguished during the control process: control standards, measuring of previous and current result against the standards, as well as corrective actions. The role of quality control in maintenance consists of measuring by programs and documentation, maintenance preparation, collecting and processing the data, as well as providing relevant information into the decision nodes. This can be easily represented by the following graphic (Figure 1):

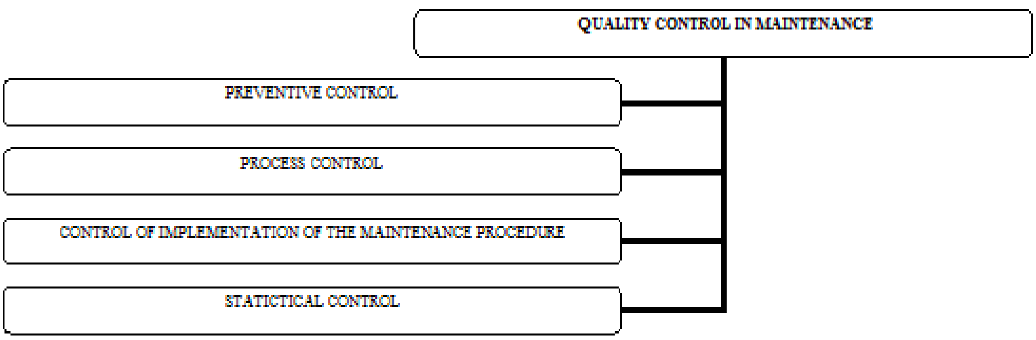

Figure 1. "Quality control in maintenance"

The function of quality within the maintenance system consists of the following tasks: reception and control of spare parts, reception and control of semi-products and products procured directly from the market, periodic control of technical systems (machines), where statistical quality control and analysis of causes and consequences should be used. The paper will be dedicated to these two methods. Controlling represents a process of regulating one or more organizational activities, so that they are done in a way which will enable achieving the maintenance goals. In contemporary management, controlling is done at all levels – from strategic to operational, including four basic groups of resources:

- physical (stock, equipment – accuracy, functionality and quality),
- personal (training, utilization, quality and similar),
- informational (completedness of work orders, records, notes and similar) and
- costs (material, spare parts, tools, norms and energy).

Control is performed using a classical feedback approach, by which the instructions for changing the maintenance standards are issued by higher levels of hierarchy, or realized in interaction with higher levels.

METHODS OF MAINTENANCE OF TECHNICAL SYSTEMS IN INDUSTRY

The maintenance strategy is possible to define as a type of maintenance systems, specified by concept, organization and character of maintenance process, as well as the relationship between individual levels on which the maintenance is performed. Traditional maintenance strategies, like preventive maintenance, are a set of procedures undertaken before the technical system failure, with the aim to prevent failure due to undermining the exploitation characteristics. The policy of preventive maintenance includes the following forms: preventive replacements by time resource; preventive maintenance according to the condition, as a diagnostic process which enables assessment of technical state of a part and technical systems and has a goal to enable maintenance actions exclusively according to the real technical state; preventive control by time resource and replacement of components depending on their state and its forecast; preventive replacement by exploitation resource regardless of the components' state; preventive control by exploitation resource and replacement in accordance with their state and forecast of the state. Corrective maintenance represents a set of procedures undertaken after the failure, with the goal to return the exploitation characteristics within defined values. This method is applied with accidental failures. Maintenance planning is difficult in case of corrective maintenance, but the utilization of the elements' lifetime is more complete. Combined maintenance implies exploitation of technical systems until the occurrence of failure. Then, corrective maintenance actions are undertaken with the aim to bring the failed part back into operation. Also, preventive maintenance actions are undertaken, in accordance with the realized time or exploitation resource. Models of managing the technical system maintenance include the verified strategies: Reliability Centered Maintenance – RCM, Total Productive Maintenance – TPM, Results Oriented Maintenance – ROM, Operation Centered Maintenance – OCM, Risk-based maintenance – RBM.

Maintenance management is the direction and organization of resources in order to control the availability and performance of industrial plant to some specified level [3]. Maintenance is a function in an organization that operates in parallel with production. Moreover besides being a support function, it has a role in gaining and maintaining competitive advantage. Therefore, it is very important for all relevant stakeholders to be aware of the role of maintenance in achieving sustainable and competitive business environment. An integrated model for maintenance function has been conceptualized and depicted in Figure 2. [4] The primary output of production is the desired product while demand for maintenance would be the secondary output as a result of production activities. This output would act as input for the maintenance function. Maintenance results in restored production capacity which would further act as secondary input to production thus completing the maintenance cycle. Thus production manufactures the product while maintenance produces the capacity for production. The quality of the final product is affected by both the production process and the quality of maintenance work.

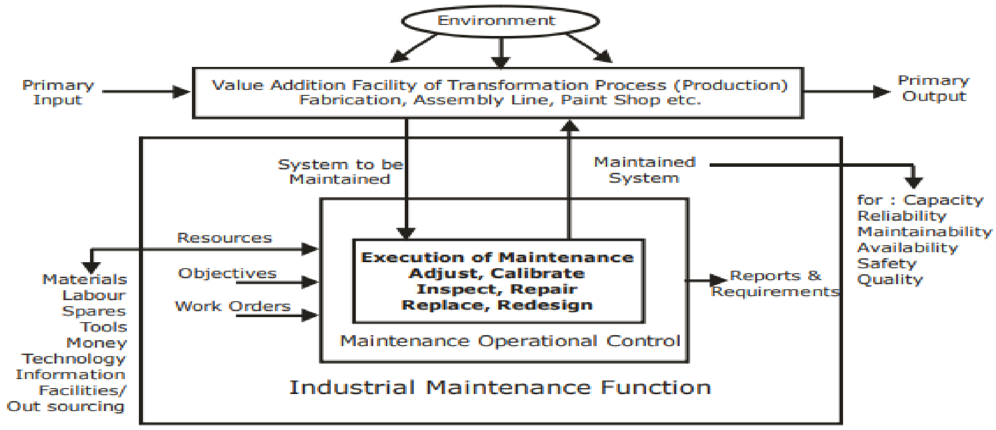

Figure 2. “An integrated input-output model for maintenance function” [4]

The maintenance process approach from the aspect of philosophy, strategy and management methods, as well as development of maintenance over time, are given in the Figure 2. Applying any maintenance system is of crucial importance for the user of the technical system, as it needs to provide effectiveness and quality of the technical system in total. [5] Applying the traditional maintenance strategies (preventive, corrective and combined maintenance) and contemporary maintenance strategies (RCM, TPM, maintenance according to state, prediction-based maintenance, “accelerated” maintenance strategies) give various results.

AN EXAMPLE OF INTERCONNECTION BETWEEN QUALITY AND TECHNICAL SYSTEM MAINTENANCE IN AUTOMOTIVE INDUSTRY

One of the most important aspects of any product is quality. The following examples shall present the way in which quality and maintenance are mutually connected during the production process. The presented examples are from a production system in automotive industry, engaged in cable production. Machines and devices on which the production is done are definitely one of its most important segments. To produce a safe and high-quality product, it is necessary to ensure the security of the devices themselves. One way to do it is maintenance. Faulties occuring during the production largely depend on security and optimization of the machines, which directly influence the quality of production system and the product itself.
One of the most frequent problems in automotive industry – cable production – is the production of connectors. The connectors are specific and for this paper very interesting product, as they are produced on several different machines, and due to their small size and structure containing wires of small cross-section, prone to various types of breakage. Therefore, this production process is very delicate.

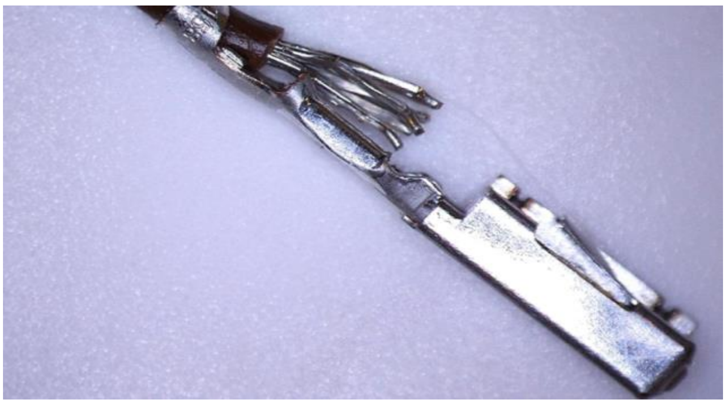

Figure 3. “Wires outside the crimp”

The Figure 3 shows the wires outside the crimp, which represents a very delicate faulty during the production process. It can cause a system failure in the final product, which is car in this case. Upon receiving the information on poor quality of a product, the immediate measures of maintenance and prevention of the faulty are undertaken. The entire production system is checked, as well as the working boards and all machines. The product itself is also checked (Figure 4).

Figure 4. “Checking the correctness of the product after the production process, as a preventive measure”

Figure 5 shows a correctly crimped connector (left) and an incorrectly crimped connector (right).

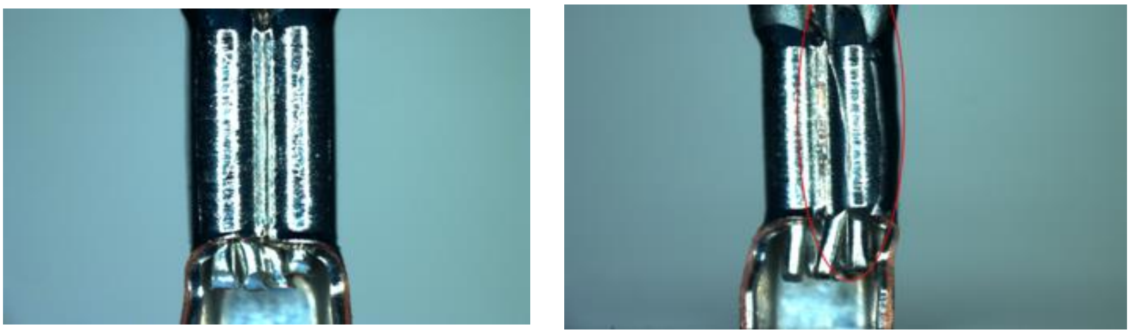

Figure 5. “Correctly crimped connector (left) and incorrectly crimped connector (right)”

Taking all causes into account and after detailed analyses, it was identified that the product was manipulated adequately during the production, but the machine on which the connector was produced was not optimized and adequately maintained.

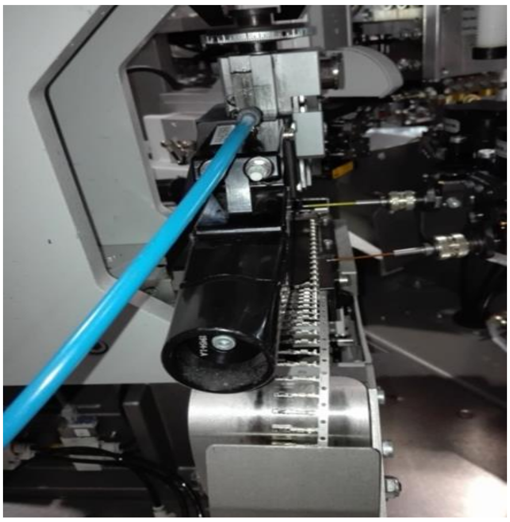

Figure 6. “Connector crimper”

The Figure 6 presents a machine on which the connectors are crimped. The cause of the faulty was identified. The pneumatic tool moves the terminal by the air impulse. The terminal can be positioned incorrectly in the process of crimping, leaving some wires outside the crimp. As a corrective measure for this cause, corrective maintenance of the machine is introduced. Also, instead of pneumatic tool, a mechanic one is used for producing the connector. The mechanic tool moves the terminals according to the position of the press, so the incorrect positioning of the connector cannot occur. Through the maintenance process and optimization of the machine, the corrective measure prevents the reoccurrence of the faulty in serial production.

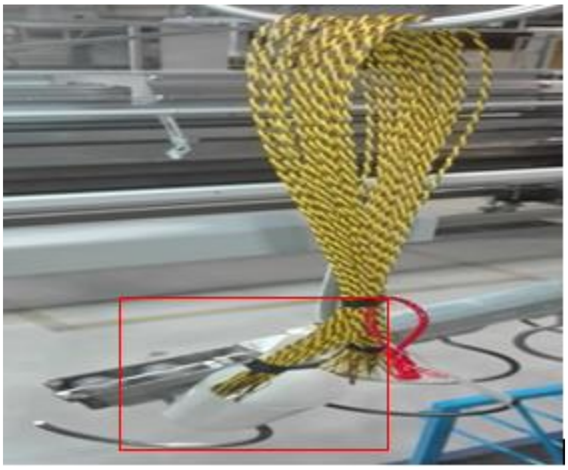

Figure 7. "Corrective measure – introducing additional tools in form of plastic cups, which prevents damage of the connectors during production"

Apart from the undertaken corrective maintenance measures, a preventive one, in the form of plastic cups, was introduced as protection from damage of the connectors during the production process.

CONCLUSION

Based on the facts presented in this paper, it can be concluded that the product quality and maintenance of technical systems in production are closely connected and cannot go without one another. Their adequate alignment leads to prevention of faulty on products, as well as prevention of production machine and the product damage. In this way, greater prosperity is achieved. Apart from keeping the continuous quality, fixing products and machines, as well as production halt are prevented. The company retains its good reputation and, most importantly, prospers economically.

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ADVOCATIVE DESIGN OF THE WORK AS A FACTOR MOTIVATION OF THE WORKER

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Abstract: Due to the changed conditions in the market, there is great influence that put new demands on all market participants. These new situations touch even the employees of the enterprises themselves. The basic resources of each organization are people. They have a very important role for the company, because their performance, knowledge and capabilities depend on the success of the company and influence the progress and development of the company. With efficient staff, the company achieves its goals, which is why it is necessary to pay great attention to them first of all by their desires in order to provide a work environment that will enable business tasks to be performed. The design of the workplace not only affects the efficiency of the employees, but also on the satisfaction and health of employees, which in the end also carries the responsibility for increasing or decreasing productivity and efficiency. In order to create an effective workplace, it is necessary to keep in mind that one workplace is effective by various factors, depending on the activity of the work. Adequate job design plays a major role when it comes to properly completing business tasks.
Key words: ergonomics, working conditions, job design, efficiency, motivation

INTRODUCTION

When the work environment is concerned, certain factors, their presence or absence may have different effects on employees. The greatest impact on productivity is the size of the room, the limitation of sound and air quality. Satisfaction is mostly affected by privacy, illuminated, while the health of workers depends to a large extent on air quality, temperature in workplaces and lighting [1-4]. However, it must be added that in all these dimensions interpersonal relations also play an important role. Working conditions directly or indirectly affect not only the emotions of employees, but also the possibility of focusing and thus the performance of workers. It is necessary to create a work environment in which employees will feel safe and comfortable and will be happy to spend time, as satisfaction will be expressed in their behavioral ways. Quality and properly adjusted working conditions can have a major impact on the effectiveness of employees. According to US surveys, average losses amount to over $ 7,300 per employee per year, due to poorer productivity and various complaints from workers due to medical and other difficulties, causing an irregular workplace, of which over 50% of injuries are related to spinal injuries [2]. The non-energy working environment means that objects, tools and even climatic conditions are not adapted to the needs of employees, their physiological proportions, physical and psychological needs. It is precisely for the reason that this example shows that large losses can occur if these requirements are not met. When working conditions are observed, it is not possible to consider its impact on employees, primarily on motivation. Motivation is one of the most important factors that influence the employee's outcome, but also the business success of the company in the market. Different inborn and acquired motives can be distinguished, whereby all wishes are to be fulfilled to the extent possible in order to achieve efficiency and better business results. With the Industrial Revolution, there is a need for more attention to be paid to the employees themselves for their needs during working engagement. As already pointed out, the motivation of employees is closely related to the work environment, and for this reason, the analysis of working conditions can not be omitted. Considering that employees spend a large part of their time in their workplaces, it is of the utmost importance to adapt to sealed work equipment, as well as the work environment itself. Each work environment consists of two spheres, both material and social. The material sphere includes production machines, objects of work, hygienic-technical protection, various equipment and installations, working and other premises such as restaurant, library, social activities, etc. While the social sphere of the working environment encompasses relations between employees, established in a formal or non-formal way, which depends on the social climate that is created [3]. All these factors or elements of the working environment influence and play an important role in the formation of the atmosphere of the work environment, and the conditions present in the workplace further affect the behavior and satisfaction of the worker and the entire image that creates the working environment. Thanks to the recognition of the importance of this factor, the research done so far gives an insight into the current situation from different aspects. The results of the UK-based survey show that exposure and stress-related stress in workplaces have increased in comparison to previous years, while satisfaction with working conditions is estimated at 3.6 on a scale of 1 (the lowest score) to 5 (the highest estimate). The influence of employees on employee satisfaction may be reflected in the fact that 88% of respondents think that quality of work is an important factor affecting job satisfaction and 49% of respondents would work for 1 hour longer if the working conditions were improved [4] . The degree of stress among employees is increasing and this does not only have a negative effect on the results of business but also causes health problems in the employees themselves, while the desire for adequate working conditions is not only a fundamental need but also an increasingly expressed desire of employees, due to which a large number of employees were willing to work longer than expected. According to the survey [5] that included the satisfaction of employees with working environment, primarily with employees who perform their work tasks in offices, only 21% of respondents are very satisfied with their workplace, 32% are satisfied, 28% of respondents have no special opinion on this factor , and only 14% are dissatisfied while 5% are extremely dissatisfied. Preferred are closed jobs or partly open positions, which at the same time provide greater freedom of cooperation between employees, but also protect the privacy of all employees. However, another survey shows that 49% of respondents estimated that the best idea comes with a work table, and 67% think they are more effective if they have the opportunity to work with associates [4], with no job type, but jobs of open character are more encouraging and promoting cooperation between employees.

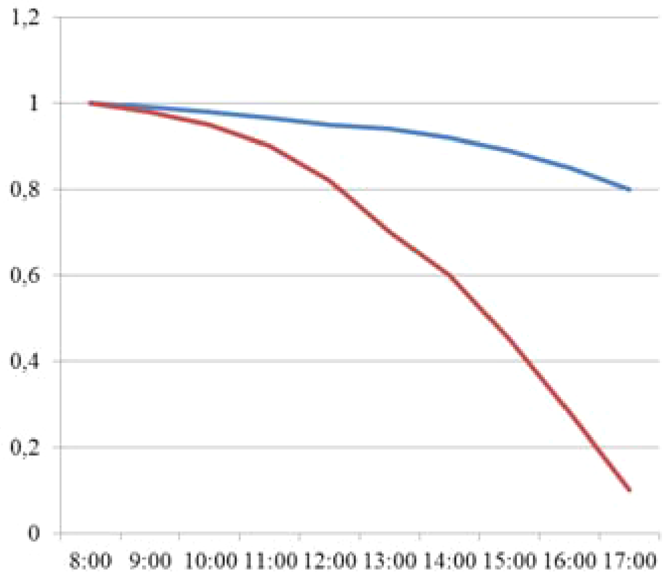

Figure 1. Comparative point of fall in productivity in different conditions [2]

Figure 1 presents a comparative overview of labor productivity trends, depending on the design of the workplace. The bottom, red line represents productivity in the usual circumstances in which no great attention is paid to the design of the workplace itself, while the upper, blue line stands for effectiveness in adapted working conditions. The peak of productivity in both cases is the highest at the beginning of working hours, however, the difference can be seen by moving away from time or later hours of working time. In adequate working conditions, the greatest decrease in productivity that can be observed at the end of working hours in inadequate conditions until the fall of the same intensity comes in the fourth time since the beginning of work.

Subject research

The scientific discipline that studies the analysis of the workplace, work space, business environment is Ergonomics. More broadly, this discipline is being largely adopted in European companies.

Unfortunately, this discipline is not very much represented in the territory of Serbia due to the lack of financial resources. The subject of the research includes the design of the working environment in order to discover the degree of its impact on employee satisfaction. Business becomes increasingly demanding business processes in many segments becoming more complicated in order to increase the safety of radicals in workplaces employers all over the globe applying the International Standards. However, a number of employers of their business processes are based on the use of non-native staffers, and also the occupational safety standard.

The problem of research

It is known that the presence or absence of certain factors in the work environment, as well as overall and working conditions, differ in effect on employees, and are different from them. It is precisely because employees do not evaluate in the same way the same factors of the working environment, but their opinions and expectations differ depending on the personality and needs in the course of the performance of their tasks, that is, from the activity in which they are employed. When looking at research related to the design of a workplace that has a major impact on employee motivation, it can be concluded that there is very little work on this topic. For this reason, a survey was conducted on this topic.

The aim of the research

This research paper deals with the problems of the workplace, that is, through the analysis of the influence of factors and the characteristics of the workplace on the employees, it is intended to create a picture of the current situation in the territory of the city of Zrenjanin. It also wishes to point out possible omissions and shortcomings in working environments, where employees attach great importance and analyze the relationship between the work environment and job satisfaction.

Research hypotheses

Main hypothesis: Adequate job design positively influences the motivation of employees
Hypothesis 1: Good working conditions increase the performance of employees

Location and sample of research

The survey was conducted in the territory of the city of Zrenjanin, by interviewing employees in companies operating in this territory. The survey includes employees from different industrial branches, half, year of service, etc.

Techniques, instruments and methods of research

The survey covered questions related to the motivation of employees where one of the main motivation factors for employees is the adequate design of the workplace and working environment. The idea of the research was to determine the extent to which employees are comfortable working environment, adequate equipment necessary for the execution of work tasks.

Research results

The paper presents the most important data collected during the research. The survey included survey of employees in the service and manufacturing sector in the territory of the city of Zrenjanin. The questions were based on the areas of job design with the goal of discovering the impact of working conditions on job satisfaction. The questions were evaluated on the basis of a five-step scale, where 1 (the value is) and 5 (the highest value). The percentage of male sex was 40%, while the percentage of women polled was 60%
One segment of work was the basis for the application of standards that are exceptional for the protection of workers' health and safety. Most respondents point out that they are not sufficiently

familiar with the application of standards themselves and that it is not entirely certain whether the company applies exclusively its standards or the application is focused on an international ISO standard. Research work included 57% of employees in the service sector, while 43% of the respondents were employed in production activities in the territory of the city of Zrenjanin. The survey covered respondents from two categories of business areas. On the basis of the obtained results, it was decided that certain issues covered by the questionnaire will be considered and addressed. The authors decided to analyze in the further work of the presented issues because they consider that they mostly help to understand the hypothesis and give the best insight into the current situation related to the topic covered by this research work.

Does, in your opinion, have an impact on the productivity of a pleasant work environment and appropriate equipment?

After analyzing the results of the total number of respondents, data were obtained showing that respondents without taking into account sex, evaluated this conclusion with the highest score of 5 27%, a score of 4 gave 50% of the respondents, the average grade 3 gave 17% of the respondents, 6% of respondents, while the lowest grade 1 was not given by one respondent. Male male respondents rated this statement with a higher rating than female respondents. 33% of male respondents rated this statement with the highest score of 5, while female respondents rated this statement with the highest score of 5 in 24% of cases. Figure 7 gives a structural overview of the male and female sex responses.
To what extent do these factors influence you and motivate you to carry out work tasks?
Respondents believe that for them the greatest motivation for successful performance of tasks is the amount of earnings they earn and this assessment was assessed with a score of 4.66, followed by the most motivated by pleasant interpersonal relationships and rated this statement with the second highest rating of 4.36, followed by the contemplation related to the pleasant working environment that the respondents rated with the score 3.9.
Respondents consider that it is most necessary to constantly invest in equipment modernization and have assessed this statement with a score of 4.42, the climate impact assessment was assessed with grade 4.26, the need for a greater focus on safety was assessed with grade 4.15, followed by a con-statation that relates in a more comfortable and convenient installation they rated with grade 4.11 and the lowest score was obtained by reference to modern communication systems that received the grade 4.07

What is the reason why the company does not invest in the modernization of equipment that would allow a pleasant working atmosphere, a safer work environment and in that way create a higher productivity of the business?

In this case, the respondents point out that the biggest reason that prevents modernization of equipment and new investments in the same lack of funds, and this statement was confirmed by 35% of respondents, it is also a very devastating finding that the lack of knowledge also represents an obstacle to the improvement of work equipment, where this statement was confirmed 31% of respondents. Next, the conclusion is that there is no need to improve 18% of the confirmed responses and the lack of awareness and the importance of the potential, there were 16% of the respondents' affirmative answers.

To what extent are you satisfied with the current working conditions in your workplace?

Most respondents consider that they are satisfied with the current conditions in their workplaces and 33% of respondents rated this statement with the highest rating of 5, 27% of respondents gave this assessment 4. Only 7% of respondents are not satisfied with the current conditions at their workplace. On the basis of the obtained data, it can be concluded that the employees are mostly satisfied with the current working conditions, which means that the equipment, as well as the working conditions, are in accordance with their needs, so that they can perform their work tasks in an adequate manner.
According to employees' opinion on job design, the following factors need to be improved: 10.19% possibility of socialization and cooperation among employees, 10.19% emphasis on team work,

11.11% more relaxed atmosphere, 14.81% more creative work environment, 12.04% better office furniture and equipment, 13.89% better computer equipment, 14.81% better protection of the environment, 6.48% security and safety at the workplace, 5.56% none of the above, 0.93 others [7]. Employees see the greatest potential for improvement seeing the possibility of cooperation among employees, and the smallest need exists in security measures.

The lowest number of respondents with 29% believe that the comfort of office furniture and equipment is only satisfactory, 26% think that improvement is needed, 24% good, 6% very good, 15% unsatisfactory [47]. How influential the work environment can have on employees is shown by the fact that 46% of the respondents stated that the quality and design of the workplace influenced their decision on whether to accept or not offered a job [11].

Employers consider that the application of International Standards requires a lot of time and so many of the material and non-material resources they often are not able to comply with because of the preference of applying for independent internal statesmen. It is necessary to attach special importance to preserving the health of employees. It is very important to apply risk control in one continuous process. OHSAS standard 18001 is based on Deming's approach in a methodology known as plan, do, check, act [12]. The application of a series of standards for assessment, health protection at work is of paramount importance for the successful operation of each company.

Employees highly appreciate the possibility of cooperation and since the open-source working environment promotes this type of cooperation and provides greater opportunities for employees to be in contact with other employees, even from other sectors, it is necessary to have in practice more such a type of job design.

Adequate radon environment not only refers to design and comfort, but also plays an important role in creating safe working conditions. When this factor is concerned, it is possible to point out that women are more likely to value the security factor from 57%, while men with 44% expect security and safety in the workplace. However, regardless of the size of the organization or activity, 75% of respondents consider that investing in job design, affecting their feelings and attitudes toward the organization, and feel more appreciated [11].

A large number of employees (97%) believe that the environment is an important factor that influences creativity in the workplace [7]. The creativity of employees is also a very important factor of successful business and what is the big influence of the environment in which they are located. Although creativity depends to a large extent on an individual, the environment surrounding it also plays a very important role in finding different and new solutions to the problems present. Without the innovation of business processes, there is no success in the market, which is why it is necessary to apply innovative business strategies. The strategy used by successful companies is to be the first in the domain of business and at the same time the best. It is necessary to extract at risk with certain funds, to support new ideas that will later give the company a remarkable success when placing it on the market.

According to the source [8], most of the companies involved in this survey (60%) support working environments primarily in the form of open offices, rather than individual offices, considering that open positions are converging employees. As with teamwork, the benefits of collaboration amongst employees encouraged by this kind of job design can have many benefits. These benefits include: better business results, richness of diversity and diversity, improvement of business skills, greater satisfaction, increased work discipline, more efficient decision-making, as well as improved communication and information [7].

The survey conducted in 2013 provides a good insight into the significance of the work environment. When asked how the examiners assess the importance of a well-organized work environment, no respondent considered it an important factor, while 38% said it was important, and 62% very important. However, 41% of respondents are not satisfied with the work environment, 44% are satisfied, 9% are very satisfied, 6% have no attitude. Also, an important indicator of the current situation in workplaces is given by the fact that 71% of the respondents consider that there are sources of distraction in the form of interference and noise at their workplaces [10].

According to the survey [5]. that included the satisfaction of employees with working environment, primarily with employees who perform their work tasks in offices, only 21% of respondents are very satisfied with their workplace, 32% are satisfied, 28% of respondents have no special opinion on this factor , and only 14% are dissatisfied while 5% are extremely dissatisfied. Preferred are closed jobs or partly open positions, which at the same time provide greater freedom of cooperation between employees, but also protect the privacy of all employees. However, another survey shows that 49% of respondents estimated that the best idea comes with a work table, and 67% think they are more effective if they have the opportunity to work with associates [4]. with no job type, but jobs of open character are more encouraging and promoting cooperation between employees.

CONCLUSION

After the collected data and the performed research, it was concluded that a great role for the successful performance of the tasks has an adequate workplace permit and pleasant working conditions. Most respondents think it is very important to provide employees with adequate equipment, as well as working conditions, but they also have a great deal of support for the outcome of pleasant interpersonal relationships in the cotyledons. Most of the respondents rated this statement with the highest rating. After the survey, all the collected data was processed in Excel.
The obtained results show that the hypothesis from which the research work has been started has been confirmed. Respondents, regardless of their gender, age, years of work experience and business activity, pointed out that modernization of work equipment is of great importance for the success of the work, but it is also very important in the collective to create pleasant working conditions, but at the same time, interpersonal relations between the employed. At the end of the conducted research, the importance of this topic, which is engaged in research work, is proven, and to what extent it is appreciated by the employees. For this reason, it is very important to see the need to improve working conditions, which has great potential to positively influence and improve business results.

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MODERN STRUCTURAL STEELS

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Abstract: Increasing demands for economical production of welded steel structures requires the application of modern high quality and special steel. The paper presents the standards of Eurocodes, the specificity of Swedish steel: Hardox and Weldox, increasingly popular structural steels and the knowledge of Corten Steel U.S. Steel, which has recently been very attractive in architecture.

Key words: steel construction, permissible voltage, strain, elasticity, probabilistic methods

INTRODUCTION

The use of iron, and then steel, as a material for supporting structures in construction is relatively recent date. The first iron construction is only a little over 200 years old. Steel constructions have specific properties and significant technical and functional advantages in comparison to other building materials, which makes them widely used for all types of construction structures. Steel as a basic material for supporting metal structures is used for almost all types of construction objects, such as flooring buildings, hangars, sports halls, stadium roofs, garages, bridges, silos, bunkers and many other structures for special purposes. [1] The use of steel in industry and construction today has become a fact understandable by itself; in addition, the use of steel in the design of housing and working spaces among architects has been ranked as a very topical topic. [2]
Steel for construction (C <0.25%), is applied in the form of profiles, sheets, tape, wire for reinforced concrete. High carbon steel is used for reinforced prestressed concrete.

Diagram stress - dilatation for steel

A typical stress diagram - a dilatation at tightening for different-quality steels is shown in Figure 1. The initial part of the diagram, for a state of lower strain, is the straight line for all types of steel, and represents the area of elasticity. For hot rolled concrete steels (GA and RA, class B according to EC2), the linearity of the stress diagram is clearly expressed - dilatation up to the yield point, according to which is taken as the technical yield point - Figure 2a). These are very tough steels, in which significant dilatations are achieved during the rupture (in the case of smooth steel, the dilatation at break can reach 26% as shown in Figure 1).

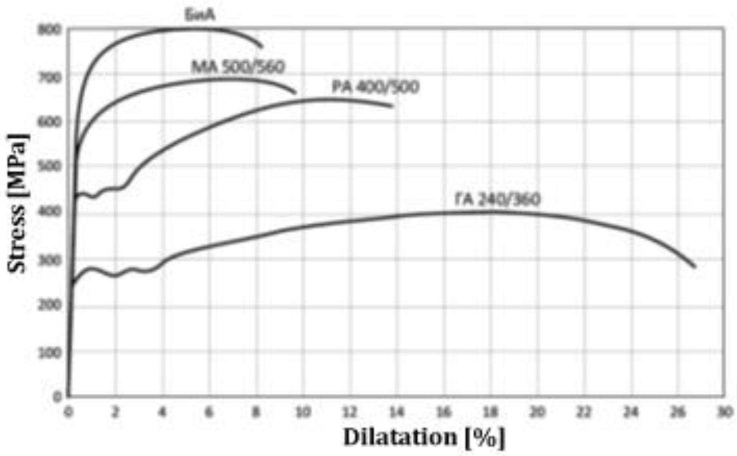

Figure 1. Diagram stress - dilatation for different types of steel

For cold-drawn steels (MA and BiA, class A according to EC2), the yield point is not clearly expressed, and hence the conventional technical yield point is defined - Figure 2 b). It represents the stress at which the residual dilatation after unloading the sample is 0.2%. The value on the diagram represents the dilatation at which the maximum value of the stress is recorded, which will be of significance for later calculations using the reinforced diagram. [3]

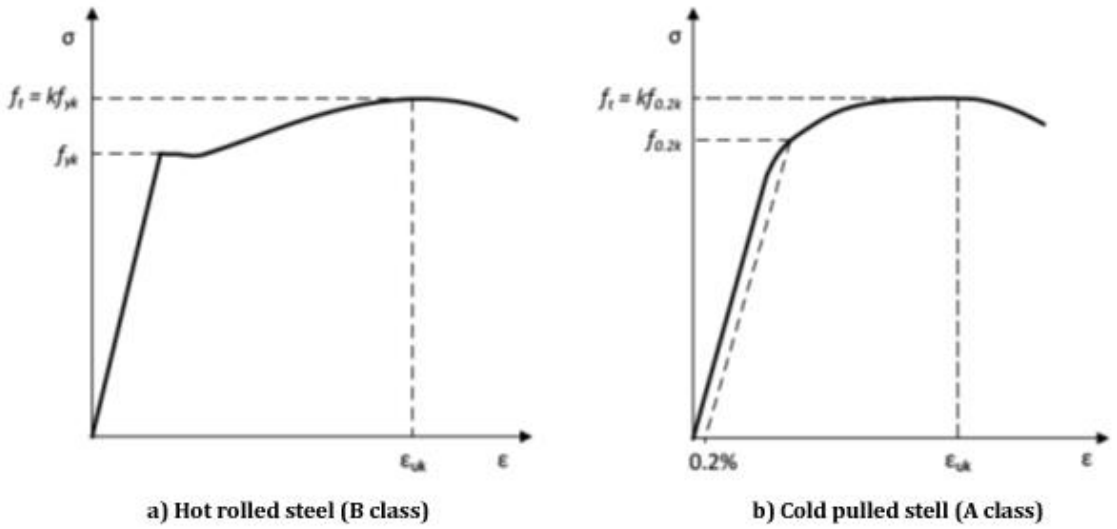

Figure 2. The yield point for a) hot rolled steel and b) cold drawn steel [3]

Eurocode - a family of European standards

The concept of tolerated stresses was until recently present in the standards for the calculation of bearing steel structures in our country. However, despite many years of good practice in designing steel constructions around the world, the concept of tolerated stresses has become obsolete, primarily because of the tendency of civil constructors to get closer to the real behavior of steel structures and to use the post-elastic reserve that steel as an extremely elastic-plastic material possesses. Bearing in mind both the progress in theoretical disciplines and the numerous experimental tests carried out around the world, it is quite understandable that for thirty years in the most developed countries of Europe and the world concept of tolerated stress has been abandoned, taking a deserving place in the history of development of the methods for calculating steel structures.

The new era belongs to probabilistic calculation methods that rely on the stochastic nature of random variables and probability theory. Namely, most of the variable sizes that figure in the construction calculation such as loads (snow wind, seismic, temperature, human traffic, traffic load), material properties and geometric data are stochastic in size and subject to probability laws. All these sizes should be introduced into the calculation using the appropriate curve distribution, and the ultimate goal is to demonstrate that an appropriate safety factor has been achieved, that is, the probability of failure or breakage of the construction is satisfactory small.

However, the application of such calculations is very complex and demanding, and as such is not suitable for engineering practice. Therefore, simplification has been made by assuming that all sizes used in the calculation are subject to the same probability law, that is to say, the same distribution curve - the normal, or Gaussian distribution function.

These methods of calculation are called semi-probabilistic, or semi-probabilistic methods, and today they are the basis for most of the modern regulations for the construction calculation, as well as the Eurocodes for constructions that are applied in all EU Member States, and most recently in our country. Eurocodes represent a family of European standards for the calculation of construction structures, which include the effects on constructions, as well as the construction calculation from various materials.

According to the content, they are divided into ten parts:
- Eurocode 0 (SRPS EN 1990): Basics of designing structures
- Eurocode 1 (SRPS EN 1991): Influences on constructions
- Eurocode 2 (SRPS EN 1992): Design of concrete structures
- Eurocode 3 (SRPS EN 1993): Design of steel structures
- Eurocode 4 (SRPS EN 1994): Design of composite steel and concrete structures
- Eurocode 5 (SRPS EN 1995): Design of wooden structures
- Eurocode 6 (SRPS EN 1996): Design of masonry structures
- Eurocode 7 (SRPS EN 1997): Geotechnical design
- Eurocode 8 (SRPS EN 1998): Design of seismic-resistant structures
- Eurocode 9 (SRPS EN 1999): Design of aluminum structures

In addition to the essential differences between the deterministic concept of calculation present in the theory of aloved stresses and semi-probabilistic concepts, which are reflected in a different treatment of stochastic variable quantities, it should be noted that the Eurocod provide engineers the posibility to fully utilize the elastic-plastic properties of the steel as a material and precisely determines the load capacity of the cross sections or elements, taking into account post-elastic behavior, that is, the plastics of the load reserve. Consequently, the behavior of the construction is no longer limited to the elastic region, but its behavior is analyzed up to reaching the limit state of load capacity or usability.

Boundary conditions are those state of construction whose reach or exceeding the construction ceases to fulfill the defined conditions of load capacity or usability. Accordingly, the boundary states can be divided into two essentially different groups:

- limit states of usability (*ULS - Ultimate Limit State*) and
- limit load conditions (*SLS - Serviceability Limit State*).

In the Eurocode, therefore, the boundary state method is applied, based on the semi-probabilistic concept of the budget. The application of these methods of calculation enables the design of more rational steel structures, which, bearing in mind the foregoing market game, was one of the main reasons for the introduction of new methods of calculation and new regulations. [4]

Construction steels

The construction steel is required to have good mechanical properties, to be well processed by cutting or deforming (forging, rolling, pulling, pressing), to have good weldability and low cost.

According to the strength (yield strength), these steels are grouped into four groups:
1. low-strength steel, Re < 250 MPa,
2. medium strength steels, 250 MPa < Re <750 MPa,
3. high strength steels, 750 MPa < Re <1550 MPa,
4. ultrahigh strength steels, Re > 1550 MPa.

Carbon structural steels belong to the first group, and alloyed steels to the second, third or fourth. Construction steels are used for steel structures or structural elements in mechanical engineering, bridge construction, shipbuilding, boiler construction, pipeline construction and similar structures. [5]

Fine-grain construction steels

Fine-grain structural steels are completely relaxed - JUS C.B0.502.

Elements such as vanadium, niobium, titanium, which bind to nitrides, or nitrides and carbides, give fine-grain steel. Fine grain construction steels are used for the construction of high pressure pipelines, pressure vessels, road vehicle elements, railway wagons, gas tanks, bridges, industrial halls, various welded structures and special purposes.

This steel group includes: basic steels, high temperature steels and low temperature steels.

Fine grain structural steels are marked in a specific way, other than JUS C.B0.002. [5]

Innovative bridges around the world

Of the 12 most innovative bridges in the world, by the Institute of Technology in New Jersey, two brigdes have been presented in this paper, respectively.

Dayang-Kunshan Grand Bridge - Jiangsu Province, China
This 164 km long bridge bridge is the world's longest bridge. It was opened in 2011 as a viaduct along the Beijing-Shanghai highway. Since the bridge was so long, designers had to consider the curvature of the Earth. The construction of the bridge involved 10,000 people and the construction lasted for 4 years. The bridge is supported by 9,500 concrete pillars and consists of over 450,000 tons of steel construction. The bridge is able to withstand typhoon, strong earthquakes and a load of 300,000 tons. [6]

Figure 3. Dayang-Kunshan Grand Bridge

Kuripla Bridge - Brisbane, Australia
Bridge "Kuripla" was the first solar bridge. It was opened in 2009. Longer than the "Blackfriars" bridge, "Kuripla" is a 469 meter long pawn and bicycle bridge. The bridge consists of a complex network of pylons, a hanging construction based on principles that produce synergies between balanced force and compression of components to create a lightweight structure that is freezing on ease is still extremely strong. The bridge contains 550 tons of steel construction and 6.7 kilometers of spiral cable. The bridge construction includes 18 steel structural panels, 20 structural steel pylons, 16 horizontal pylons and 72 finished concrete slabs. The bridge has a system of LED lighting that can be programmed to produce a range of different light effects with 75% to 100% of power coming from solar energy. [6]

Figure 4. Kuripla Bridge

Weldox and Hardox steels

Increasing demands for economical production of welded steel structures condition the application of modern high quality and special steel. Undoubtedly, such steel products are from the Swedish corporation SSAB Oxelősund AB, with a steel spiral of commercial name Weldox and Hardox steel. Due to the high wear resistance (Hardox), the high yield strength of 290 to 1100 MPa, and the toughness and at -60 ° C (Weldox), these steels can meet the design requirements and the economics of making welded steel structures in mechanical engineering, construction and process equipment.

Standardized fine-grain structural steels in the flat products area, in relation to their properties and purpose, are classified into steel-bearing steel structures (S), pressure vessels (P) and pipelines (L). They are delivered as normalizing rolled (N) and thermomechanically rolled (M) or improved (Q). The base for the development of fine steel is a completely soothed structural steel (S355) in a normalized state which, besides Al, also contains elements Ti, Nb, V, Mo that build nitrides and carbonitrides, as centers of crystallization to create a fine-grained structure. Controlled completion of rolling in the normalizing annealing area and controlled cooling rate produced steels of normalizing the proper state of delivery, increased flow and toughness. By introducing thermomechanical rolling, with modifications of the temperature range of the ending of rolling and controlled accelerated cooling, further reduction of the crystalline grain and precipitation reinforcement is possible, thus producing steels with a high yield stress, good toughness and low temperatures, good resistance to stress corrosion, uniform features by thickness and good weldability.
There are three groups of fine-walled structural steel:

- Normalized glow (microalloyed) steam output from 255 to 500 N / mm^2;
- Improved (water-cooled) steam stress steel up to 950 N / mm^2 and high-strength steel (400HV, 500HV and 600HV wear resistant);
- Thermo-mechanically-rolled steel pumps with a yield strength of 700 N / mm^2.

In order to further increase the tensile properties, thermo-mechanically-rolled fine-grain steels, in addition to the presence of micro-regulating elements, also contain alloying elements, primarily Cr, Mo, V, and the delivery status is tempered and released (Q). Weldox and Hardox steels, the method of production and properties important for further processing (deformation, welding) and application, include quality steel, delivery conditions N, M and Q for a wide range of applications. **Hardox** steel sheets are designed for high wear and tear wear, which ensures high hardness, high strength and excellent toughness. They are applied to equipment used in the handling of ores, and which is exposed to various types of stress-abrasion - slip and impact loads, often combined with high deformation. Hardox steels can have a hardness of 400 or 500 HB and handle all these stresses, with five to ten times longer service life than conventional steel for the same purpose.
Weldox steels are high quality steels with yield strength of 355 MPa to 1100 MPa, with a tensile strength of 460 MPa to 1500 MPa and have guaranteed toughness at temperatures up to - 60 ° C. In addition to the low content of C, these steels have low content of alloying elements, and therefore a low carbon equivalent, which allows excellent weldability without the use of special precautions. [7]

Manufacture of Hardox and Weldox Steel

Hardox and Weldox steels are cast in ingots. Before rolling, the ingots are heated to approximately 1200 ° C, and then progressively roll to the required final shape, i.e. panel or profile. For **Hardox** steels controlled rolling ends in the austenitic area. The warming temperatures of slabs are usually lower in comparison with conventional rolling. The first part of the rolling is performed in the area of recrystallized austenite (above 950 ° C), where recrystallisation is done by rolling, while the austenitic grain is reduced by reducing the thickness of the cartridge. Rolling is then continued in the area of metastable austenite (between Ar3 and Ar1), where cold deformation occurs, and the austenitic grains remain deformed. At this stage there is no recrystallization or complete recrystallization. During the transformation, each deformed austenitic grain provides many ferrite initiations along the crystalline

boundaries and deformation belts that occur in the interior of the crystalline grains. Subsequent transformation creates a large number of ferrite grains that enhance the strength and toughness.
In **Weldox** steel, for more efficient controlled rolling, the alloying is done with smaller amounts of Nb. This element raises the area of recrystallized austenite to higher temperatures, which enables the production of larger plastic deformations of austenite during rolling. For different types of Weldox steel, controlled cooling is also applied with water cooling. Three options are used:
a) for Weldox 355, 420, 460 - cooling with water to room temperature, which gives very good weldability properties, with low hardnesses in heat-affected zones (ZUT). These steels are resistant to stress corrosion.
b) for Weldox 500 - water cooling below Ar1, then cooling in the air that gives excellent values
toughness of steel, with a little increase in strength. They are used for low temperatures, for pressure vessels, pipelines, ships. It is possible to use an annealing to reduce stress due to welding, without harmful consequences.
c) for Weldox 700 -1100, as well as thicker Weldox 460-500, - cooling with water (at 900 ° C) to room temperature, then release to 580-650 ° C, which gives good toughness at low temperatures, and code thick sheets and high strength. The effects of cooling water allow reducing the alloying. Sheet metal, which needs to be improved, must be cooled by air. [7]

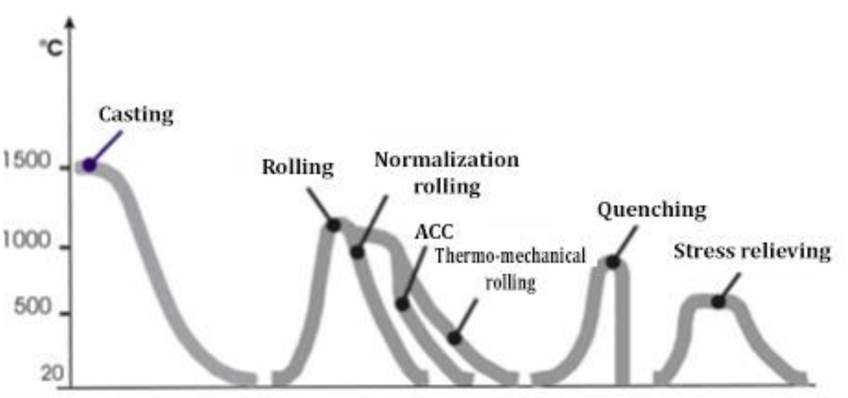

Figure 5. Schematic representation of steel types obtained by changing rolling and cooling conditions [7]

Corten steel

Corten steel has become more and more popular in architecture and interior design. When used properly, it fits and complements its natural environment, and the shades of red, brown and orange are becoming even more texturalally interesting as exposure to the rain and sun adds traces and lines on the surface of the material, with darker or brighter tones of the rust effect.
Raw steel, most commonly known under the trade name Cor-Ten ™ (Corten) of U.S. Steel is a group of alloys of steel that develop stable oxidation and do not require additional coatings. After exposure to normal environmental conditions, it acquires a dense, brown colored barrier, that is, a layer that protects it from further oxidation.
Cortene steel acquires its self-protection properties from added corrosion-resistant alloys, such as copper, nickel and chromium. The most popular rusty steel is ASTM A 588, also known as Cor-Ten ™ B, or an "improved" version of cortex steel. The material is available in roll form and boards in accordance with the American standard ASTM A 709, and it can be made of various structural shapes, and in a wound state in accordance with the ASTM 606 standard, from which the roof and decorative panels are made.
Corten steel is used extensively for bridge construction, especially in the southern parts of the United States, where salts for ice solubility in winter are not usually used. The use of cortex steel is not recommended in coastal areas, where ice-soluble salts are widely used, in places where ventilation of metal surfaces is limited, or where steel is protected from initial weather conditions. The Aloha Stadium in Honolulu, Hawaii, was built in 1975, is an excellent example of a situation in which the

exposure to the salt filled with salt has prevented the stabilization of cortex steel, allowing steel to continue corrosion beyond acceptable limits.
In addition to aesthetic, the advantages of corten steel versus colored or galvanized steel are: lower processing costs (in fact, none), lack of harmful chemical compounds from protective coatings or paints, reduced maintenance and simplified inspection, less risk of injury due to elimination of cleaning and painting, and larger longevity compared to color structures. Disadvantages include the potential coloring of adjacent materials, additional attention is required when handling the material and possible uncontrolled crops under certain weather conditions or salt exposures.
In contemporary architecture, cortical steel can be used in every type of project, and it is perfect for urban and rural environments alike. Its industrial appearance provides him with a place in an increasing number of projects whose designers want special features in the exterior or interior. [8]

Figure 6. Application of cortex steel in the interior [8]

CONCLUSION

With its characteristics, steel has proved above all to be a reliable, highly accessible and suitable material, metal, in the construction of building structures, bridges, buildings. Standardized, clean or especially alloyed, enriched by the addition of individual elements, long-lasting endurance and load capacity of various loads, pressures, in characteristic weather and geographical conditions, today is a challenge for designers and architects in finding new designed solutions. This entails specific technological testing and improvement of its properties for the special use of the material in question. There are several types of steel according to the application, ie the purposes, types of machining or fabrication of certain steel profiles.
Steel of different chemical composition, with improved properties and characteristics, provides the possibility of economical production and quality of welded structures. As such, steel is today the theme of the prosperity of individual countries, industry and creativity.

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