TITI 2021

XII International Conference

XII International Conference

TEXTILE SCIENCE & ECONOMY

PROCEEDING

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SUSTAINABLE FUTURES IN FASHION & TEXTILE

FACTS

UNIVERSITY OF NOVI SAD
TECHNICAL FACULTY „MIHAJLO PUPIN“
ZRENJANIN, REPUBLIC OF SERBIA

12th international scientific – professional conference

TEXTILE SCIENCE AND ECONOMY

Proceedings

Zrenjanin, 10th December 2021.

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University of Novi Sad, Technical Faculty „Mihajlo Pupin“, Zrenjanin, Republic of Serbia

Publisher:
University of Novi Sad, Technical Faculty „Mihajlo Pupin“, Zrenjanin, Djure Djakovica bb, 23000 Zrenjanin, Republic of Serbia.

For publisher:
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CIP - Каталогизација у публикацији
Библиотеке Матице српске, Нови Сад
677(082)(0.034.4)
INTERNATIONAL Scientific-Professional Conference Textile Science and Economy (12 ;
2021 ; Zrenjanin)
Proceedings [Elektronski izvor] / 12th International Scientific-Professional Conference Textile
Science and Economy, 10th December 2021, Zrenjanin ; [editor Marija Pesic]. - Zrenjanin :
Technical Faculty "Mihajlo Pupin", 2021. - 1 elektronski optički disk (CD-ROM) : tekst, ilustr. ;
12 cm
Nasl. sa naslovnog ekrana. - Str. 6: Introduction / Marija Pesic. - Bibliografija uz svaki rad.
ISBN 978-86-7672-349-2
а) Текстилна индустрија - Зборници
COBISS.SR-ID 53728009

Note:

All the papers presented in this publication have been reviewd. However the editor’s and organizer are not responsible for the contents presented within paper.

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INTRODUCTION

Technical faculty “Mihajlo Pupin” University of Novi Sad has organised the twelfth International Conference “ Textile Science and Economy ” TNP2021.

This year, the conference gathered a large number of participants who shared their ideas and achievements in various fields of the textile industry. Recently, the textile sector has been facing with very important challenge related to the sustainability of our planet and it directly affects the business in the textile and fashion sector. Connecting and cooperating on the basis of knowledge and experience represents a significant path towards sustainability and development of the textile and fashion industry.

Through the presentation of the participants' paperst the conference analyzed the current situation in the textile industry, presented new approaches related to textile materials, technologies and business models that can contribute to improving the solution of sustainability.

The TNP Conference became a traditional meeting of researchers from all over the world, every year. We are open and thankful for all useful suggestions which could contribute that the next, XIII International Conference – Textile Science and Economy, become better in organizational and progra sense.

The Chairman of the Organizing Committee:

Asst. Prof. Marija Pesic

Zrenjanin. 10th December, 2021

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CONTENTS

SUSTAINABLE SURFACE PROCESSING BY LASER FOR TEXTILE DESIGN

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ABSTRACT

This paper explores processing of textile by laser on wool and polyester blended fabric. As a contactless processing, the laser beam could melt, evaporate and engrave textile surface to achieve unique pattern appearances on the fabric with shade changing effects without the application of water and chemicals. During laser processing, the parameters of the resolution (dpi) and the pixel time (μs) have been modified and optimized for the requirement of surface design. The results indicated that digital laser surface processing is an sustainable and cost-effective option for textile surface design. With lower resolutions, engraved vague patterns with small laser beam dots can be achieved. While the treatment resolution increased, clear patterns could be performed. Based on the same resolution, the higher pixel time can export more energy, which makes the pattern look more clearly. As a sustainable and feasible surface treatment approach, laser processing has potential application in textile industry for textile processing.

Key words: Laser processing, Surface design, Textile, Technique, Sustainability

INTRODUCTION

In recent years, some techniques have been applied to reduce the impact of pollution from dyeing and printing processes which could carry out sustainable approaches for textile manufacture. Digitalized processing has become a popular approach to treat textiles for function or embellishment purpose. As a contactless processing, processing of materials by CO_2 laser is starting to reveal its potential in textile design such as no physical contact, a high degree of automation and fast and precise cutting and engraving (Yam, 2010). It has been increasingly applied in textile industry to generate simple or complex graphics and patterns onto fabric surface through laser beam scanning. Laser processing can be conducted by using the sources of carbon dioxide gas laser (CO_2 laser), neodymium-doped yttrium aluminium garnet laser (Nd: YAG) or diodes lasers (Brichtová, 2007; Roux, 1989). Of all the various types of lasers, CO_2 laser is the most efficient for processing of material which is not good conductors of heat and electricity. Because at the wavelength of 10.6 microns, the laser can easily be absorbed by most organics that absorb 10 micron light (Rajagopal, 2008; Ready, 1997; Yuan et al., 2012). Although many research have applied laser processing of some fabrics, most of the studies focused on the laser cutting method. Even though decolor indigo dye on fabrics has carried out using laser engraving pattern on denim fabric or the cotton finishing process (Chow, Chan & Kan, 2011; Kan, Yuen & Cheng, 2010; Ondogan et al., 2005; Pezelj, Cunko & Andrassy， 2004; Štěpánková, Wiener & Dembický, 2014; Tarhan & Sarıışık, 2009; Tortora & Johnson, 2013; Yuan, 2018). Nowadays, laser has been applied in denim industry as a bleaching tool to create patterns on the denim fabric with color fading, worn appearance or printing effect which can instead of conventional chemical treatment (Dascalu et al., 2000; Jiang, 2015).

In this study, laser processing is conducted on wool and polyester blended fabric to create unique patterns. The fundamental factors that affect the quality of fabric and changes in the fabric surface are physical and mechanical properties. To assess the performances of the laser processed fabrics, the measurements of weight, air resistance, surface observation, color appearance, tear strength and low-stress mechanical properties were investigated. During the design stage, the graphic method and resist method are applied to create patterns on textile by laser processing. All the results indicate the laser processing is an innovative and sustainable way for textile designs.

METHDOLOGY

Laser processing

In this study, laser processing is carried out by using a commercially designed pulsed CO_2 laser machine coupled to a computer-controlled table under controlled atmospheric conditions. The experimental parameters for the resolution - intensity of laser spot (20, 30 and 40 dpi), and the pixel time - the time of the laser head positioning on each image point (120 and 270 μs), were varied to investigate the laser processing effects on wool/polyester blended fabric.

Process

The laser processing of textile is shown as follows: (1) generate graphics in software, (2) convert the graphics to grey scale, (3) send graphics and patterns to laser system, (4) set processing parameters, (5) identify the location of the laser processing area, and (6) conduct laser processing.

Material

Wool/polyester blends have a wool-like feel and appearance with some wool-like feel and appearance, and some of the easy-care aspects of polyester (Collier & Tortora, 2001). It also may enhance the abrasion resistance and easy-care properties such as crease retention and wrinkle resistance, and this also can prevent bagging, sagging and stretching (Mendelson, 1999). In this study, 45% wool and 55% polyester blended plain weave fabric (density: 48 ends/inch & 40 picks/inch) with fabric weight of 80.35g/m^2 and thickness of 1.35 mm under 5 g/cm^2 pressure was applied for laser processing. The fabric was conditioned at 21±1^{o}C and 65±5% relative humidity for 24h before experiments and evaluations.

Physical and mechanical properties

Fabric weight

The weight (g/m2) of the square fabric samples sized 200mm×200mm was measured by using an electronic weight meter (GR200, A&D Company Ltd., Japan) in accordance with the ASTM D 3776-07 “Standard Test Methods for Mass Per Unit Area (Weight) of Fabric”.

Air resistance

The air resistance of the fabric samples was measured based on the constant rate of air flow at 0.04m/s generated by the piston motion/cylinder mechanism and passed through a specimen into atmosphere using Kawabata Evaluation System (KES-F8-AP1) under air flow resistance tester (Kato Tech Co., Ltd., Japan) following the Kawabata specifications.

Observation of the fabric surface

The weight (g/m^2) of the square fabric samples sized 200mm×200mm was measured by using an electronic.

Tear strength

The tear strength of the fabrics before and after laser processing was measured by an Elmatear digital tear tester (James H. Heal & Co Ltd, England) in accordance with ASTM D 1424-07a “Standard Test Method for Tearing Strength of Fabrics by Falling-Pendulum Type (Elmendorf) Apparatus”. Five samples per fabric type with dimensions of 80mm×100 mm for both the warp (for tearing across the weft) and the weft (for tearing across the warp) directions were evaluated. The results of the tear strength are represented in gram-force (gf).

RESULTS AND DISCUSSION

Physical and mechanical properties

Fabric weight

The changes in unit weight of original and laser engraved fabric samples were measured and the results are shown in Figure 1.

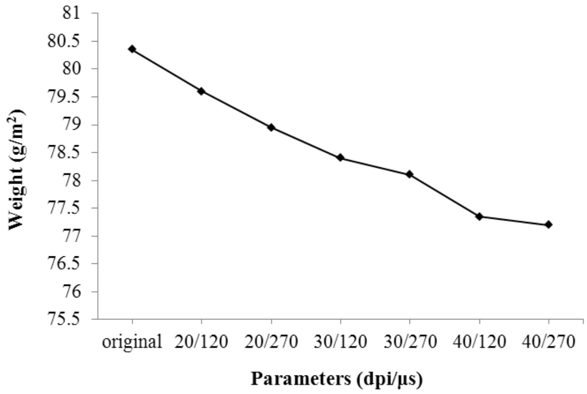

Figure 1: Weight of original and laser engraved fabric samples

The results show the weight of the engraved fabrics decreases from 0.9 % (20 dpi/120 µs) to 3.9 % (40 dpi/270 µs) which due to the reason that high resolution and long pixel time can engrave, melt and evaporate some of the wool and polyester fibres on the surface of the fabrics. Therefore, the unit fabric weight decreases, and the fabrics become lighter when compared with original fabric.

Air resistance

Air resistance is one of the major properties of textile materials and an important factor that influences the wearer's comfort of textile materials. It is governed by factors such as fabric thickness, density, structure, and surface characteristics. The results of air resistance tests of the original and laser engraved fabrics are shown in Figure 2.

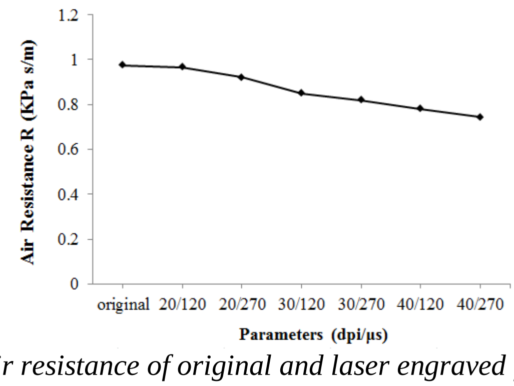

Figure 2: Air resistance of original and laser engraved fabric samples

A higher air resistance means that a smaller amount of air could flow through. The values presented in Figure 2 represent the air resistance property of original and laser processed samples. There was a decrease from about 0.71 % (20 dpi/120 µs) to 23.7 % (40 dpi/270 µs) in air resistance of the treated fabrics compared with the original one. The value changes of air resistance are related to the fabric thickness and surface characteristics. It is clear that there are only slight changes between the air resistance of original and engraved samples when the resolution at 20 dpi from 120 µs to 270 µs were used because only a minimal amount of fibres were affected by the laser beams. The greater changes in air resistance were possibly due to the melting and evaporation of the surface fibres by laser thermal processing. The decrease in air resistance was possibly due to the surface fibres were etched away by laser beams and more air spaces between the fibres and fabrics resulted. It became therefore possible for more air to pass through the fabric, resulting in lower air resistance.

Surface observation
Figure 3 show surface micrograph images of the fabrics before and after laser processing with different resolutions and pixel times.

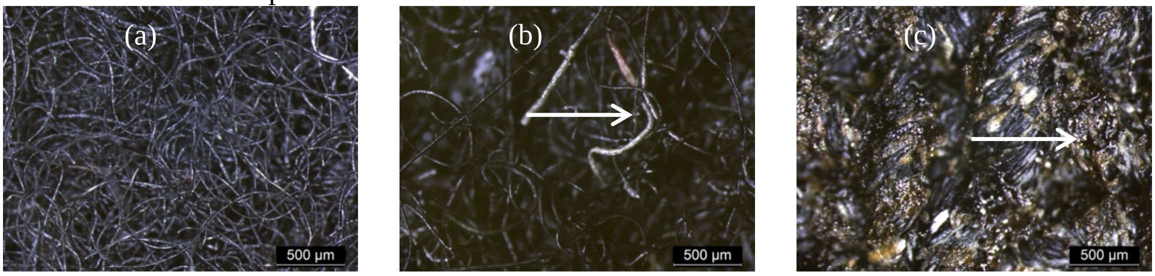

Figure 3: Surface micrographs of original and laser engraved fabric samples

With reference to the micrograph images of the original and laser engraved fabric samples as shown in Figure 3, different surface morphology images of wool/polyester blended fabric is observed. With the application of laser energy, the wool fabrics show different engraved effects. Figure 3(a) shows an original micrograph image of wool fabric with naturally wavy wool fibers. Through laser processing with a lower resolution and shorter pixel time, a few fibers become burned as shown in Figure 3(b). When the pixel time is prolonged, the wool fibers turn yellow and melt with polyester fibers as shown in Figure 3(c). The results clearly show that with higher resolutions and longer pixel times, the laser energy was increased, so some of the surface fibers form burnt, bubbled and etched effects on the fabrics and this could also affect the color appearance.

Tear strength
The tearing strengths of the fabrics in both the weft and warp directions were evaluated and the results are shown in Figure 4.

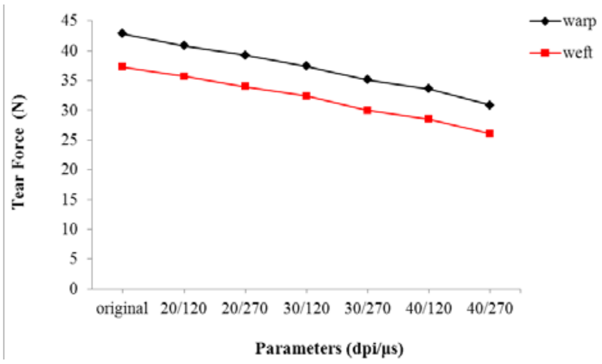

Figure 4: Tear strength of original and laser engraved fabric samples

The results show that there is a decrease in the tearing strength from about 5 % (20 dpi/120 μs) to 28 % (40 dpi/270 μs) in the warp direction and 4 % (20 dpi/120 μs) to 30 % (40 dpi/270 μs) in the weft direction for the treated fabrics. This is due to the reason that some fibers are engraved and melted by the laser beams, so that the strength of the fabrics decreases.

Design application
Graphic method
This method involves the use of a computer with graphic software to design, edit and process images which make the design process faster and permit ideas and designs to be easily changed. After the

patterns were designed, the fabrics were placed in a laser treatment cabinet for processing after confirming the position and size of patterns.

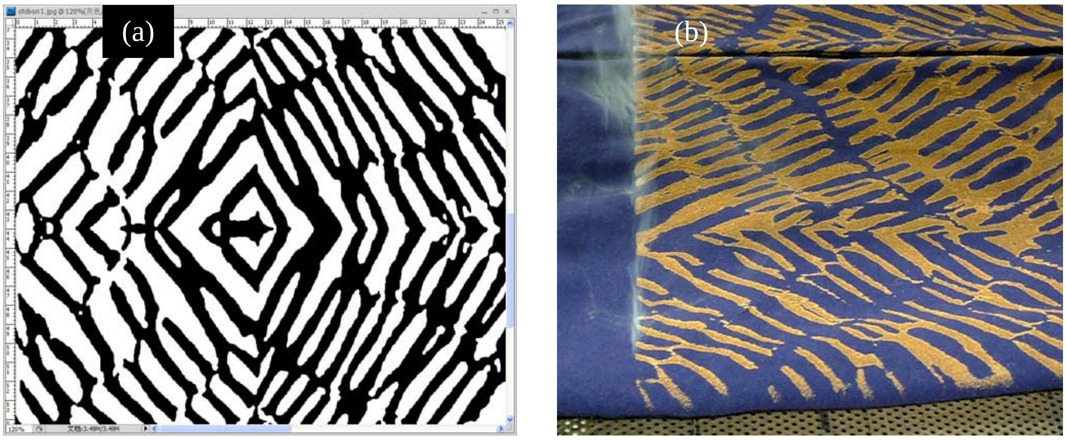

Figure 5: Laser engraved wool/polyester fabric with graphic method

The wool and polyester blended fabric shown in Figure 5(b) was designed and engraved by laser at 30 dpi/270 μs in accordance with the designed patterns. The pattern shown in Figure 5(a) was made using computer-aided design method. Some wool fibers on the fabric surface were ablated and burnt which resulted in different degrees of lightness of yellow. The un-engraved areas retained the original color against the engraved areas. This design demonstrates the effect of laser processing on the wool and polyester blended fabrics by means of graphic pattern design methods. As a result of design pattern and laser processing, the fabrics with novel textures and patterns are made possible.

Resist method

Resist method is used in textile design for decoration. Based on resist method, some imagery, intricate patterning and interesting effects could be achieved. There are many types of resist method such as in tie-dye by use of tying, stitching, folding or clamping the cloth to prevent the dyestuff affect the inner areas. In this research, the resist method of stitching and tying were applied for textile design by using laser processing. After processing, some vivid changes in the color shade with tie-dye patterns were achieved as shown in Figure 6.

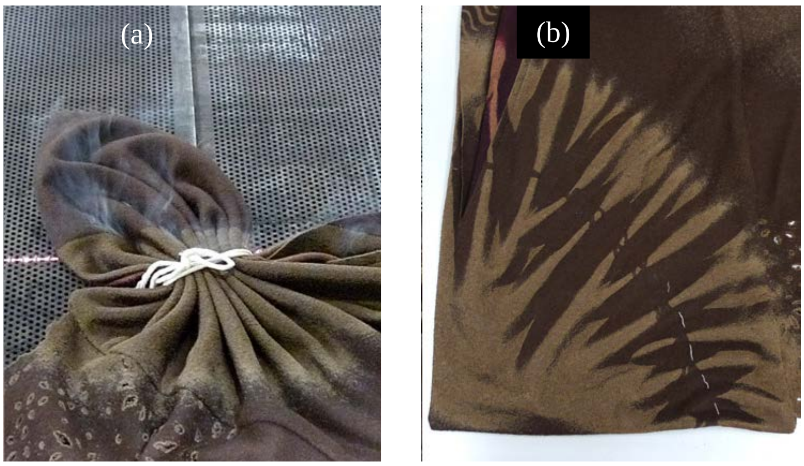

Figure 6: Laser engraved wool/polyester fabric with resist method

The treatment result shows the laser treated brown fabrics engraved at 40 dpi/270 μs. According to the resist pattern design method, the fabric was tied and stitched with thread as shown in Figure 6(a) for laser processing. This design was explored to study the effects of laser processing on the wool and polyester blended fabric in combination with the resist method of tying and stitching. After laser treatment, some fibers on the fabric surface burned and melted, the resisted areas retained their original color whereas the engraved areas show a different shade of brown according to the intensity of the treatment in Figure 6(b).

CONCLUSION

Laser processing of textile for surface design on wool and polyester blended fabric is carried out in this paper. The characterizations of original and laser treated wool and polyester blended fabrics are assessed and analyzed. The results indicate that the physical and mechanical properties such as weight, air resistance, surface observation and tear strength are modified after laser processing. The colour of laser processed textile surface turned yellow compared with the original fabric and the yellowness was enhanced with the increase of the laser treatment parameters. All the changes are related to the reason that the fibers on the surface of the laser engraved fabrics have ablated, burnt, engraved and evaporated in accordance with an increased pixel time and resolution in each case. After laser processing, the results indicate that this technique is suitable for surface design and embellishment of textile surface because of its practical value including: (i) flexibility; (ii) better quality; (iii) production efficiency; (iv) accuracy; (v) more perfection in the finishing of the final products; and (vi) environmental friendliness.

The textile design indicates that unique surface designs could be developed by combining laser processing and developed design methods such as graphic method and resist methods. In accordance with the design results, the benefits are (i) a surface design process of laser processing could be conducted in textile design; (ii) convenience for textile embellishment with computer-aided design method; (iii) a selection of unique laser processing effects could be achieved on textile surface with certain parameters on wool and polyester blended fabric; and (iv) flexibility of orders and small batch customization production. The application of laser processing for textile surface designs could also cater to the demand for sustainable design and products in textile industry and market.

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THE TEXTILE INDUSTRY'S ENVIRONMENTAL FOOTPRINT: METHODS FOR DESIGNING MORE SUSTAINABLE FUTURE

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ABSTRACT

The article examines particular aspects of the environmental footprint made by the textile industry. Today, we face vast ecological challenges, and for much pollution and many environmental damages caused, the textile and fashion industry is responsible. This research paper aims to summarize the critical problems of the industry from the perspective of a producer, introducing the problem with which this producer faces and the innovative solutions they strive to solve the matter in an environmentally aware way in cooperation with researchers and students. The authors also introduce their participation in one international academic project in which their student group was involved with their Photobook Project. The author seeks a constructive response to future opportunities by presenting good practices in the sustainable circular economy and environmentally friendly textile manufacturing, introducing innovative applications for a more sustainable future.

Key words: textile industry, sustainability, environmental footprint, waste management, circular economy

INTRODUCTION

We live in a world of environmental crises, where every single action of humankind deeply affects our Earth's well-being. Today, the textile industry faces vast ecological challenges. It is responsible for much pollution, such as greenhouse gas emissions, large-scale exploitation of water resources, energy consumption, and environmental pollution by microplastics; just a few of the many environmental damages caused by the textile and fashion industry. According to 'Global Footprint Network,' humanity needs the equivalent of 1.7 Earths. (Global Footprint Network n.d.) One of the largest, fast-growing, globalized, labor-demanding, and polluting industries globally, the textile industry is responsible for countless environmental, ethical, social, and individual issues.

The three main end uses of textile production are clothing, home furnishing, and industrial use. One of the areas, the clothing sector, occupies an immense production cycle, especially Fast Fashion. Fast fashion empowerment has drawn a conspicuous amount of environmental, ethical, and social concerns. For decades, professionals in the clothing industry have been implementing different approaches to ecological problems, and now many organizations are aspiring to make circular fashion a new trend. Unfortunately, it is not as exciting and easy-going as it sounds.

The carrying capacity of the Earth's natural ecosystems is finite. With the disruption of the ecological balance, the needs of humanity exceed the available resources of the planet. In light of today's economic development, *"there [is] growing evidence that humanity [is] moving further into unsustainable territory"* (Meadows et al. 2005) warn in their book entitled Limits to Growth: The 30-Year Update. That is why we have to promote sustainability.

GLOBAL TEXTILE INDUSTRY: ECONOMIC FACTS

However, the last year was a challenge for all the sectors of the world economy as well as for the textile industry because of the global pandemic situation; nevertheless, in 2020, the global textile market was worth $ 1,000.3 billion and is expected to grow further over the next ten years due to population and economic growth. (Grand Wiew Research 2021)

The fashion segment led the textile market and accounted for more than 74.0% of the global revenue share in 2020, owing to the increasing consumer spending on clothing and apparel. In addition, high consumer requirements for crease-free suiting and shirting fabrics and quality dyed and printed fabrics across the globe are likely to drive the global market demand for textiles from 2021 to 2028. Nevertheless, the demand for medical textile products has increased despite the loss of labor, especially in developing countries, and decreased apparel production and textile supply chain. (Grand Wiew Research 2021)

Key environmental Challenges

There are five main lifecycle stages that any textile product goes through, in which a considerable amount of natural resources is consumed and hazardous emissions are produced. Those stages are:

- Raw Material Preparation
- Manufacturing Process
- Distribution
- Consumer Use Phase
- End of life

The textile industry is the second most polluting industry after oil, responsible for one-tenth of global carbon emissions, and the fourth most impactful category is primary raw materials and water use (less than 1% of the world's textiles are processed into new textiles). The production of clothing has roughly doubled in the last 15 years. The amount of fiber produced per year has reached 100 million tonnes worldwide, increasing by 3-4% every year. Globally, USD 460 billion worth of garments and textiles that could have been worn or used are discarded every year. The industry's ecological footprint in the European Union in 2015 was 195 million tons of carbon dioxide, and its water footprint was 46400 million m^3. Plastic microfibers, which are shed from synthetic clothing and enter the water supply system, account for 85% of the waste on the ocean shore. The EU textile industry is estimated to generate 16 million tons of waste per year, of which only 25% is recycled.

Our research deals with creating innovative methods for the waste that arises during production and by producing defective products or accumulating unsellable stock.

Importance of application of the Circular Economy Model in the Textile Industry for Achieving Greater Sustainability

The Hungarian government aims to move as quickly as possible to an innovative, green, digitized circular economy capable of processing its waste. The transition to a circular economy is a priority task, a severe challenge at a national level, and the implementation of sustainability principles is given priority in all policy areas and government measures. Recently, several strategic documents and action plans have been developed, which include in their name the objective of linking ecological and economic sustainability. A proposal has also been made to set up a redemption and deposit system for PET, aluminum, and glass. The set goals include the simplification of selective waste collection and the development of an overlapping model. As a first step, they plan to create places where we can give away our unnecessary things, used items, clothes, books, even on the way to work. The next phase is to set up municipal collection points in each settlement, where any waste can be sorted. Applications for constructing these collection points will be announced early next year. The next step in this will be to expand existing landfills and support the construction of new landfills.

In 2018, the Hungarian Business Council for Sustainable Development, the Dutch Embassy, and the Ministry of Innovation and Technology established the Circular Economy Platform, to which 61 member companies have already joined, and nearly 140 business solutions have been developed. It is necessary to find out together how the elements of the circular economy can be applied in the operation of companies. Anyone can join the Platform, regardless of membership. They aim to involve and educate businesses about the benefits of the circular economy by organizing yearly workshops, working group meetings with the support of ING Bank. This year, the Platform's flagship project is the training of domestic companies in the circular economy based on Dutch methodology.

The primary key in motivating people to be more sustainable is to improve education about the topic, with the primary objectives being the following:

- to acquire and understand the basic concepts of the circular economy
- to understand the limited availability of resources
- to develop the ability to apply the circular economy business model
- to identify the needs of companies concerning the circular economy
- develop systems thinking and problem-solving skills
- understand the management tools related to the circular economy
- identify technological and economic opportunities and constraints, and find the best solution
- to develop the ability to cooperate and the necessary interpersonal skills
- to minimize the negative impact of production stages, consumer recovery stages, and recycling stages on the environment

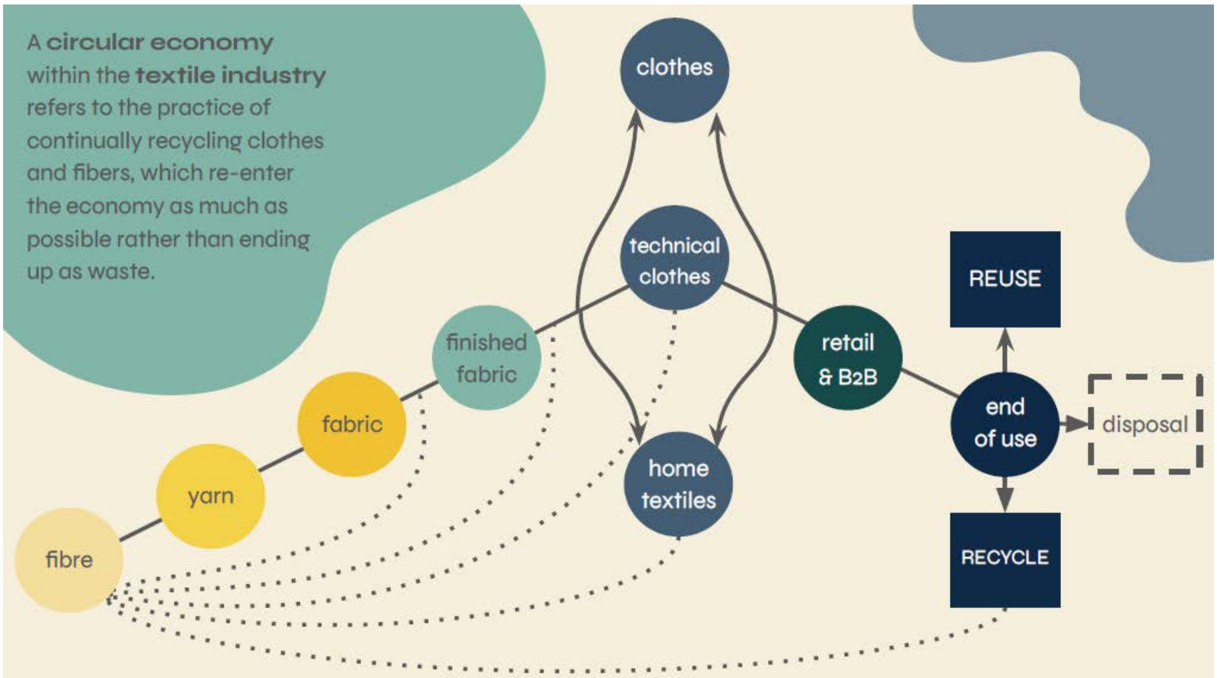

Figure 1. Processes in the textile value chain and opportunities for circulation (Student Prezi)

A circular economy within the textiles industry refers to clothes and fibers continually being recycled to reenter the economy as much as possible rather than ending up as waste. "A New Textiles Economy" stated the four key ambitions needed to establish a circular economy: *"phasing out substances of concern and microfiber release; transforming the way clothes are designed, sold and used to break free from their increasingly disposable nature; radically improving recycling by transforming clothing design, collection, and reprocessing; and making effective use of resources and moving to renewable input."*

METHODS: RECYCLING SOLUTIONS FOR HOSIERY PRODUCTION WASTE

Amazon Ltd. was founded in 1991; it has been manufacturing tights, which is still its main activity. In recent years, the production technology and the quality of the finished products have also been constantly evolving. The production capacity of tights has also gradually increased. Currently, it is 500,000 pcs/month**.**

Figure 2. Hosiery machinery and the waste generated during the production (right)

Amazon Ltd. produces approximately 15 bags of waste during one month of production. One bag of waste is around 5-6 pounds, which means in a month, 15 x 5.5 = 82.5 kg waste from hosiery production is generated. There are still eight hosiery factories in the country, which means 82.5 kg x 8 = at least 660 kg polyamide hosiery waste is generated monthly in Hungary. It means that nearly 8 tons of hosiery-only waste in the country each year is not reused, only stored in warehouses. The stocking factory Amazon Ltd., which has been on the market since 1991, has accumulated nearly 30 tons (990 kg x 30 years) of production waste since its foundation.

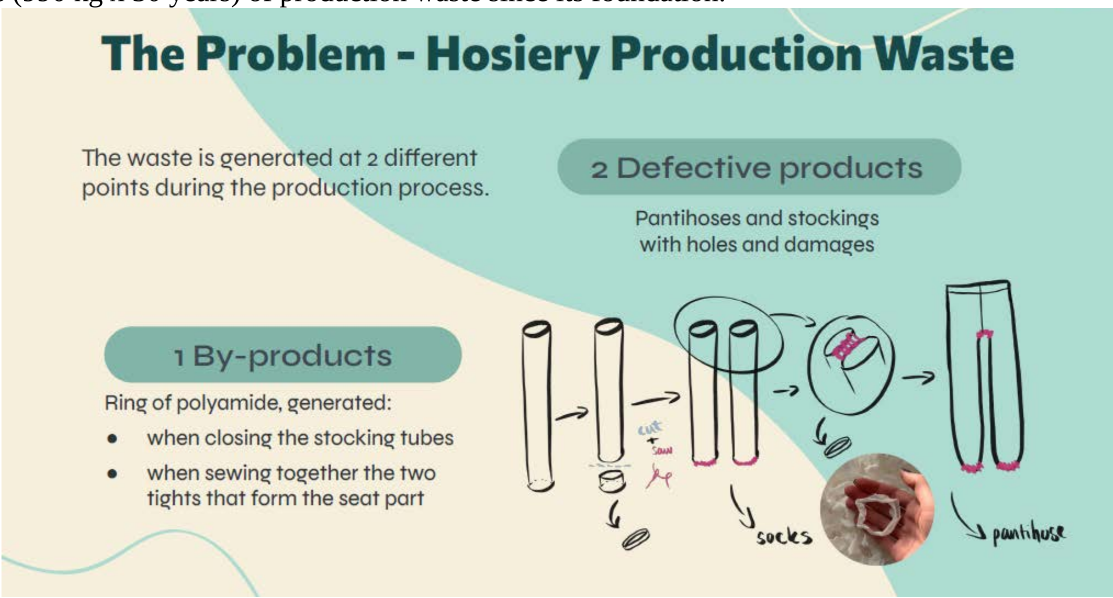

Figure 3. Presentation panel of the students with a short introduction of the core problem

The polyamide production waste generated during hosiery production has not yet been processed in Hungary. The research aims to develop innovative and environmentally friendly technology instead of disposing of textile waste. On the one hand, disposal is harmful to the environment because the polyamide shrinks, melt, and does not burn completely, while decomposition products that are harmful to health and the environment are also produced. The company's aim is also to produce secondary raw materials from production waste. With this, not only would it be possible to process the waste generated during its processes, but our company could also use the by-products and waste materials of other companies by buying and applying high-speed nylon recycling, single extruder machinery. The project aims to find solutions for processing polyamide waste by extending the company objective with innovative technology to reduce the environmental impact.

Recycling Processes for PA6

Recycling polyamide 6 is essential, mainly because its presence in landfills is hazardous and may result in massive fires containing hazardous gases. There are different ways of recycling Polyamide 6. These are:

- De-Polymerization or Chemical Recycling

This method disintegrates the long polymer chain into monomers that can be polymerized again, converting the waste into products with the quality of the virgin polymer.

- Extracting Recycling or Recovery of Polymer Components

This method is used to recover individual components of the polymeric mixture without attaining the monomer level.

- Thermal Recycling

This method involves only energy recovery during incineration of the polymer waste.

- Mechanical Recycling or Re-melting

This technique is to perform melt-bending of the complete structure.
The research group TEXCoLAB organized by the Rejtő Faculty deals with the application possibilities of this last method. As a part of the research, students were involved with their innovative individual projects in the design work. We have managed to create an inspiring and functional collection made of 100% recyclable materials.

RESULTS: DESIGNING SMALL FURNITURE WITH HOSIERY WASTE

According to our research, 16 million tons of waste are generated per year by the textile industry within the European Union. In our sample project, we were looking for a solution to reusing stocking waste extracted by a Hungarian hosiery factory, Amazon Ltd. The student project was about designing small furniture made up of defective products and falling textile scraps. This waste can be an excellent filler as the textile also has antibacterial properties, so it does not seem mite, mold, and remain durable.

Figure 4. Thesis masterwork project "Small Furniture in Spirit of Circular Economy" by Zsófia Antalóczy (2021)

DISCUSSION AND DISSEMINATION OF THE PROJECT RESULTS IN THE FRAMEWORK OF INTERNATIONAL PROJECT COOPERATION

Our student group applied the research results for its project introduced for an international academic audience realized within the LABi3 project of the Hochschule Hannover University of Applied Sciences and Arts. In that project, the Óbuda University Rejtő Sándor Faculty has been involved as a Consortium Partner in the 2019-2023 period. The coordination group aimed to work out with the international partners innovative teaching methods highlighting the issues of sustainability and Sustainable Circular Economy (SCE) in the framework of international cooperation, involving different academic disciplines.

The work progressed in for regular, prescheduled online meetings, in which the participating universities worked out the framework of the final achievements expected. The final goal was to work out new teaching materials by using advanced online tools and platforms, giving an example of SCE in the territory of their country. The final goal of this conceptually designed program was building a progressive community in a few steps. After the Kick-Off Meetings organized during September 2020 and the Pleminirary Phase during the 2020/2021 semester, during the winter semester of Academic Year 2021/22, the students participated in student workshops, can share their experiences, were involved in quiz sessions, and finally they prepared and presented their project presentations in front of an international audience in the framework of "PHOTOBOOK PROJECT."

Figure 5. Illustration for the project agenda

The topic of the Óbuda university Student group was "Circular Economy in The Textile Industry – A Case Study." 5 students from 3 countries participated in the group work and were guided by two instructors from the Environmental Institute and Product design Institutes. The students in the group have different responsibilities. Despite the intensive and strenuous tasks, the students involved in the research and development projects unanimously said that it was a fantastic opportunity for them.

CONCLUSION AND IMPLEMENTATIONS

This article presents some of the innovative recycling emerging in the textile industry. Given the limited number of pages, all of this was only outlined. Our work shows that conscious action is very much needed in the textile industry and that there is great potential for linking conscious corporate governance and R & D & I projects from both the producer and consumer side, society, and academia. Even our early results resonated favorably, and we could present disseminable results with it. We intend to continue our work on these projects in the future and to launch similar projects.

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OPTIMIZATION OF UV PROTECTIVE PROPERTIES OF HEMP CONTAINING KNITTED FABRICS

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ABSTRACT

Prolong and frequent exposure of human to the sun can cause various health problems. Therefore, the ultraviolet (UV) protection provided by clothing becomes a subject of considerable interest. Several clothing parameters are associated with the effectiveness of UVR protection among which is the yarn structure and geometry. Despite this fact, there is a lack of investigations on the effects of yarn parameters on the UV protection effectiveness. Therefore, in this study, the influence of yarn twist intensity on the UV protection properties of single jersey knitted fabrics was investigated. The knitted fabrics were produced from the hemp yarn and by combining it by the three variants of the cotton yarns differing in the twist level. The knits were spectrophotometrically assessed and Ultraviolet Protection Factor was calculated. The results demonstrated that by combining the cotton yarn with the hemp yarn into knitted fabric, the UV protection capacity of the knit was improved. The extent to which the UV protection properties of the knitted fabrics were changed depended on the twist intensity of the cotton yarn. In conclusion, the twist intensity of yarn was confirmed to be the significant determinant in the engineering of UV protective clothing materials.

Key words: UV protection, yarn twist, knitted fabric, hemp, cotton

INTRODUCTION

In the recent years the media have highlighted the damage of the ozone layer and the resulting increase of ultraviolet radiation (UVR) reaching the earth. The beneficial effects of human exposure to UVR are well known. The main benefit is promoting the synthesis of vitamin D. Other beneficial effects of UVR are mainly therapeutic. However, prolonged and repeated occupational or recreational sun exposure of the human causes some detrimental effects. The most obvious short-term effect of over-exposure to UVR is sunburn or redness of the skin. Besides, chronic sun damage leads to skin photo-aging and non-melanoma and melanoma skin cancer. Therefore, the UV protection arouses considerable interest. The UV protective measures include the use of photoprotective clothing, sunglasses and sunscreen. Clothing is considered to be the most important tool for UV protection. There are several possible pathways for UV light distribution when UVR reaches textile fabric. UVR can be reflected, absorbed or transmitted by the fabric. Part of UVR which passes directly through the material via gaps (pores) between the fibers and yarns is referred to "transmission" (Stankovic et al., 2009).

The studies on the performance of clothing as a barrier to UVR dated from the recent decade. Several factors influencing the effectiveness of textile fabrics in reducing UVR were indicated to be dominant – composition (fiber type), construction (tightness of weave), weight and thickness. Color and other processing techniques (bleaching, usage of UV absorbers) can also affect UVR blocking capacity of textile fabrics. With the use of dyes, organic or inorganic UV absorbers, the UV protection properties of textile fabrics can be improved. However, the limitation factor for these treatments is the weak washing fastness. In addition, these treatments raise some sustainability issues such as excessive water consumption and environmental pollution (Rodrigues et al., 2014). Nowadays there are some eco-friendly treatments for imparting high UV protection to textile fabrics, but these technologies are complex, time-consuming and expensive (Alabeid and Zhao, 2017). Therefore, an engineering approach to optimization of the UV protective properties of textile fabrics has been developed, which is based exclusively on the design of yarn and fabric structure. Most of the studies have been devoted to the interaction between UVR of textile fabric (woven or knitted) and its structural parameters (Dobnik Dubrovski and Majumdar, 2017; Majumdar et al., 2015; Majumdar et al., 2012). Some investigations dealt with the interactive effects between UVR of fabrics and the yarn properties. The influence of yarn linear density on the UV protection capacity of the fabric was investigated by Majumdar et al. (2010) and Hatua et al. (2013). It has been shown by Stankovic et al. (2009) that yarn twist influence to a great extent the UVR of knitted fabrics by controlling the packing density of fibers in the yarn. These studies have focused on UVR of cotton fabrics given that cotton covers a significant part of the world textile market.

As an alternative to cotton, hemp fibers are experiencing a renaissance in recent years as environmentally friendly, biodegradable and renewable fibers with great sustainable potential in all (environment, economy, and health) aspects (Novakovic et al., 2020). In the investigation conducted by Kocic et al. (2016), the UV protection ability of the hemp knitted fabric was improved by folding of the hemp yarn. Bearing in mind that synthetic fibers have better UV protection capacity Stankovic et al. (2017) developed hemp/filament hybrid yarns by using folding technique and produced the rib knitted fabrics with improved UVR protection. Kocic et al. (2019) showed that an improvement in the UV protection properties of hemp-based knitted fabrics could be achieved by two-assembling the hemp with other cellulose (cotton, viscose) yarns during knitting, avoiding any additional mechanical operation. In this study, the hemp yarn was assembled with the cotton yarn to improve the UV protection ability of the knitted fabric. However, the additional question was whether the basic yarn parameter – twist intensity can be used as a tool for modifying the UV protection ability of the fabric.

MATERIALS AND METHODS

In this investigation, hemp yarn with nominal linear density of 50 tex and twist of 370 m^{-1}, and three cotton yarns with the same nominal linear density of 50 tex and different twist levels (490, 590, and 690 m^{-1}) were used for production of single jersey knitted fabrics. The knitted fabrics were produced by feeding simultaneously two yarns through feeders to the needles. This made it possible to produce 100 % hemp (2Cs), and three variants of hemp/cotton (50%/50%) knitted fabrics composed of the hemp yarn and one of the three cotton yarns differing in twist level (CsCo1; CsCo2; CsCo3). The process of knitting was conducted with the same machine settings for these four knits, in order to obtain as much as possible identical structure. After dry relaxation (20 °C ±2°C and 65% R.H. ±2%), the knitted fabrics were wet relaxed according to the procedure SRPS F.S2. (Physical Tests for Textile – Determination of the shrinking values for fabrics). The structural properties of the relaxed knitted fabrics are presented in Table 1. Thickness of the knitted fabrics was determined in accordance with ISO 5084:1996 (Textiles: Determination of thickness of textiles and textile products). Stitch density, surface density, and stitch moduli (surface and volume) were determined following the procedure described in the literature (Koblyakov, 1989). Porosity of the hemp-based knitted fabrics was calculated as $P = 100 - (\rho_k/\rho_f)\cdot 100$, where ρ_f (g/cm^3) is the fiber density and ρ_k (g/cm^3) is the bulk density of the knitted fabric calculated by dividing its surface density (mass per unit area) by thickness.

Table 1: Structural properties of the hemp-based knitted fabrics

Parameter, unit		2Cs	CsCo1	CsCo2	CsCo3
Stitch density	Course (cm^{-1})	13.7	13.0	12.0	12.5
	Wale (cm^{-1})	5.5	5.5	6.0	6.0
	Surface (cm^{-1})	75.4	71.5	72.0	75.0
Thickness (mm)		0.916	1.047	1.068	1.069
Surface density (g/m^2)		360.4	366.6	379.8	399.5

The UV protection properties of the hemp-based knitted fabrics are assessed by in vitro test method that is based on the determination of the Ultraviolet Protection Factor (UPF), which presents a quantitative measure of the effectiveness of the fabric to protect human skin against UVR. This method is widely accepted laboratory-based test method according to which the percentage of the UVR transmission is measured using a spectrophotometer. A UV/VIS/NIR PerkinELmer Lambda 9 was used. According to standard EN 13758-1:2001+A1:2006 (Textiles – Solar ultraviolet protective properties – Part I: Method of test for apparel fabric), the measurements were conducted in the wavelength range of 290-400 nm in 5 nm steps on four specimens for each knit . The UPF was calculated as the ratio of the average of the amount of UV radiation emitted by the source to the amount transmitted through a sample of textile materials with an allowance for differing biologic effectiveness of the various UVR wavelengths. ANOVA statistics was used for the analysis of the results. In this statistics, the F-ratio is used to test the hypothesis that the effect is real. When the F-ratio is greater than the critical (F_{crit}), and the probability value (p) is less than $\alpha = 0.05$, the influence of the tested effect is statistically confirmed.

RESULTS AND DISCUSSION

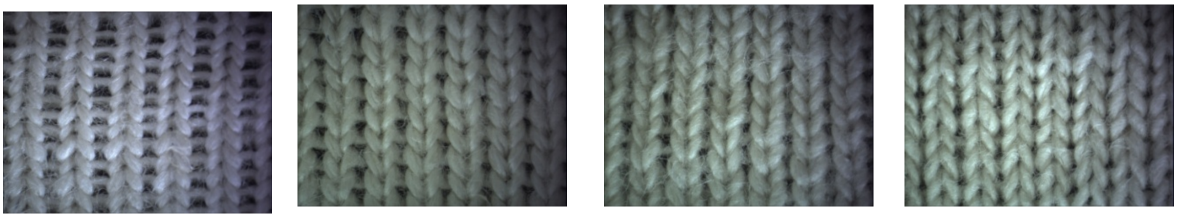
Although the hemp-based knitted fabrics were produced under constant machine settings, they differed to some extent in their structural properties, as presented in Table 1. It can be noted that the stitch density was reduced by introducing the Co1 and Co2 yarns into knitted structures. In addition, the stitch density of the CsCo3 knitted fabric was quite similar to the hemp knit, but with different stitch configurations, which was indicated by their different course and wale density. This can be explained by some differences in the internal structure of the hemp and cotton yarns. The hemp yarn was considered to have high bending rigidity (low flexibility) due to the reduced flexibility of hemp fibers. By introducing the cotton component into two-assembled yarns (CsCo1, CsCo2 and CsCo3), their bending rigidity must have been reduced leading to changes in stitch configuration. On the other hand, the cotton yarns differed between each other in bending rigidity as a consequence of their different twist level. The lowest bending rigidity for the lowest twisted cotton yarn (Co1) could be expected as the packing density of fibers was the lowest. Consequently, the flexibility of the Co2 yarn was lower due to the higher twist level in respect to the Co1 yarn. As a consequence, the stitch configuration was changed depending on the cotton yarn used (Table 1). The fiber packing density in the highly twisted cotton yarn (Co3) caused a further reduction in the flexibility of the yarn and consequently changes in the stitch configuration, but with the stitch density similar to that of the hemp knit. With an increase in the twist level of the cotton yarns, their residual torque was increased, which caused an increase in the thickness and surface density of the knitted fabrics (Table 1).

The analyzed differences in the structural properties of the knitted fabrics were reflected in the differences in their geometry, which was expected to affect their UV protection properties. As can be noted in Table 2, the knits were characterized by different porosity. Higher porosity of the CsCo1 and CsCo2 knits resulted from their lower stitch density. The lower porosity of the CsCo3 knit as compared to the other two hemp/cotton knits is in line with the previous discussion on the structural properties of the knits.

Table 2: Geometry parameters of the hemp-based knitted fabrics

Parameter, unit	2Cs	CsCo1	CsCo2	CsCo3
Porosity, (%)	74.0	76.5	76.2	74.9
Surface stitch modulus	0.85	0.71	0.72	0.74
Volume stitch modulus	1.60	1.12	1.30	1.51

Visual examination of the knitted fabrics by a stereomicroscope indicated that besides total porosity, the pore distribution was also different in the knitted fabrics, as presented in Figure 1. This was also quantitatively confirmed by calculated moduli of the knitted fabrics (Table 2), which will be analyzed later.



2Cs CsCo1 CsCo2 CsCo3

Figure 1: Photographs of the hemp-based knitted fabrics

According to the European standard EN 13758-2: (Fabrics – Solar UV protective properties – Classification and marking of apparel), textile fabrics with UPF above 40 classify in the “excellent” protection category and mark as “40+”. Results of the UPF values of the hemp-based knitted fabrics, presented in Figure 2, indicated that all the tested knits were characterized by the excellent UV protection ability. In addition, by combining the hemp yarn with one of the cotton yarns, the UPF of the knits increased, but the extent of the increase depended on the twist level of the cotton yarn. The highest UPF was noted for the knit (CsCo2) produced from the two-assembled hemp and medium twisted cotton yarn, followed by CsCo1 and CsCo3 knits. ANOVA statistics confirmed the significance of differences in the UVR transmission between the knitted fabrics [(F (5.08)> F_{crit} (3.49); p(0.017)<α(0.05)].

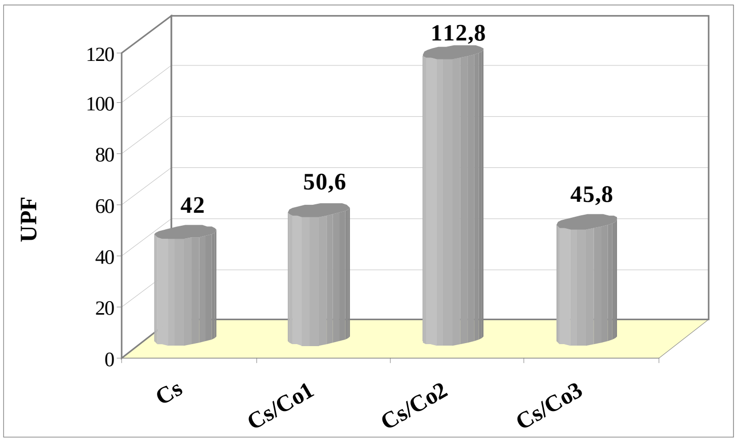


Figure 2: UPF of the hemp-based knitted fabrics

Considering the previous discussion on the structural properties of the hemp/based knitted fabrics, it may be concluded that twist intensity of the cotton yarns influences the UV protection properties of the knitted fabrics, primarily because of the changes in their geometry. Surface stitch modulus shows the ratio of the surface of a stitch and the surface occupied by the yarn in a stitch. A higher value of the modulus indicates the higher size of the pores between the yarn segments in a stitch. This facilitates the UVR transmission and consequently reduces the UV protection capacity of the knit. As presented in Table 2, the hemp knitted fabric was characterized by the highest surface stitch modulus indicating larger open pores (interstices) which can also be easily seen on the photograph (Figure 1). Therefore the hemp knit had the lowest UPF. However, the UPF of the CsCo2 knit was twice as high as CsCo1 knit, even though they were characterized by similar surface stitch modulus. To explain this, we should refer to the volume stitch modulus which indicates the ratio between the volume occupied by a stitch and the volume filled with yarn within the stitch. A higher value of this parameter indicates higher open space in a stitch, which means that the CsCo2 knit should transfer more UVR (and has lower UPF) as compared to the CsCo1 knit. However, the CsCo2 knitted fabric was characterized by the highest UPF indicating that the difference in the open space in a stitch arose from the depth of the pores (evidenced by its higher thickness as compared to the CsCo1 knit). It seems that deeper pores in the CsCo2 knitted fabric contribute to enhancing the absorption of the scattered UV radiation inside the pores and thus, reducing the UVR transmission.

CONCLUSION

In this study, an attempt was made to optimize the UV protection properties of hemp-based knitted fabrics by employing twist intensity of yarn as a design tool. The results demonstrated that the modification of the single jersey hemp knitted fabric by introducing the cotton yarn as a component in the two-assembled yarn caused a decrease in the UVR transmission and consequently an improvement in the UV protection ability. The changes in the UV protection ability of the hemp-based knitted fabrics depended on the twist level of the cotton yarns by which the structure and geometry of the knits were modified. This way, the twist intensity of the yarn was confirmed to be a useful tool for designing the desired UV protection ability of the fabric.

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RECENT DEVELOPMENT OF PIZOELECTRIC NANOGENERATORS BASED ON PVDF

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ABSTRACT

Nanogenerators have trigged enormous interest because of their unique advantages in instant response and great potential application in development self chargeable electronics. Lots of studies concentrate on PVDF nanogenerators as flexible, transparent green generators but they need some modifications to improve their electrical output. One of the most important strategies to boost piezoelectric nanogenerators is using composite structures and improve their polymer β phase content in their crystalline structure, improve their dielectric permittivity, and as a result, their piezoelectric charge constant (d33). Herein minireview, we try to review the recent development of piezoelectric nanogenerators based on PVDF base on their useability on industry

Key words: PVDF, nanogenerators, piezoelectric, Smart textile

INTRODOCTION

The development of renewable, portable and sustainable energy sources is one of the important issues for economic growth and increasing the quality of human life. Nanotechnology has provided emerging fields in nano energy with the possibility of extracting energy from sustainable and self-sufficient sources of the environment. There are different types of energy sources such as solar, thermal, chemical, biological, mechanical, etc. that can be collected and used from the environment. Among these, mechanical energy is one of the most valuable types of energy due to applications related to movements, especially human movements and ease of access anywhere and anytime. This energy in large levels and various forms such as body movements such as walking, bending, talking, breathing, heart rate, mechanical movements such as vibration, air flow, friction, water flow, hydraulic forces, etc. in our environment there is; But most of these resources are ignored and wasted. (Kim et al., 2011)

Piezoelectric is one the most important ability of some materials to allow them to make electricity from mechanical stress. the piezoelectric effect(Sukumaran et al., 2021) was first discovered by the Curie brothers in 1880(Lee et al., 2020). and after that Kawai and Kureha discovered the piezoelectric effect on PVDF in 1969(Lu et al., 2020). In general, materials with piezoelectric properties can be divided into two categories of organic and inorganic materials, for example, organic materials can be referred to PVDF, (PVDF–TrFE) ‹$C_6H_{16}BrN$,nylon and ZnO, PZT, PMN–PT, $BaTiO_3$ and etc referred to inorganic. Organic materials have various advantages such as flexibility, light weight, stability and easy lamination process. Meanwhile, PVDF is very important due to its very high piezoelectric properties, transparency, mechanical durability and flexibility.(Cascella et al., 2020)(Ali et al., 2021)

Nanogenerator concept first mentioned by Wang in 2006. (Fan et al., 2016) In piezoelectric exchangers, two electrodes are placed on either side of the piezoelectric material, so that electrons can move in the external circuit, to reduce the potential change due to the change in polarization of the material. When the pressure on the material is removed, the polarity of the material returns to its original state and the electrons are placed back in the external orbit. This process causes electrons to move and generate piezoelectric voltages in piezoelectric nano-exchangers or PENGs(Kamaruzaman et al., 2021)

PVDF and its copolymers have special properties such as high flexibility, chemical stability, light weight and easy production. Many studies have researched how to enhance the properties of these exchangers using different methods in the production, structure and addition of fillers in compounds(Ryu et al., 2019) PVDF is commonly found in the four crystal structures α, β, γ and δ. The α phase is the most stable state under environmental conditions.(Ren, 2021). The β phase has ferroelectric properties and has the largest amount of ferroelectric effect, estimated at $13\mu C/Cm^2$, this phase reports the highest amount of piezoelectric effect compared to other PVDF phases. This ferroelectric property of phase β is due to its bipolar torque in the macroscopic structure. This arrangement is known as all trans (TTTT). Also, with the tensile process, the α phase can be converted to β By Comparison between pure pvdf and pvdf-TrFE Fortunato et al.2021(Fortunato et al., n.d.)report the Enhancement of Piezoelectric Coefficient (d_{33}) in PVDF-TrFe/$CoFe_2O_4$ nanocomposites d_{33}=39Pm⁄V Under the effect of periodically poled lithium niobate (PPLN) DC magnetic field was applied through a ferromagnetic core, and DC magnetic poling is to increase the orientation of β phase enhancement of the β-phase alignment through an applied DC magnetic field Because of the strong molecular interface between filler and matrix in composites. PVDF-TrFe had better performance compared to PVDF. The most common chemical derivatives of PVDF are PVDF-TrFE and PVDF-HFP. Meanwhile, PVDF-TrFE has a higher cost of production, but is preferred over PVDF due to the easier acquisition of phas. β(Ren, 2021)

There are two operating modes for the energy harvesting with respect to the direction of polarization, which are shown in *Figure 1* The coefficient d33 as the longitudinal coefficient, indicates the electrical polarization created in the direction of the input voltage. On the other hand, the coefficient d31 as the transverse coefficient depicts the electric polarization created in the direction perpendicular to the applied stress(Sukumaran et al., 2021)

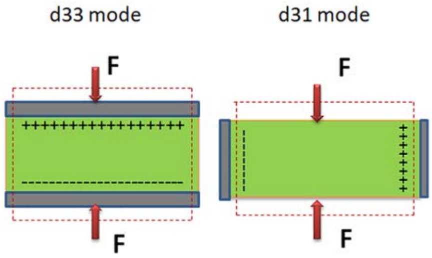

Figure 1. The piezoelectric d33 and d31 modes(Sukumaran et al., 2021)

The open circuit voltage can be describe by (Erturun et al., 2021)

$$V_{OCP} = \frac{d_{33}\varepsilon Y h_0}{\varepsilon_r}$$

where ε, d33, Y, h_0, and ε_r are the strain in the perpendicular direction, the piezoelectric coefficient, Young's modulus, the thickness, and the dielectric constant of the PNC material, respectively (Erturun et al., 2021).the aim of this mini-review is to investigate the developments of the PVDF nanogenerators by different methods of synthesis and making composite by different filler or layers.

FABRICATION PROCESS

In recent decades, various methods used for the production of ferroelectric layers, including(Ryu et al., 2019)(Mittal, 2009).electrospinning, spin coating, solution casting, template-assisted method, thermal drawing, dip coating and etc.

One of the improving methods for PVDF in electrospinning is using Graphene and its derivatives.
(Leaper et al., 2021).These membranes were enhanced by the addition of reduced graphene oxide functionalized with superhydrophobic polyhedral oligomeric silsesquioxane molecules (POSS-rGO) into the spinning solution(J. Yang et al., 2021)With in-situ synthesis of rGO graphene oxide (GO) was

added into polyvinylidene fluoride (PVDF) to prepare nanofiber mats by electrospinning. The content of β phase of PVDF was improved by adding GO until fillers ratio increased to 2 wt%. even (El-Kader et al., n.d.) Using pulsed laser ablation technique for polymer blend nanocomposites were fabricated in film shapes. graphene oxide (GO) nanoparticles were incorporated into PVDF/PVC with casting method the GO@PVC/PVDF displayed high stability under hot temperature up to 200℃. Gitanjali H.Tabhane et al. 2021 reduced-graphene oxide (RGO) and RGO-PANI were chosen as the inclusion phase (filler). enhancing the dielectric and ferroelectric properties of PVDF-$BaTiO_3$ (P/BT) nanocomposites impregnated with RGO and RGO/PANI(Polyaniline) nanofillers. In-situ polymerization method was adapted to fabricate the RGO/PANI nanocomposite and spin coating method was used for P/BT composites. All the composites showed enhanced dielectric properties with increasing temperature. The P-E hysteresis loops were obtained using Radiant Ferroelectric Tester at different voltage cycles. The dielectric constant of the P/BT matrix with 0.03% RGO loading exhibited the highest dielectric constant 2×10^5 (Tabhane et al., n.d.).in other research S. Badatya et al.2021 highly sensitive graphene quantum dot (GQDs) has been used to reinforce poly (vinylidene fluoride)-co-hexafluoride propylene (PVDF-HFP) by a spin coating method. this nanogenerator compared to flexible piezoelectric nanogenerator has a very high output voltage of 6 V and output current of 25 nA compared to signal generated from pristine PVDF-HFP nanogenerator Formation of b-phase in GQDs /PVDF-HFP The improvement in the PVDF-HFP may be attributed to the alignment of electric dipoles induced by the local electric field caused by conductive GQDs. Performance of GQDs/PVDF-HFP has also been real time demonstrated as self-powered human breathing and finger movement sensors which make it suitable for promising wearable energy harvesters and for powering nanosystems. The incorporation of GQDs enhances the nucleation and stabilization of the piezoelectric polar β-phase. The piezoelectric performance of GQDs/PVDF-HFP composite film is measured under a vertical compressive force of 1 kgf(Badatya et al., n.d.).

Another method for improving the nanogenerators based on PVDF is to use nanosheets in their matrix.
In 2021, Dediti Batacharya et al. Succeeded in extracting very high voltage output from nanotransformers by completely dispersing the MoS_2 nanofilms in PVDF. In this work, by using two layers of ITO coated with PET as an electrode in experiments with finger touch, finger and wrist vibration, bending, etc., they managed to receive significant voltages. For example, the highest voltage in bending with a force of 10.6 KPa was reported to be 22V. They interact, thus increasing electrostatic interactions and enclosing the PVDF chains between the MoS_2 plates, which results in the production of an active β phase in the nanocomposite. This process in crystallization can be justified by the law of crystallization due to surface charge, which can be seen in PVDF for various other fillers such as $BaTiO_3$, clay, ionic salts, carbon nanotubes, etc(Bhattacharya et al., 2020). Another study in the field of flexible sensors with the combination of MXene plates in PVDF substrate, in 2021, Qing Zhao et al. Reported that this combination has increased the mechanical strength and piezoelectric response, d_{33} coefficient, composite. In this study, by examining different weight percentages of MXene, using the method of electrospinning in the manufacture of fiber matt, heat press and roller, the optimal amount of this compound was 0.4 wt% with a response rate of d_{33}, 43 PC/N(Zhao et al., 2021). In 2020, Sean Wang et al. In an article on the amplification of automatic linear sensors based on PVDF-TrFE used MXene plates (with the chemical formula $Ti_3C_2T_x$) by electrospinning method. Electrically directly by increasing the amounts of MXene. The hydrophilicity of the MXene structure also prompted researchers to refer to the structure as having the potential to become a humidity sensor. However, by studying the different values of these nanosheets in the nanocomposite structure in the DSC test, the density of diffraction peaks decreased with increasing MXene concentration and the optimum amount of this compound was estimated at 2 wt%. Report 3.64 under 20N pressure and 1Hz frequency(Wang et al., 2021). And even they can use nanorods as a reinforcement In the study of piezoelectric composites, Rad.S Sabri et al. In 2019 improved the voltage output of nanoparticles consisting of ZnO/PVDF, nanorod and $BaTiO_3$ along with BT NS nanoparticles using electrospinning method. The combined output of all three components PVDF+ZnO+ $BaTiO_3$ is introduced as PZB, which the outputs are produced significantly up to 12V

with a force of 1.5 N. the improvement of the relationship between the polymer chains and the phase by the addition of ZnO and beryllium nitrate (BT NS) particles(Sabry & Hussein, 2019).

One of the common ways of enhancing the nanogenerators is to use them with ferroelectric ceramics and metallic nanoparticles in composites structures. surface modification in ceramics in two ways Promote the interfacial interaction Improve dielectric compatibility(Sasmal et al., n.d.). Here, a multi-layered $BaTiO_3$ (BTO) /poly(vinylidene fluoride) (PVDF) PNG has been designed by spin coating layer by layer assembled method. Benefiting from the composite strategy and interlaminar electric field effect, the Different number of layers was investigated. open-circuit voltage and short-circuit current performance of BTO/ PVDF composite PNG with different layers were displayed . As the number of layers increases the open-circuit voltage of the PNG increases 6.5 times, from 2.19 to 14.22 V. It was found that the dielectric response of the composite films depends on the frequency, the higher the frequency, the smaller the dielectric values(Yinhui Li et al., 2021). In 2020, Ji Jiang et al. Investigated the effect of diameter changes on piezoelectric layers consisting of PVDF-$BaTiO_3$ as touch sensors (PPTS). In this work, the researchers affected the viscosity of the solution by changing different percentages in BTO and achieved different diameters of these fibers. Also, the piezoelectric layer PVDF-$BaTiO_3$ was sandwiched between two layers of PDMC and as an electrode of two A thin layer of copper was used. In this paper, the presence of 10 wt% of BTO is introduced as the optimal composition and according to the stress-strain test, it was stated that $BaTiO_3$ nanoparticles in PVDF can improve and store more tensile energy and prevent deformation. But to the optimal extent, after reaching this amount, excessive accumulation of three-dimensional particles causes the destruction of the strong structure and reduces the tensile stress. However, the composition of inorganic nanoparticles generally makes the polymers slightly brittle and reduces elongation at break. (Jiang et al., 2020) In the following, a study by Vilie Zhou et al. Produced a PVDF / BTO nanocomposite based on the layer method prepared from the solution. In this paper, it was reported that BTO improved the β-phase by 62.7%, but that the composite required post-production processes and had to undergo mechanical tension to complete in order to achieve the required polarization for piezoelectric properties. Finally, by comparing this composite with pure PVDF, it was reported that it has more piezoelectric properties than pure structure and a coefficient of d_{33} = 13 Pc / N was reported(Li-zhu et al., 2021). In another study by Kalani et al. In 2020, BTO particles with a tetragonal structure combined with PVDF were used to make nanogenerators by electrospinning. In this work, it was observed that the compressive sensitivity and piezoelectric property were significantly increased by using BTO ceramics. This nanofiber layer with gold plating spread on its surface was subjected to a force period of 0.5 N and a frequency of 2.5 Hz and in this experiment reported an output of $6mVN^{-1}$, which is compared to the output of pure PVDF with an output of /88. 1 mVN^{-1} had a significant increase(Kalani et al., 2020). In 2021, Xinping Ho et al. Investigated the combination of BTO and BFO metal oxides in PVDF structure by electrospinning method. This nanocomposite has been introduced as a versatile nanocomposite because it provides the ability to accurately study mechanical, magnetic, optical and electrical stimulation signals simultaneously in the form of a flexible structure with good mechanical stability. In general, the properties of dielectric, piezoelectric, pyroelectric, lighting, optical shrinkage, electric magnet and electrical reaction are improved and by adding BFO in the structure of this piezoelectric, one of the limitations of piezoelectric materials is the ability to absorb visible light due to band gap in 2eV The optimal amount of combination of these two ferromagnetic substances studied in this paper was reported (B75) (0.75) BTO- (0.25) BTO(Hu et al., 2021). In 2021, Yuangju et al. In a study aimed at modulating stress and increasing the electromechanical bonding of composite nanocomposites, placed a sheet of PDA between BTO and PVDF. According to the studies, PDA increased stress transfer and made the modulus difference between BTO filler particles and PVDF layer more compatible. Also, by comparing the composite sample in which the PDA structure was not used among its parts, a 128% increase in piezoelectric output was observed(Su et al., 2021).

Hydroxylated $BiFeO_3$ as efficient fillers in poly(vinylidene fluoride) for flexible dielectric, ferroelectric, energy storage, and mechanical energy harvesting application. The effect of

hydroxylation helps to improve interfacial interaction between filler and matrix the interfacial interaction between the filler and PVDF matrix by introducing a strong hydrogen bonding between the –OH group of the hydroxylated $BiFeO_3$ filler surface and the $–CF_2$ dipole of PVDF in place of electrostatic interfacial interaction between non-hydroxylated BiFeO3 and the $–CH_2$ dipole of PVDF With the formation of a strong hydrogen bond between OH and BiFeO3 The amount of polar phase increased to around 91% for a 7 wt%(Sasmal et al., n.d.).In 2020, Nabil Chakhchai et al. Studied the effect of electrical activation of PVDF piezoelectric medium with TiO_2 nanoparticles. In this study, PVDF / TiO2 composite layer was prepared by solution casting method and by examining the FTIR spectrum, both α and β phases were observed in PVDF. During these observations, TiO_2 was introduced as a nanoparticle activating piezoelectric media(Chakhchaoui et al., 2021).
Hydroxylated BiFeO3 loaded PVDF film (7BFOH) by this new type of interfacial interaction After rectification, was able to charge a 10 µF capacitor up to ∼3 V which was able to light up some LEDs between filler and matrix. zirconium acetate was doped into BaTiO3 to form barium and they get ready with the sol-gel method named zirconium titanate(BZT)($BaZr_xTi_{(1-x)}O_3$) in the PVDF matrix by solution casting. the prepared structure made different percent of BZT in the PVDF matrix to enhance. the 20wt% showed the best output voltage up to 4.6V the power 12.807 µW(Jeder et al., n.d.).

PVDF/ZnO nanocomposite with high output power and current density lightweight and flexible polyvinylidene fluoride (PVDF)/zinc oxide (ZnO) nanocomposite method: a low-temperature phase-inversion process The synergetic effect of low-temperature, phase-inversion, and the integration of ZnO nanoparticles primes on enhancing the electroactive polar β-phase in the nanocomposite(Chandran et al., 2021). Piezoelectric property investigation on PVDF/ZrO_2/ZnO been investigated. piezoelectric nanogenerator (PNG) based on poly (vinylidene fluoride) (PVDF)/Zirconium oxide (ZrO_2)/Zinc oxide (ZnO) nanocomposite by solution casting method. The addition of nanofillers significantly affects the structural property of PVDF, and their addition helps in the improvement of the piezoelectric property maximum peak to peak voltage (V_{pp}) of 3.2 V. While the crystallinity of PVDF decreased with the addition of zinc. The β- phase content as the maximum (70.2%) was observed in PVDF/5%ZrO2/5%ZnO nanocomposite(Naik et al., n.d.). In another study to distribute the elastic modulus in PVDF nanotubes, the PZT doping method was used in the structure. In this study, conducted by Xiaojun Qiao et al. By PZT doping, the piezoelectric properties were significantly improved, which can be expressed as increased stability under bending, and a higher modulus was reported(Qiao et al., 2020). in H. Parangusan et al. study in 2021, the ZnS microspheres are prepared by hydrothermal method and core-shell structured PANI/ZnS microspheres are synthesized by in situ polymerization method and then used as filler for the preparation of flexible [P(VDF-HFP)] based piezoelectric nanogenerator. flexible P(VDF-HFP)/PANI-ZnS piezoelectric nanogenerator is prepared by Electrospinning. the high piezoelectric peak-to-peak output voltage of 3 V compared with the neat [P(VDF-HFP)] (* 120 mV)the piezoelectric nanogenerator is tested for the piezoelectric performance by evaluating the output voltage The high output performance of the composites nanofibers is due to the incorporation of core-shell PANI/ ZnS microsphere(Parangusan et al., 2021)

Flexible lead-free NBT-BT/PVDF composite films prepared by hot pressing bismuth sodium titanate-barium titanate were embedded in the matrix of polyvinylidene fluoride in (40, 35, 30%) homogeneous distribution of the piezo-active filler. hot pressing the flexible films caused a transformation of electro-inactive PVDF α-phase into electro-active β and γ phases. Anelastic measurements showed that the elastic modulus increases as well with the fraction of active ceramic phase 40% up to 9 V and ~ 80 µW of output voltage and power. All the evidence reviewed above show that proper tailoring of material properties is possible by selecting adequate polymer and filler pairs, which combined with the choice of a suitable processing method will allow the improvement of existing and the widening of the potential applications(Petrovic et al., n.d.). The KNNSb/PVDF-HFP were prepared by electrospinning and (KNNSb= $K_{0.5}Na_{0.5}Nb_{0.9}Sb_{0.1}O_3$) investigated as filler in composite solution. its Developed composite nanofiber film was used for fabricating a flexible nanogenerator using poly(dimethylsiloxane) as an encapsulating material KNNSb nanostructures act as a nucleating agent for β-phase formation in the PVDF-HFP matrix and improved the output voltage compared to pure PVDF-HFP.(Chary et al., 2021). In 2021, Chavi Mitroval et al. Also used PVDF reinforcement using $0.5(Ba_{0.7}Ca_{0.3})TiO_3$-$0.5Ba(Zr_{0.2}Ti_{0.8})O_3$ filler, using solution casting method. Better interface between the filler and the polymer, the surface of the fillers was coated with dopamine and the distribution of fillers improved in the matrix. The highest energy output occurred at 10 wt% of the filler, which was about 1.84 V and the coefficient d_{33}= 620 Pc/N was reported, which has increased compared to pure BTO with a coefficient of d_{33}= 100 Pc / N (Mitharwal et al., 2021).

In 2021 A. Peri et al. study on enhancement in the b-phase of Poly(vinylidene fluoride) (PVDF), which contributes to its piezoelectric property, as a function of $MoSe_2$ weight percentages (0%, 3%, 7%, 10%) by drop-casting method. We have demonstrated that the addition of $MoSe_2$ resulted in the enhancement of the b-phase content in PVDF, from 66.59% to 84.48%(Peri et al., n.d.). varying MoS_2 concentration by hydrothermal technique has been reported which clearly indicates the enhancement of the β-phase content in PVDF, from 54.8% to 84.0%. A maximum peak-to-peak V_{oc} of 13.8V was obtained from the 7 wt% MoS_2-PVDF film without any load resistance(Prajapati et al., n.d.).

In 2020, Yong Yang Zhuang et al. Investigated the effect of doping cerium metal (Ce) along with $BaTiO_3$ on the structure of PVDF as nanocutants. In this study, cerium-doped BaTiO3 nanofibers with a molar ratio of 0.6 / Ce / Ba were produced by sol-gel method and then electrospun. In fact, in this structure, the core of the shell, in which Ce-BTO is located, produces an electric field, and the reverse electric field in the fiber shell is produced from PVDF polymer. This combination improves the output voltage in these converters and at the end of this study, the researchers suggested that by increasing the percentage of Ce output voltage, it has the ability to improve more than this amount(Zhuang et al., 2020).
A nanocomposite with core-shell structure by Au-TiO_2 and PVDF by a three-step-synthesis strategy including the sodium citrate reduction method, sol-gel method, and high-temperature hydrothermal method had synthesized. this combination improved the Effect of visible light in process of photocatalytic degradation(Yan et al., n.d.).

Simultaneous Electrospinning and Electrospraying are other ways to enhance the nanogenerators' structures. Simultaneous Electrospinning and Electrospraying of hybrid tribo/piezoelectric nanogenerator (HTPENG) with an innovative structure of ‘‘microspheres@nanofibers’’ was developed new methods to enhance the electrical output properties of nanogenerators and stimulate new ideas for the structural design of nanogenerators in the future. Poly-L-lactic acid (PLLA; piezoelectric constant d_{14}= 9.02 pC N^{-114}) and poly(vinylidene fluoride) (PVDF; piezoelectric constant d_{33}=18–32 pC N^{-1}) are most commonly used in polymer-based piezoelectric nanogenerators. A hybrid specimen was formed using PLLA nanofibers and PVDF microspheres based on electrospinning and electrospraying shown in *Figure 2*, and its piezoelectric constant d_{33} reached 54.2 pC N^{-1}, which is far superior to those of pure PLLA and pure PVDF. and these method had affected charge density that plays an essential role in the electrical output properties of nanogenerators(X Li et al., n.d.)

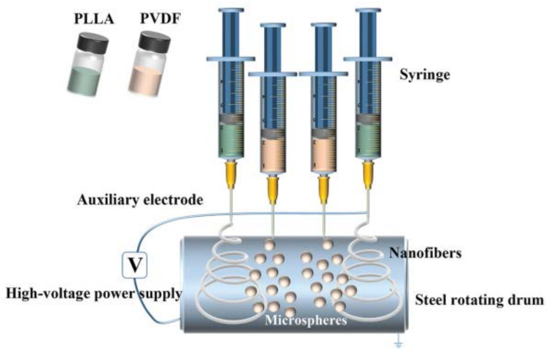

Figure 2. llustration of electrospinning and electrospraying apparatus(X Li et al., n.d.)

In 2020, Yang Li et al. used electrospinning and electrospray methods, shown in *Figure 3* In their research to structure piezoelectric transducers. In this study, an electrospun PVDF layer and an electrospray layer were used from PVDF@$CsPbBr_3$ rosary beads. respectivelyPVDF@$CsPbBr_3$ particles showed excellent hydrophobicity even after 24 hours and turned green under UV light. The researchers justified this behavior by trapping the nanoparticles in the PVDF layer. This method also increases the Colombian forces in the interaction of β-phases and facilitates the change of polarity. Therefore, the addition of nanoparticles by electrospray method during the coating layer has increased the durability and flexibility of the piezoelectric transduce(Yang Li et al., 2020).

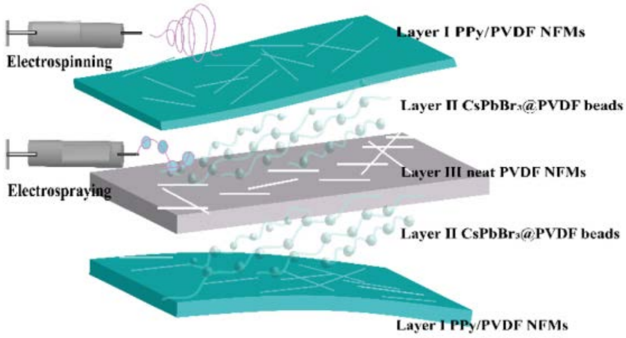

Figure 3. Schematic of the 3D multilayer NFMs constructed by PPy/PVDF NFMs (Layer I), $CsPbBr_3$@PVDF beads (Layer II) and neat PVDF NFMs (Layer III) (Yang Li et al., 2020).

The enhancement method, can even be effective on both piezoelectric and triboelectric output. In 2021, Xiaoxi Li et al. Succeeded in simultaneously amplifying the piezoelectric and triboelectric effects by producing a laminated nanocomposite. In this work, a PVDF-based composite was electrospun using carbon-coated ZnO. In FTIR, it was observed that by adding this nanoparticle to the polymer substrate, 88.3% of β phase was produced, which is only 81% in the composition of ZnO nanoparticles without carbon coating. Also, the d_{33} coefficient was reported to be 39.5 PC / N and the mechanical stability of the device was measured under 4000 cycles at 14.7 N and the stability output was reported. It also negated the surface potential of the polymer and ultimately improved the turboelectric output by 4 times(Xiaoxia Li et al., 2021).

Improvement can happen even without adding external element as reinforcement and can only happen by make different structural behavior of PVDF. Ping Huang et al. Studied flexible piezoelectric sensors in 2021. In this study, using carbon quantum dots to increase the piezoelectric property and mechanical stability of PVDF-HFP, this porous structure was produced using spin casting method and Carbon quantum dots were able to increase β production by 14.4% due to their high contact surface(Huang et al., 2021). In 2021, Fan Xu et al. In a study examining a three-dimensional wave-shaped electrified layer, they molded an electrified layer of PVDF to design an acoustic detector (add shape) that was able to detect the following frequencies: 0.1 Hz. The piezoelectric properties of this waveform layer were also investigated. In general, three different wave structures and a smooth plate were discussed. both Theoretical and practical results showed an increase in output voltage, the researchers justified this by increasing the effect of polarization, although the mechanical strength and fracture was reduced to rupture, but the waveform plates has high deformation, under low pressures, and when they use as nanotransformers this deformation will make better polarization and have a better stress distribution in the force distribution at the piezoelectric polymer surface.

This is great for detecting weak feature changes, and polarization will be easier. The output of the piezoelectric was measured with a home made device and it was observed that the response of plates changed with the dimensional properties. (Xu et al., 2021) In addition to the above, other structural changes such as layer thickness can affect the output voltage. As Chuncheng et al. Stated in a 2020 study, piezoelectric feedback increases with decreasing doped layer thickness. In this study, using $BiCl_3$ compound as different percentages of solution in PVDF with electrospinning process, piezoelectric layer was prepared and the optimal amount of this compound was evaluated 2wt% of PVDF, the percentage of these compounds directly on the thickness of the layers according to It was effective in changing the viscosity and diameter of fibers. According to the results, the author notes that although the phase and electrical conductivity are amplified using $BiCl_3$, the optimal composition of the material plays a very important role in the piezoelectric output. Also, the strain rate at the surface of the layers in the piezoelectric layer is an important element in the production of polar loads(Chen et al., 2020). In 2020, Lu Yang et al. Studied PVDF-based multilayer nanocomposites. In this study, by combining carbon nanoparticles in PVDF solution with weight values of 0, 0.2, 0.4, 0.6, 0.8 and 1 wt% was added and the plates were electrospun. The important variable of this article was the arrangement of layers and their study in three forms (3, 5 and 7) layers. In this structural system, the pattern X-Y-X, X-Y-X-Y-X and X-Y-X-Y-X-Y-X are used and Y is the fixed factor of the plates at a rate of 0.4 wt%. As polarization outputs were reported in terms of the two main variables in this paper, namely the number of layers and the difference in filler concentration, the authors conclude that using layering can help increase the polarity of the structure as well as directly address the importance of the layer relationship. Composite intermediates were noted for improving the pressure stability properties of electric fields(L. Yang et al., 2020).

B. Panigrahi et al. showed that different solvents for PVDF can affect its output, they investigated The various properties like structural, morphology, dielectric, piezoelectric, and ferroelectric are affected. Further, a piezoelectric nanogenerator was fabricated and results of poled and unpoled films have been investigated. The device output was utilized to light up a LED and charge a commercial capacitor. they study the PVDF granules and N-Methyl-2-pyrrolidone (NMP) solvent were taken in the stoichiometric ratio. The PVDF film was fabricated by the solvent casting method. The XRD shows the presence of polar and non-polar phases. The electrical voltage and current responses of unpoled and poled PVDF are shown in the *Figure 4*(Panigrahi et al., n.d.)

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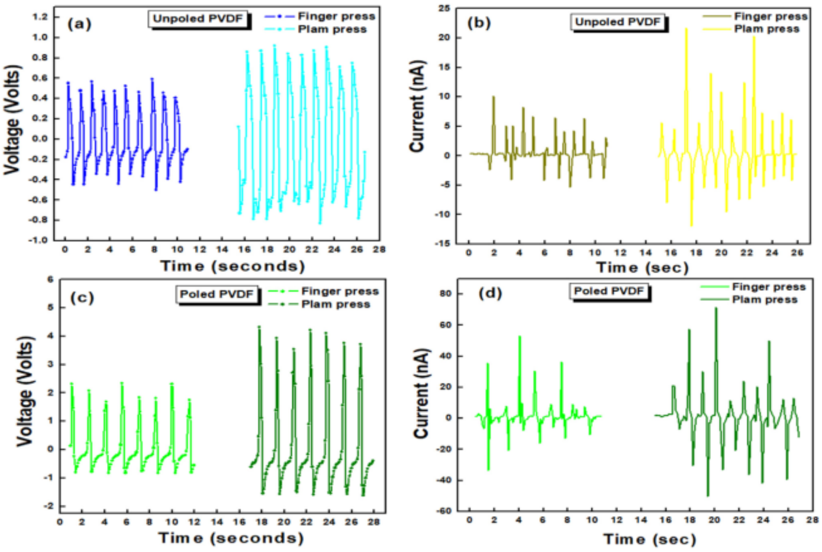

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Figure 4.The electrical voltage and current responses of unpoled and poled PVDF based piezoelectric nanogenerator at different applied mechanical force conditions(Panigrahi et al., n.d.)

A hybrid piezoelectric PVDF-HFP for boosting power generation was prepared with the mold casting method and studied to determine the suitable solvent for achieving higher piezoelectric property of the piezoceramic polymer were investigated. two different solvents have been compared dimethylformamide (DMF)+Acetone and N-methyl-2-pyrrolidone (NMP)+Acetone and its showed efficiency of dimethylformamide (DMF) solvent to increase the rate of crystalline phases due to their moderate evaporation rate and their high dipole moment that leads to enhanced piezoelectric performance. This approach proves its effectiveness to strengthen the piezoelectric performance especially by doping with silver nanoparticles (Ag NPs). The composite with DMF solvent exhibits improved output voltage around 2.21 V and output power of 0.22 μW, which are, respectively, around three times and 9 times higher than the composite without Ag NPs. In addition, the NG shows good stability over 900 cycles illustrating their robustness. (Bouhamed et al., n.d.).\

CONSLUSION

Lots of studies concentrate on PVDF nanogenerators as flexible, transparent green generators but they need some modifications to improve their electrical output, in this mini-review, various methods of amplifying nanogenerators were reported. And summarize these studies and how do they work.

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INNOVATION AND SUSTAINABILITY IN FASHION INDUSTRY THROUGH NETTLE FIBRE

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ABSTRACT

The textile and apparel industry is one of the most important and strategic sectors for the boosting of the world economy, while causing a major environmental impact.
In this scenario, it is essential and increasingly consensual to invest in creativity and sustainability as factors of product differentiation and creation of added value. Therefore, the design process must go beyond the creation of products that are aesthetically appealing to the consumer, but also, placing the sustainability of the environment as a primary factor to minimize the consumption of natural resources.
The nettle is widely known as an "unloved" plant due to its unpleasant and even painful texture when incorrectly handled. However, it has very interesting therapeutic properties and stands out for its high sustainability, from cultivation, extraction and fibre processing to the development of a long-lasting final product with unique characteristics.
In this paper, the authors seek to demonstrate the importance, properties and application potential of nettle fibre in the development of sustainable products for fashion industry. The paper also seeks to lay the foundations to, in the future, join and develop new technological solutions and contribute to reinvent sustainable fashion design practices.

Key words: Fashion Design, Fashion Ethics, Nettle Fibre, Sustainability.

INTRODUCTION

Throughout the history of fashion and design, textiles are closely associated with innovation on a scientific and industrial level. As the human society is increasingly seeking for a more sustainable lifestyle, focused on environmental concerns and individual's cultural values, designers and engineers, are trying to provide eco-friendly alternatives, in line with the new principles that fashion consumers demand. Currently, concepts such as ethical fashion and sustainable fashion are the driving forces of scientific and industrial research pursuing new textile solutions aiming to combine the development of innovative fashion products with enhanced features, aesthetically appealing and ensuring the existence of natural resources for future generations.

The nettle plant, which is considered by many as a weed, has been depreciated for its unpleasant texture due to the small hairs/spikes, founded on the leaves of the plant, which causes burning sensation on the skin upon touch. Despite, this drawback the nettle is a long-used plant, whose first applications date back to the Bronze Age (Srivastava & Rastogi, 2018, p.282). Its textile usage goes back in times of scarcest resources and lack of other fibres during the Second World War. In this context, nettle fibre emerged as an alternative to the most common and traditionally used fibres (like cotton), being applied in the production of uniforms for the German army, and camouflage fabrics.

Its cultivation does not require soils rich in organic material nor consumes a large quantity of water. It is a highly resistant plant, which does not need considerable care and grows easily. Additionally, the residues after the nettle fibre extraction can be used for other purposes, such as fertilizers or animal bedding.

HISTORICAL OVERVIEW

With properties similar to flax and hemp, nettle was firstly used before the introduction of cotton (Vogl & Hartl, 2003). There are reports of the use of nettle in ancient civilisations (3000 BC - 2000 BC), which appreciated the stinging of the plant on various paralysed limbs to stimulate circulation and providing warmth to them (Upton, 2013). Ancient European civilisations and Native American Peoples are also considered to have used nettle fibre to create bags, ropes and fishing nets (Srivastava & Rastogi, 2018).

During the First World War, the textile potential of this plant was comprehended, particularly through the intervention of German scientists who collected wild nettle plants for extraction and classification. They concluded that it would be an excellent substitute for cotton (Harwood & Edom, 2012).

The use of this material was, once again, boosted during the Second World War as soon as traditional resources run out. As result of a set of factors, such as: availability, yield, ease of fibre extraction, suitability for existing machinery and the cost of the whole process (Harwood & Edom, 2012), which determined their textile validity, this fibre gained a new space in the textile industry.
During this period, England also harvested 100 tons of the nettle plant for the extraction of green dye to be applied in the camouflage pattern of army uniforms (Srivastava & Rastogi, 2018).

Bogard et al. (2021) affirms that nettle fibre has a high potential for different application, but difficulties to mechanize the different processes have led to abandon it. Growing environmental concerns has led to the consideration of using this fibre again.

NETTLE PLANT

The plants of the *Urticaceae* family are widely known, including about 46 species worldwide with different morphology, shape and appearance. The plant thrives in both temperate and tropical climates, reaching between 60 to 200 centimetres of height. (Harwood & Edom, 2012).

The word "nettle" derives from the Anglo-Saxon word "noedl", which means needle, while the Latin term "urtica" means "to burn" (Kregiel, et. al, 2018). This nomenclature alludes to the effect caused by the small hairs located on the leaves of the plant and spikes in the stalk.

In Portugal, there are 4 known species of nettle plant, Urtica dioica (Figure 1), Urtica pilulifera (Figure 2), Urtica membranaceae (Figure 3) and Urtica urens (Figure 4), whose distribution, habitat and flowering season are presented in Table 1.

Figure 1: Urtica dioica [1]

Figure 2: Urtica pilulifera [2]

[1] Retrived November 2021: Andreas Rockstein, Jardim Botânico UTAD, Flora Digital de Portugal (2017).


Figure 3: Urtica membranaceae [3]


Figure 4: Urtica urens [4]

Table 1: Nettle species in Portugal

Species	Sinonymities	Distribution	Habitat	Flowering Season
Urtica dioica [1]	*Urtica galeopsifolia Wierzb. ex Opiz* *Urtica tibetica W.T. Wang*	Cosmopolitan, present in temperate regions of both hemispheres	Cultivated land; Ruderal	May - June
Urtica pilulifera [2]	*Urtica balearica L.* *Urtica dodartii L.* *Urtica pilulifera balearica (L.) Willk. & Lange*	Mediterranean Area, Middle East and South West Asia	Cultivated land; Fallow land; Ruderal	February - November
Urtica membranaceae [3]	*Urtica caudata Vahl.* *Urtica dubia Forssk., nom. inval.* *Urtica lusitanica Brot.*	Mediterranean Area	Ruderal	All year
Urtica urens [4]	*Urtica trianae Rusby*	Europe, North Africa to Middle East; introduced to tropical America and Australia	Cultivated land; Ruderal	March - September

Urtica dioica is, nowadays, the most common species, however, they are all possess by the same properties, namely, analgesic and dermatological applications (Said, Otmani, Derfoufi & Benmoussa, 2015). Regarding textile main applications, such as fabrics and biocomposites, this specie is also the most common source, considering it has a more abundant growth not only in Europe but also in Asia and North America (Sett, et. al, 2014).

NETTLE FIBRE EXTRACTION

Bacci et. al (2011) developed a comparative study of main nettle fibre properties according to the different extraction methods of this fibre, as well as their effects on the fibre quality. Normally, the extraction process is carried out mechanically, through a process known as decortication, in which the dry membrane surrounding the stem of the respective plant is extracted (Radhakrishnan, 2014).

Additionally, nettle fibres can also be extracted from the plant stem through field retting when the plant stem is pulled from the soil or cut off and laid down on the field to dry, through the action of sunlight. Another extraction process consists of soaking the plant in water, removing the soft tissues until the cellulosic structure is kept intact, this process allows obtaining more uniform and better-

[2] Retrived November 2021: Donald Hobern, Jardim Botânico UTAD, Flora Digital de Portugal (2017).
[3] Retrived November 2021: Flora de Galicia, Jardim Botânico UTAD, Flora Digital de Portugal (2017).
[4] Retrived November 2021: Eugene Zelenk, Jardim Botânico UTAD, Flora Digital de Portugal (2017).

quality fibres. It is also important to highlight that the waste of this process can be used for other applications, such as fertilizers or bedding for animals (Bacci et. al, 2011). A brief description of the pros and cons of these different methodologies is summarized in Table 2.

Table 2: Extraction methods of nettle fibres, processes and their advantages and disadvantages (Bacci et. al, 2011; Di Virgilio, et al., 2015; Moudoi et. al, 2021)

Methods	Process	Advantage	Disadvantage
Dew Retting	Plant stems are spread evenly on the grassy fields, to receive a combined natural action causing break down of its cellular tissues	Reduced price; suitable for areas with heavy dew; doesn't need water.	Reduced quality fibres; Weather dependent; Occupation of lands without being cultivated.
Water Retting	Stems are submerged in water, that can penetrate into the central part and swells the internal cells	Uniform and better-quality fibres.	Less attractive do the industry; anaerobic fermentation may taint the fibres.
Mechanical Extraction	Decorticated fibres were washed with water and dried in sunlight eliminating the water content	High-quality fibres; shorter retting time.	More expensive than the common methods, such as dew or water retting.
Controlled Microbiological Retting	Use of aerobic and anaerobic pectinolytic strain	Reduction of water retting time; Improves fibre quality.	Expensive operations.

Major factors such as: the extraction method; the plant species; geographical location; climate conditions and age of the plant, play a major role in the fibre properties (Kregiel, et. al, 2018).

NETTLE PROPERTIES

The nettle is a resilient plant, and its intensive cultivation may contribute, in the long term, to reduce erosion of poor soils. This plant is also resistant to diseases and pests, being resilient to more than 40 insect species. Moreover, the nettle does not need pesticides, fertilizers, or large quantities of water. These unique characteristics make of this fibre a more sustainable alternative to other cellulosic fibres, such as cotton (Dreyer & Edom, 2005).

According to Cook (1984), after extraction, nettle fibre has a soft and pleasant touch. Its fibres are hollow, which allows air to accumulate inside, creating a natural thermal insulation: these fibres can absorb and release humidity more efficiently than other natural fibres, such as flax and cotton, making them, inherently fibres with high thermoregulation power. A comparative analyse of main chemical and mechanical properties for the principal bast fibres are shown in Table 3 and Table 4.

Table 3: Chemical properties of different natural fibres (Sathishkumar et. al, 2014)

Fibres	Cellulose (%)	Hemi cellulose (%)	Wax (%)	Lignin (%)	Pectin (%)
Nettle	86	10	4	-	-
Cotton	82,7 - 90	3	0,6	-	-
Flax	64,1 – 71,9	64,1 – 71,9	1,7	2 – 2,2	1,8 – 2,3
Hemp	70,2 – 74,4	17,9 – 22,4	0,8	3,7 – 5,7	0,9
Ramie	68,6 - 91	5 – 16,7	-	0,6 – 0,7	1,9

Table 4: Mechanical properties of different natural fibres (Célino et. al, 2014; Girijappa et. al, 2019; Brebu, 2020)

Fibres	Density (g/cm^3)	Diameter (μm)	Tensile Strength (Mpa)	Materials Stiffness – Young's Modulus (Gpa)	Break Elongation (%)
Nettle	1,51	20	560 - 1600	24,5 - 87	2,1 – 2,5
Cotton	1,2 – 1,6	14,5	250 - 597	5,5 – 12,6	7 - 8
Flax	1,2 – 1,5	23	345 - 1500	27,6 - 85	2 - 4
Hemp	1,3 – 1,47	31,2	368 - 1100	17 -70	1,6
Ramie	1,4 – 1,6	50	400 - 1000	27 - 128	1,2 – 3,8

APPLICATIONS

The interest in sustainable fibres has been increasing and consolidating in recent years. The importance of these fibres has been attracting the attention of several brands in the fashion industry, which have it in the pipeline or already marketed. The products made of nettle fibres are normally in blends with other cellulosic fibres.

The Dutch brand G-Star Raw, presented in 2010 the Sustainable RAW project in which the shown pieces were entirely designed with innovative sustainable materials, including nettle. One of the most paradigmatic is a blend of nettle and organic cotton, which led to a new range of sustainable denim products with reduced environmental impact (Suhrawardi, 2018).

In 2019, the duo Vin+Omi presented a collection at the London Fashion Week show, in which 8 of the pieces were developed with 100% nettle fibre, whereas another 4 pieces of the collection were made from a blend of nettle and alpaca wool. The nettle was harvested from Prince Charles' Highgrove estate, and it was a suggestion from the royal family member to use this material (Hitti, 2019).

Recently, the New York sustainable fashion brand, Pangaia, launched a new family of jeans and jackets with a blend of fibres, containing a small percentage of nettle fibre, specifically, Himalayan wild nettle (18%) and organic cotton (82%). The project is called PANettle™ and the brand claims that both pieces are bio-based and that they are long-lasting, (Ho, 2021). Figure 5 depicts some examples of such innovative products.

Figure 5: Jeans and jacket from Pangaia's Project (PANNettle™)[5]

CONCLUSION

The literature review allows to conclude that nettle fibre is, in fact, very promising in the field of sustainable fibres for the fashion industry. Despite the extraction process of fibre being a complex and lengthy process, its cultivation, production and massification, in a near future, seems to be a winning bet for the production of natural fibres with a low environmental impact and lower costs.

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THE USE OF BANANA FIBERS IN COMPOSITE MATERIALS

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ABSTRACT

Composite materials are among the leading actors of today. Composite materials are known as important engineering materials due to their superior mechanical properties. We are now witnessing the life form of composite materials in many different applications. Due to increasing environmental concerns, the importance, and the application areas of biocomposite structures have been increasing day by day. At this point, banana fibers are obtained from agricultural wastes and find a life form in composites as reinforcements and meet many different application needs. Banana fibers display high strength, good dimensional stability and mechanical properties, environmental sensitivity, usability, low cost, biodegradability, renewability, and sustainability properties. In this paper, the utilization of banana fibers mainly in composite materials was reviewed.

INTRODUCTION

Composites are materials in which the desired properties of different materials are mechanically connected to each other and combined. Each of the components of the composites significantly preserves its own structure, characteristics, physical and chemical properties. Composite materials are known as important engineering materials due to their superior mechanical properties [1]. Natural fibers are the most important reinforcement material for composites [2]. Reinforcement materials help support the structural load of composites [3]. It adds strength and durability to the material [3]. In short, reinforcement materials improve the mechanical properties of composites [2,3]. Natural fibers are produced and found in a wide geography in the world, are biodegradable and do not pose a danger to the environment. In addition, it is thought that natural fibers will have a good potential as an alternative to petroleum and fossil-based fibers in the future in that sense. Banana is one of the oldest plants in the world. There are about 300 species of banana. Approximately 70 million metric tons of bananas are produced annually in tropical regions of the world [4-6]. After each banana harvest, the pseudo-stem (trunk) of the banana plant is discarded away as agricultural waste. Banana fibers are obtained from these pseudo-stems (leaves) of the banana plant, which is an agricultural waste, find many different uses. Thanks to its important performance properties, banana fibers find increasing application areas day by day. One of these areas is composites. In this paper, the use of banana fibers mainly in composite materials was reviewed.

THE UTILIZATION OF BANANA FIBERS IN COMPOSITE MATERIALS

As a result of the literature research, banana fibers, which are considered as leaf fibers, are known as an important fiber used in composite materials besides their use in textile materials [2,7,8,9,10,11,12]. Banana fibers have high strength, specific strength, better dimensional stability, mechanical properties, environmental sensitivity, usability, low cost, and biodegradability compared to synthetic fibers [1,2,7,10,13,14,15,16,17]. Banana fibers, which used to improve the desired properties of composite materials according to their application areas, are also common to use with polymer matrices [2,7,8,9,10,11,12,18]. There are many different studies in which banana fibers were used in insulation materials, concrete blocks, compacted soil blocks, automotive parts, and some other specific composite applications etc. Banana fibers are used as reinforcement material in thermoset plastic products, construction materials, automotive and transportation applications [3,8,10]. As a result of the experimental studies carried out, it was stated that needle punched nonwoven fabrics made of banana-jute and banana-propylene mixed fibers can be utilized as filter fabric and insulation fabric [19].

Manohar and Adeyanju [20] compared banana fiber thermal insulation with traditional building thermal insulation in their studies. Thermal conductivity measurements of 38 mm thick plate-like banana fiber samples were made. It was concluded that while the density of banana fiber is minimum, its thermal conductivity is at low levels, and as its density increases, its thermal conductivity increases. The results show that the minimum thermal conductivity of banana fiber is higher than all conventional insulation. The optimum thermal conductivity for the use of banana fibers in building thermal insulation has been determined as between 0.02 W / m.K and 0.06 W / m.K [20].

In general, inorganic materials such as mineral wool, light and cellular concretes, foam glass, fiberglass, plastic foams, Styrofoam and expanded perlite are used in building thermal insulation [20]. However, the use of inorganic insulation materials is harmful to human health and the environment in the long term [20]. For this reason, natural fibers such as banana fibers have started to be used in developing innovative insulation techniques and materials [20,21]. Loosely filled fibrous materials that trap air inside the pores provide low thermal conductivity at a relatively low density, and therefore such materials are often used for thermal insulation [21].

In another study conducted by Manohar [21] on building thermal insulation, he compared banana fiber thermal insulation with coconut fiber, sugarcane fiber and palm oil fiber thermal insulation. The thermal conductivity values of all fibers used in the study, respectively, were 0.04415 W / m.K with a density of 70.4 kg / m^3 for banana fiber, 0.0488 W / m.K at 69.57 kg / m^3 density for coconut fiber, 95.94 kg / m^3 for sugarcane fiber and 100.30 kg / m^3 for palm oil. It has been measured as 0.0572 W / m.K at a density of m^3. Banana fiber, one of the four lignocellulosic materials considered, exhibited the lowest thermal conductivity value with 0.04415 W / m.K at a density of 70.4 kg / m^3. The thermal conductivity of the banana fiber gave usable result as a building thermal insulation [21].

The utilization of local materials in the construction of buildings in the construction industry is an important step for sustainability [3]. For this, the use of compacted soil blocks is becoming popular. In particular, banana fiber reinforced green compacted soil blocks show better properties in bending and compressive strength. The material properties of banana reinforced green compacted soil blocks can be greatly affected by fiber type, fiber volume, fiber geometry and length (aspect ratio), fiber surface conditions, production method and composition of matrices. In general, the use of banana fibers in green compacted soil blocks increases the lateral load performance of the wall and enables them to be used in low-cost residential construction [3].

In the study carried out by Deelaman et al. [17], the influence of banana fibers on the mechanical and physical properties of lightweight concrete blocks was examined. They used banana fiber, cement, sand, lime, gypsum, and aluminum powder in the study. The study was conducted on two groups: using banana fiber instead of cement and using banana fiber instead of sand. The results were recorded as the densities of concrete blocks to which banana fiber was added tended to decrease as fiber content increased in both cases. They were observed that the mean compressive strength of the block decreased as the banana fiber content enhanced. The reason for this was interpreted as the high fiber content reduced the bonding efficiency between cement and fiber. Increased fiber content caused increased water absorption and change in length but decreased concrete block density [17]. The usage of waste materials such as banana fiber in geotechnical applications has also been investigated in the literature [22]. In Sunny and Joy's study, banana fiber was added to marine clay. Optimum value has been obtained for marine clay stabilized with banana fiber. They were observed that the optimum moisture content value of sea clay to be used in road pavements increased and dry density decreased with the addition of banana fiber. In addition, it was stated that the shearing strength enhanced with the addition of banana fiber, and it became suitable for use as sub-ground soil in road pavement [22].

Saad et al. [23] conducted a similar study and used banana fibers and palm leaf fibers to improve the brittle behavior of high strength concrete. In this study, before combining the fibers with high strength concrete mixtures, they were subjected to a chemical treatment using alkali (NaOH) to improve the surface properties of the fibers. As a result of this study, the reinforcement of high strength concrete with banana fibers reduced the compressive strength of high strength concretes at all ages and transformed the brittle fracture to ductile fracture. In previous studies in this area have shown that the usage of natural fibers in brittle concrete structures enhances the tensile strength and tensile capacity of concrete [23]. Therefore, the utilization of natural fibers in such materials can be considered as a promising alternative [23].

Another study was about the usage of banana fibers in the automotive industry. Natural fiber reinforced composites with thermoplastic and thermoset matrix are used in door panels, seat backs, headliners, package trays, instrument panels and automotive interiors by European car manufacturers and suppliers [8,15] Banana fiber reinforced composites were used for underfloor protection for passenger cars by Daimler Chrysler [15]. Mercedes uses in the Class A vehicles with floor protection product made of banana fiber composites [15,24,25]. Banana fiber reinforced metal laminate for automobile components can reduce vehicle weight and overall vehicle CO_2 gas emissions [3].

Empty fruit leaves and stems of the banana plant are considered as waste product of banana planting and therefore without any additional cost, banana fiber reinforced composites have of industrial importance for the utilization of banana fiber wastes [9,16,26]. Papyrus Australia LTD has developed a technology to convert banana plant harvest waste into wood products such as paper, furniture, packaging, and other industries [27]. The Martinique-based company FIB and CO converts most of the banana plant into a completely natural, sustainable coating "Green Leaf" used for decorative and acoustic panels [28]. Banana plant wastes are used in lamination and coating products.

Thus, with the natural strength of banana fibers, excellent strength has been achieved in panel products. It has been observed that it provides good structural properties, especially by adhering multiple layers with 90^{o} together [27,28]. The materials of table in the café at the Camille Kendall Academic Center of the Universities in Shady Grove (Rockville, MD) were made of a composite material containing banana fibers [29]. Since materials such as glass, carbon, aramid fibers, epoxy resins and thermoplastics, which are used today as a reinforcement for composite materials, cause serious environmental problems, these are replaced by natural fibers, especially with fiber of ideal physical and mechanical properties such as banana fibers [1,2,7,13,14,15,30,31-32]. Epoxy resin is one of the widely used polymers as a matrix and as a structural adhesive for fiber-reinforced composite materials, commercially important, thermosetting [2,3,33]. Banana fiber reinforced epoxy resins provide better mechanical properties such as increased tensile and bending strength, high thermal resistance, and excellent chemical resistance (Fig.1) [3,33].

Fig. 1 (a) Banana fiber reinforced composite material [32], (b) Banana fiber reinforced epoxy composite [45], (c) Coating material obtained from the stem of banana plant [27], (d) Banana fiber coatings [27], (e) Banana fiber reinforced furniture [27], (f) Table made of banana fiber [29]

The European Union obliged the use of 95% recyclable materials in the vehicles to be produced especially in the automotive sector, with the decision taken in 2015 [30,34,35]. Therefore, natural fibers suitable for low cost, lightweight, bio-composite materials with very good mechanical properties have started to be preferred in automobile production. Banana fibers are one of the leading these natural fibers due to their recyclable, biodegradable, environmentally friendly characters and also their superior performance characteristics. In addition, the use of banana fibers is very important for waste management [30,34,35]. In this sense, as an example, SUZUKI exhibited the Concept EV, designed using banana fiber [35]. As shown in Fig.2, epoxy resin and green matt banana fiber composites have used outside the body of the EV [35]. EV's seat fabric is made of colored banana fibers and cotton fiber blend yarn [35].

Fig. 2 Car made from banana fiber (Concept EV- SUZUKI) [35]

There are several studies on the utilization of banana fibers as a component in different industries [36,37]. For instance, Mishra examined the impact strengths of novalak resins supplemented with banana, hemp, sisal fibers and observed an increase in impact strength of composites prepared with these fibers [37,38]. Kumar et al. [1] have conducted experimental studies on the manufacture and strength of banana-glass-sisal fiber reinforced hybrid composites. They examined its mechanical properties such as tensile strength, impact strength and bending strength [1]. It was concluded that banana-glass-sisal fiber reinforced hybrid composites showed superior properties and can be utilized as an alternative material for synthetic fiber reinforced composite materials [1].

In another study, woven banana fiber, kenaf fiber and banana/kenaf hybrid fiber composites were examined, and it was found that the mechanical strength of banana/kenaf hybrid composites increased due to hybridization [39]. In another study conducted on the effect of hybridization on banana/kenaf fiber reinforced hybrid composites, it was concluded that hybrid composites resist water absorption better than non-hybrid composites [39]. Sivaranjana and Arumugaprabu [10] investigated the mechanical and thermal properties of banana fiber-based hybrid composites. In this study, they revealed that there is 30-50% increase in the mechanical properties of banana fiber reinforced composites such as tensile, bending and impact strength. They also observed an increase in the thermal resistance of banana fiber reinforced composites [10].

Chrispin Das et al. [2] evaluated the mechanical properties of banana fiber and particle reinforced epoxy composite. In this study, tamarind husk powder was used as a filling material for banana fiber reinforced polymer composites and epoxy resin was chosen as the matrix. The banana fiber and the ground particles were mixed with epoxy resin, then mixed with the hardener resin and pressed with a molding machine to form a composite plate. Increases in tensile and flexural strengths of composite materials with 40% fiber content were observed and they have been concluded that it showed maximum mechanical properties. Therefore, 40% fiber content has been specified as the optimum value for production [2].

In the study conducted by Zaman and Beg [15], they examined the mechanical properties of low-density polyethylene unidirectional composites reinforced with banana fiber. They also tested the biodegradability of composites reinforced with low density polyethylene and modified banana starch, which were evaluated by various techniques. Composites made of banana fiber processed with 4% starch showed better mechanical properties compared to composites treated with monomer at the end of the study. They observed that the water uptake values of the composite made of banana fiber processed with starch were lower than those of the control counterparts. They concluded from the soil burial test that the treated samples retained much greater durability than the untreated sample [15].

In the experiment conducted by Joseph et al. [40], optimum fiber length in banana fiber-reinforced composite materials, the effect of volumetric ratios of fibers on mechanical properties and properties of fiber matrix bond were investigated. As a result of the experiment, it was observed that as the usage rate of banana fiber in the material increased, the mechanical properties of the material increased, and banana fibers bonded well with phenol formaldehyde [31,34,40]. As a result of Pothan's studies, it was concluded that the tensile strength of the yarn produced from banana fiber was strengthened in a volumetric ratio [41]. Maleque et al. [42] have observed an increase in tensile, impact and buckling resistance of banana fiber-reinforced composite materials in their studies. In the study conducted by Waghmare et al. [7], The mechanical properties of the banana fiber bio-composite were investigated. As a result of this study, they were noted that banana fiber reinforcement increases the tensile and bending strength of the composite, banana fibers treated with alkali have improved properties, environmental friendliness of banana fibers provides a great advantage and can be used in polymer composites [7].

In another study, it was revealed that the vehicles manufactured from composites which the vast majority are reinforced with banana fiber and called Manaca in Brazil, have achieved the desired success in road tests [24,43,44]. Banana fiber reinforced composite materials were compared with glass fiber reinforced composite materials. It is concluded that banana fiber reinforced composite materials can be produced with less energy, faster and the weight of the produced material is approximately 10% lighter. This also demonstrates that banana fiber has a very high utilization potential with its low density and low-price advantage [30].

It is known that the mechanical properties of the composites depend on the orientation of the fibers used and have better properties when placed in the appropriate orientation [34]. As part of a project from the Department of Industrial Engineering at the National University of Colombia in Manizales, fibers from the leaves of a banana plant were used to obtain high-quality reinforcing material [32]. Unlike inorganic materials such as glass and carbon fibers, cellulose, hemicellulose, lignin is present in the structure of banana fibers. Banana fibers have an irregular structure. Therefore, Lady Johana Rodríguez has developed a process that changes the internal structure of the fibers to make banana fibers of irregular structure suitable for use as reinforcing materials [32]. In this process, the banana fibers were soaked for 24 hours in a solution of epichlorohydrin, anhydrous acetic reactant and acetone and then washed with acetone and distilled water and dried [32]. After the treatment, it was observed that water resistance of banana fibers increased by 33.3% and moisture resistance increased by 32.43%. In addition, it was shown that using micrographs with scanning electron microscopes, the surface is smooth and adheres perfectly to the polymer matrix [32].

CONCLUSION

Banana fibers are obtained from the pseudo-stem of the banana plant, which is waste. In other words, banana fibers are natural plant fibers obtained from waste. Banana fibers are biodegradable, eco-friendly, sustainable, renewable, and natural plant fiber extracted from agricultural waste. Banana fibers, which show important performance properties, have an important place in composite products. Due to the improved mechanical properties of banana fibers, composites based on these fibers are widely used in construction, automotive, etc. Banana fiber has potential use in various industries. It is expected that banana fiber composites could become even more attractive in the future due to its ecofriendly footprints. In the future, new studies, new application areas and different perspectives with banana fibers and composites containing banana fibers will lead to the widespread use of banana fiber.

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BORON FIBERS AND THEIR APPLICATIONS

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ABSTRACT

Boron has been utilized in many different fields. One of these areas is boron fiber. Boron fiber is a kind of metallic fiber consisting of boron atoms in ribbon form. The production of composite materials has been developed with production technology. It is usually produced from boron atoms extracted from boron halide compounds such as boron trichloride. Boron fiber displays high durability, high tensile strength, high compressive strength, and high modulus. This structure allows boron fibers to be utilized in a wide variety of applications, from more technical applications such as aerospace and aircraft to more commercial industrial applications such as sport equipment and entertainment and leisure products such as tennis, squash, badminton rackets, bicycle frames, golf clubs, and fishing rods etc. The unique mechanical properties of boron fibers encourage their use in fiber applications in the 21st century. Boron fibers attract the attention of researchers and the market due to their unique properties such as the ability to form combinations and high strength.

Key words: Boron, boron fibers, cvd, chemical vapor deposition

INTRODUCTION

Boron has been utilized in many different fields and has been a material for many industries until today [1,2,3]. Boron, which is in group 3A with the symbol B in the periodic table, possesses an atomic number of 5 and an atomic weight of 10.81 [4,5]. When examined chemically, it forms boron oxides (B_2O_3) and/or boron salt compounds such as $B_2(SO_4)_3$ as metals, since it has the properties of both metals and non-metals; it forms boric acid (H_3BO_3) compounds as well as non-metallic elements [6]. Depending on its location, it is around 1 ppm in the earth's crust and around 3-4 ppm in the seas, while it is found in volcanic gases and hot waters in a very high amount. When the boron reserves in Turkey and the USA are examined, it is known that it is around 100 ppm in hot water resources [7]. Due to its good physical and chemical properties, its usage areas in different industries are increasing day by day and it accelerates the studies on this subject. The structural, chemical, and physical properties of boron mineral, which has started to find a wide place in the industry, are shown in **Table 1**, **Table 2**, and **Table 3**.

Table 1. Structure of Boron [8-12]

Atomic Diameter	1.17 Â
Atomic Volume	4.63 cm^3 / mol
Electron Arrangement	1s2 2s2 2p1
Valence Electron	2s2 p1
Electron Number	5
Ion Diameter	0.23 Â
Proton Division	5
Neutron Number	6
State of Being Crystalline	Equilateral quadrangle

Table 2. Chemically Content of Boron [8,10-12]

Electronegativity	2,04
Electrochemical Structure	0,1344 g / amp-sa

Potential Energy of Valence Electrons	190
Ionization Potential	8.298 (1st ionization value) 25,154 (2nd ionization value) 37,93 (3rd ionization value)
Electron Number	50,02 kj / mol

Table 3. Physically Structure of Boron [3,13,14]

Atomic Mass	10,811 (g/mol)
Boiling Point	3727 (°C)
Coefficient of thermal expansion	8,3 µm/(m.K) (at 0 °C)
Electrical Conductivity	1,0 E-12 µS/cm
Thermal Conductivity	0,274 W/cm.K
Density	2,34 g/cm3, (at 25 °C)
Appearance	Yellow-Brown nonmetal crystal
Elastic modulus Mass	320/GPa
Atomization enthalpy	573,2 kJ/mol, (at 25 °C)
Fusion enthalpy	22,18 kJ/mol

Boron fibers were first studied for structural applications in 1960 [15,16]. Boron fibers are inorganic chemical fibers. Boron fibers are one of the first fibers with high strength and their first point of origin was used in the aviation industry. It was initially funded by the US Air Force's goal of producing higher performance systems. It has found a place in the market with the effective results obtained as a structural material that can be applied by the aviation industry at a commercially acceptable level [17]. AVCO Specialty Materials company located in the USA, is the first company to manufacture boron fiber [18]. However, boron has a small production capacity and is expensive compared to its rivals such as graphite fiber and DuPont's Kevlar™ [17].

Boron fiber (also can be called as boron filament) is a kind of metallic fiber consisting of boron atoms in ribbon form. The production of composite materials has been developed with production technology [19]. It is usually produced from boron atoms extracted from boron halide compounds such as boron trichloride [20]. Boron fiber, usually well-known as boron filament, is an amorphous element of B5 by-product, indicating a major industrial utilization of elemental (free) boron [21].

Boron fibers are the first continuous high-performance fibers produced in the industry. There are various methods for the production of boron fiber in the literature; however, chemical vapor deposition (CVD) and thermal decomposition methods (TDM) are preferred commercially. Other methods are not as efficient and useful as these two methods. Among these two methods, CVD is the most preferred one [18]. Boron fiber is obtained by applying a CVD process on a tungsten substrate [22,23]. It is possible to obtain boron fibers by several different chemical means, but the most preferred one is as in the following reaction;

$$2BCl_3\,(g) + 3H_2\,(g) \rightarrow 2B\,(s) + 6HCl\,(g)$$

So, as aforementioned, boron fiber is manufactured in single-filament reactors by CVD and boron fibers display an exclusive blend of high compression strength, high modulus and large diameter [24]. Boron fibers can be considered as wide (large diameter) fibers and in their manufacturing process, elemental boron is deposited on an even tungsten wire substrate that generates diameters of 4.0 mil (102 micron) and 5.6 mil (142 micron) [24-27]. The boron fiber is basically amorphous boron with a fully borided tungsten core and this textured surface delivers a brilliant interface in resin-matrix composites, eliminating any necessity for sizing treatments [25,27]. Boron filament production example on tungsten boride substrate is shown in Fig. 1 [24].

A 12µm diameter tungsten substrate was passed through a mercury-sealed gas inlet and drawn through the reactor and the sample was resistively heated to 1,300°C by a direct current (DC) power supply whereas boron trichloride and hydrogen are given at the upper side of the reactor [28]. When the tungsten passes inside of the reactor, boron was generated on the sample by the hydrogen reduction of the boron trichloride and gases of idle boron trichloride, hydrogen chloride byproduct, and unreacted hydrogen were exhausted via an outlet port at the bottommost of the reactor (named as exhaust gases in Fig 1) [24,28]. Those exhaust gases were then either scrubbed or recycled for upcoming manufacture usage and the boron filament, typically around 100 µm in diameter, passes through another mercury seal while it gets out the reactor and is packed onto a take-up spool [28]. In-line optical scanners monitored the fiber diameter before take-up, and modifications can be carried out to speed up or slow down the rate as required by a feedback loop to guarantee the diameter is within the preferred specifications. A distinctive characteristic of boron fiber is its rough, corncob structure (Fig. 2) and this textured surface characteristics procures an outstanding interface in resin-matrix composites and therefore enriches mechanical gripping between fiber and resin (therefore eliminating any necessity for sizing applications) [24,28].

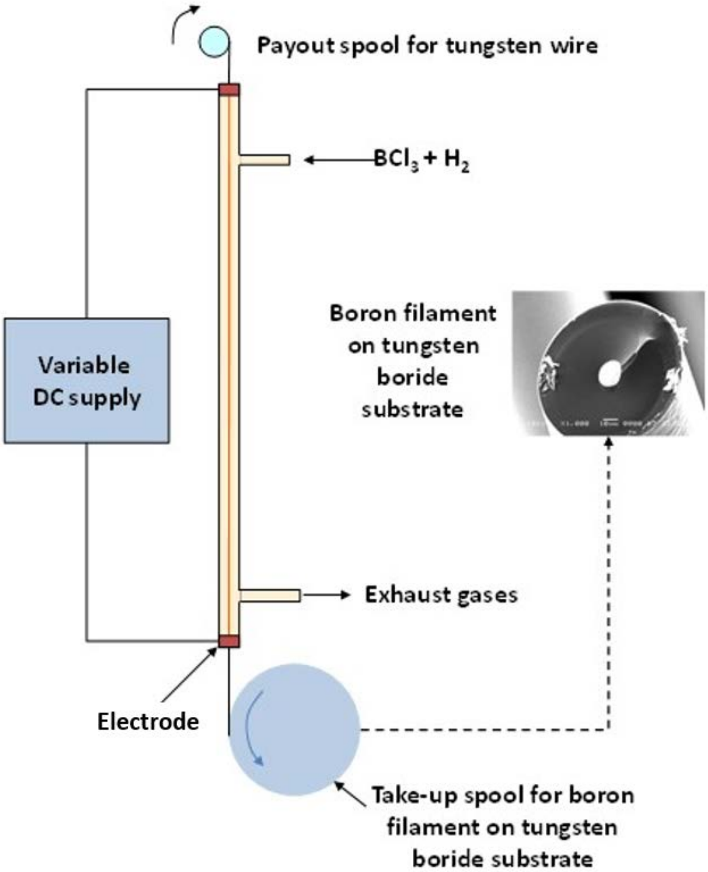


Fig. 1. Boron filament production on tungsten boride substrate [24]

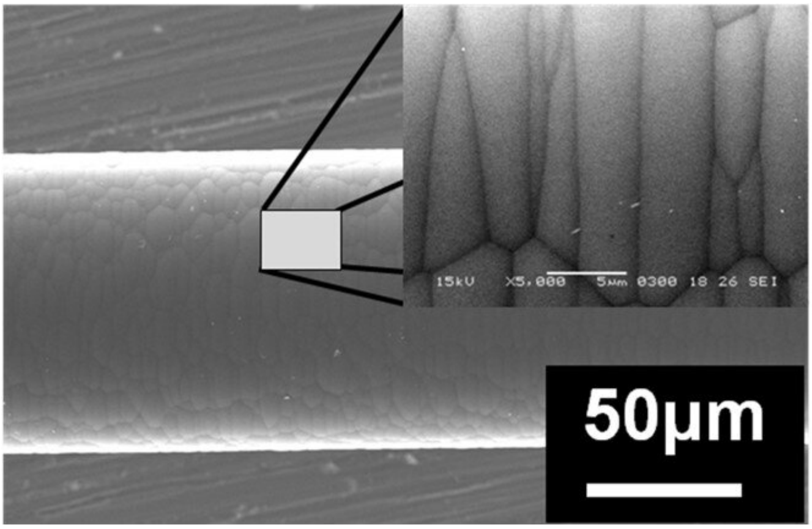


Fig. 2. Longitudinal view of Boron fiber [24]

Although the values are close to each other, there are different values for the diameters of boron fibers in the literature. Boron fiber surface, composed of nodules, specific is separated by borders. The nodules in it form one by one on the substrate, approximately when it approaches around 80-90 microns filament diameter, it expands outward in conical structure. The nodules on it form a structure as if they have shrunk [18]. Boron fibers possess relatively large diameters (100–140 μm and 100–200 μm) in comparison with most other reinforcements [29,30]. The density of boron fiber is around 2.48-2.82 g/cc [27]. Specific gravity of boron fibers is 2.57 for 100 μm fibers and 2.49 for 140 μm fibers and as boron fibers are more pricey than several types of carbon fibers, their usage is much more limited [29]. Structure of boron fibers allows these fibers to be utilized in a wide range of applications, from more technical applications such as aerospace and military aviation applications to more commercial industrial applications such as sports equipment. Also, boron fibers are very stiff, and they exhibit high durability, high tensile strength, high compressive strength, and high modulus [25,27,31]. Particularly, boron fibers are extremely stiff (for instance, 5 times stiffer than glass fibers) and not easy to weave, braid or twist, however they could be made into resin-impregnated tapes for hand lay-up and filament winding practices and the high cost of boron filaments possess significantly limited their usage in experimental aircraft and space applications [32].

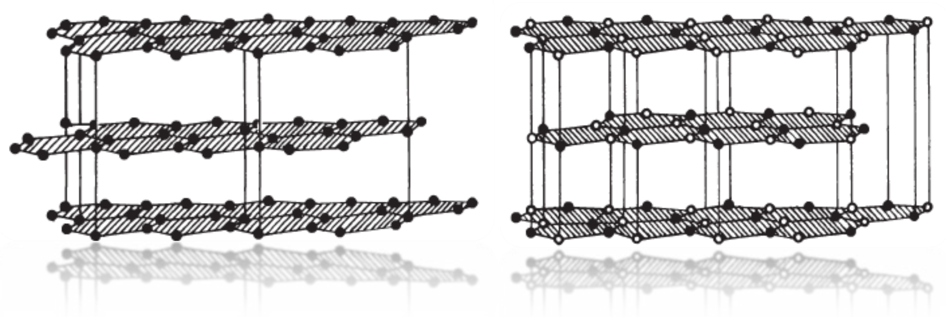
Boron fiber is an amorphous elemental boron product that characterizes the foremost industrial utilization of elemental (free) boron, and a common utilization of boron fibers is in the production of high tensile strength tapes [21,27]. The average tensile strength of boron fiber is around 3-4 GPa and the Young modulus of boron fiber is around 380-400 GPa [21]. Boron fibers are widely used as a component of high-strength, lightweight composite materials used in advanced aerospace structures [27]. It can also be utilized in commercial applications, consumer goods, sports, and entertainment and leisure products such as golf clubs, rigid golf shafts, bicycle frames, fishing rods, tennis, squash, and badminton rackets in order to strengthen [20,21,27]. However, because boron fiber has a complex manufacturing process, it is expensive and not widely used. Since boron fibers are generally made in strips, there are restrictive conditions in their production.

Therefore, this increases its retail value and causes it to be a high-priced material [33]. Although it is expensive and narrow in usage; structures and parts produced from boron fiber exhibit their trouble-free properties in their usage areas. The physical properties of boron fiber make it a more valuable alternative to many other fibers. In general, boron fibers are known for their high fiber strength. Boron fibers are able to withstand a lot of pressure [34]. Comparisons of other potential materials used in these areas with boron fibers are shown in **Table 4**.

Table 4. Comparison of Tensile Characteristics of Boron with Other Materials [18,35]

Materials	Strength		Modulus	
	Average (psi x 10^3)	**Strength (in x 10^6)**	**Average (psi x 10^3)**	**Strength (in x 10^6)**
Continuous boron filament	400	4.0	60	600
E-glass filament	500	5.4	10.5	110
Beryllium	90	1.3	44	660
Steel	28 to 600	0.1 to 2.1	30	110
Titanium	60 to 240	0.1 to 1.5	19	120
Aluminum	9.8 to 88	0.1 to 0.9	9.8	100
Magnesium	25 to 55	0.4 to 0.9	6	100

Boron fiber is produced by a chemical vapor deposition (CVD) process where boron and some other elements, and often compounds containing a halogen, are superheated, reacting with hydrogen gas [34]. In this reaction, the resulting product is then combined with a tungsten filament. This tungsten filament is used as the core for each fiber, while layers of boron atoms are deposited on the filament. Boron nitride has a graphite-like crystal structure and is composed of hexagonal rings of atoms cap directly on top of each other (Fig.3) [36]. What is more, since boron filaments are manufactured by chemical vapor deposition (CVD) technique, more costly than graphite [26].



Hexagonal Graphite *Hexagonal Boron Nitride*

Fig. 3. Hexagonal Structure of Graphite and Boron Nitride [36]

Boron fibers are often used in conjunction with an epoxy matrix. Since the thermal expansion of boron is close to that of aluminum and there is no potential for galvanic corrosion. For this reason, it is used in the repair of cracked aluminum aircraft coatings. In addition, boron fibers are primarily used in military aerospace applications [37,38].

Boron fibers are used in the repair of many commercial aircraft used today. While boron fibers are used in the repair of aircraft structures; boron/epoxy binders are applied to cracked or damaged aircraft parts and bonded. In this way, it helps to reduce the localized fatigue stress in the area. With the use of boron fibers in this application, less maintenance and longer inspection intervals are provided, resulting in cost savings and safety. Because boron/epoxy is a high modulus, lightweight material, repairs are thinner and lighter than the metallic binders they replace. Also, no drill holes are necessary, which can increase stresses and damage the underlying structure. Other important properties of boron fibers are their high electrical resistance, their transparency to eddy currents, and their ability to be molded according to the contours of the structural space (**Table 5**) [17].

Table 5. Mechanical Property Data for Boron Fiber Composites [17]

Property	Boron Epoxy	Boron Al	Boron Mg
Tensile strength, MPa(ksi)	1590 (230)	1520 (220)	2030 (300)
Tensile modulus, GPa (msi)	210 (30)	214 (31)	289 (42)
Flexural strength MPa(ksi)	2050 (300)		2140 (310)
Flexural modulus, GPa (msi)	190 (38)		269 (39)
Compression strength, MPa (ksi)	2930 (425)	2760 (400)	3270 (475)
Compression modulus, GPa (msi)	210 (30)	207 (30)	248 (36)
Interlaminar shear strength, MPa (ksi)	110 (15,6)	159 (23,0)	147 (21,4)
Density, g/cc (Ib/square inch)	2,0 (0,072)	2,6 (0,095)	2,2 (0,0,081)
Fiber volume (%)	50	50	60

THE UTILIZATION OF BORON FIBERS IN DIFFERENT APLICATIONS

Although the first emergence of boron fibers dates back to the 1960s, there are also some studies in the early 2000s. However, due to its expensiveness and the problems experienced in production, recent studies have not been found much, and new issues to be realized on this subject are waiting as an open field for research. One of the first studies on this subject was carried out in 1963. In this study, Talley et al. [39] investigated whether the BCl_3 concentration in the BCl_3-H_2 system has an indispensable value for the production of boron fibers. In this study, they found that the deposition temperature is the most critical parameter. The accumulation rate of boron is very high at temperatures below 1000^{o}C. If it is 1250^{o}C to 1350^{o}C, it is large. It was observed that crystallites generally formed along the filament [39]. Talley et al. [39] developed new techniques to test the mechanical properties of boron filaments. In particular, they displayed the shrinkage of boron [39].

Gruber [40] investigated (1970) the chemical kinetics and mass transport of boron fibers using the CVD technique, boron trichloride and hydrogen gas. As a result of this study, surface reactions suggestions have emerged in Langmuir type kinetic models to determine the rate of mass transports [40]. Carlton et al. [41] studied (1970) the reduction of boron trichloride at temperatures between 800^{o}C and 1400^{o}C. In this study, the tube deposition rate of hydrogen was examined. Thermodynamic and kinetic analyzes of the system were performed in a specially prepared experimental design. In addition, dichloroborane ($BHCl_2$) production was also investigated in this study. With the obtained data, it has been revealed that dichloroborane is in stability [41]. Vandenbulcke and Vuillard [42] conducted their study in 1977 to confirm the mechanism proposed by Carlton [41]. In their study, correlation was obtained for mass transfer in impinging jets [42].

Krawitz and Bhardwaj [43] investigated (1983) the structure of boron in boron fibers utilizing boron trichloride and hydrogen at a temperature of 1000-1400^{o}C. By developing a custom computer modeling they investigated the form of non-crystalline and chemically deposited fibers in the structure. According to the results obtained, boron fibers consist of randomly oriented boron atoms and a continuous network of boron [43]. There are also studies in which different analyzes were performed using the CVD method and different results are obtained. Michaelidis and Pollard [44] examined the pipes in the CVD method in 1984. Similarly, Sekine et al. [45] examined the kinetics of boron thin film on tungsten utilizing CVD in 1989.

Imaishi et al. [46] conducted a study on macro and micro modeling of CVD synthesis in 1997. As a result of this study, they created a reaction to produce an intermediate product with a reaction schematic in which the material source passes into the gas phase [46]. There are three different studies that had been done in different years using CVD by Sezgi et al. The first study was published in 1997 [47]. In this study, dichloroborane was used during boron fiber formation by CVD in a double pulse jet reactor. In another study by Sezgi et al. in 1999 [48], they explored the CVD mechanism of boron by hydrogen reduction of BCl_3 in a double pulse jet reactor. They used the BCl_3 and H_2 gas mixture and they had prepared in the experimental setup. In the study of Sezgi et al. in 2000 [49], CVD of boron and dichloronborane formation, studied the effects on the hot tungsten substrate in a parallel flow reactor. It was concluded that diffusion resistance is important for boron fibers in parallel flow seen in the reactor [47-49].

On the other hand, Dilek et al. [50] studied (2001) the kinetics of boron carbide formation from the gas mixture of BCl_3, H_2 and CH_4. $BHCl_2$ formation was experimentally confirmed by this mechanism in experiments performed in atmospheric environment [50]. While boron fibers also take their place among composite materials, there are also comparative studies with composite materials used in different sectors. In 2014, there was a study that compared Boron and Kevlar-49 thermoset composites, which have especially strong mechanical properties. In this study carried out by Yeung et al. [51], boron fibers and Kevlar-49 were examined. Boron fibers not only have strong tensile strength, but also facilitate strong compression in different composites. Kevlar-49 reinforcement is not preferred much in high performance structural applications. The physical and mechanical characteristics of the fibers used in this research are shown in **Table 6** and **Table 7** [51].

Table 6. Properties of Boron and Kevlar-49 [51]

1	2	3	4	5	6	7	8	9	10
F1#	Boron	140	2630	399.9	399.9	166.9	0.20	4136.85	4826.33
F2*	Kevlar-49	12	1467	151.7	4.1	2.9	0.35	2757.90	517.12

#as provided by the manufacturer, Specialty Materials Inc.
**as provided by the manufacturer, Dupont Inc. USA*

Notes: Column headings are as follows: (1) Fibre notation; (2) Fibre type; (3) Fibre diameter, df, (μm); (4) Density, ρf (kg m–3); (5) Longitudinal Modulus, Ef1 (GPa); (6) Transverse Modulus, Ef2 (GPa); (7) Longitudinal Shear Modulus, Gf1 (GPa); (8) Longitudinal Possion's Ratio, νf1; (9) Longitudinal Tensile Strength, σfT (MPa); and (10) Longitudinal Compressive Strength, σfC (MPa).

Table 7. Characteristics of the Thermosetting Plastics Used as Matrices [51]

1	2	3	4	5	6	7	8
S1	Polyimide	1218	3.45	1.28	103.4	206.8	89.6
S2	LM Polyester	1163	2.21	1.11	55.2	103.4	55.2

Notes: Column headings are as follows: (1) Matrix notation; (2) Matrix material; (3) Density, ρm (kg m–3); (4) Modulus, Em (GPa); (5) Shear Modulus, Gm (GPa); (6) Tensile Strength, σmT (MPa); (7) Compressive Strength, σmC (MPa); and (8) Shear Strength, τm (MPa).

According to the data obtained as a result of this research; it was determined that boron-based reinforced thermoset composites have higher strength and elastic modulus structure than the compressive strength of Kevlar-49 composites. Since both have fiber content, their strength values were found to be similar. However, it has also been found that boron fibers are open to research on this subject [51].

So, to sum up, boron fibers can be created by depositing boron vapor onto fine tungsten wire and boron fibers possess utilizations in reinforcement, especially of aluminum [52]. The special usage areas of boron fibers can be briefly summarized as follows. For instance, one of the utilizations of boron fiber composites was in the horizontal tail surfaces of the F-14 Tomcat fighter aircraft made by Grumman Aerospace Corp. (now Northrop Grumman, USA) [27,28]. Similar use of boron fiber was made by McDonnell Douglas (now Boeing) for the horizontal and vertical linings and rudder on the F-15 Eagle fighter aircraft [28]. These two aircrafts were both fixed-wing design aircraft that needed high-strength, high-modulus fiber to decrease flutter and minimize the mass of each aircraft [28]. Those two were the first steps of high-performance fiber usage in a production application and therefore boron fibers became the first high-performance fiber to be utilized in a production application [28]. One of the other interesting uses of boron fibers was the way they were involved in NASA's moon mission. During this moon mission, cloth made in part from boron fibers was utilized in the drill stems for collecting lunar rock samples [52]. Moreover, other applications involving boron fiber are the tubes for the mid-fuselage structure of the Space Shuttle Orbiter made by General Dynamics, the dorsal longeron of the B-1B bomber airplane made by Rockwell, horizontal stabilizers for the Sikorsky H-60 Black Hawk helicopter, the Dassault Mirage 2000 aircraft rudder [28]. Furthermore, Textron Specialty Materials developed of a hybridized composite material comprising of boron and carbon fibers and the addition of 4.0-mil boron fiber to carbon fiber composites could improve the compressive strength of the composite by 100-200% in comparison with solely-carbon-composites [28]. Recently, the high compressive strength of boron fiber allowed a considerably enhanced payload to be carried on the Reaper UAV (**U**nmanned**A**erial**V**ehicle) (General Atomics, USA) with its usage in the spar caps below the wings of the Reaper [28]. Another recent application for boron fibers is the utilization in space structure components for optical imaging [28]. Recently, the usage of boron fibers is implemented or considered for some other application types such as armor, satellite components business, Predator, the new F-15EX fighter aircrafts and hypersonics [28,53]. Apart from these interesting technical application areas in aerospace, aircraft, and sports equipment, boron fibers display no commercial application in the home fashion and/or in apparel [54].

CONCLUSION

Boron fiber has no commercial application in the home textiles and in apparel or garments. On the other hand, boron fibers are utilized in aerospace and aircraft industries and in different sport equipment and entertainment products such as tennis, squash, badminton rackets, bicycle frames, golf clubs, and fishing rods etc. The unique mechanical properties of boron fibers, it promotes its use in fiber applications in the 21st century. Although the unique properties of boron fibers, such as the ability to form combinations, high durability, high tensile strength, high compressive strength, and high modulus, cause an increase in interest; due to its expensive and limited production, it limits its use in certain areas. The usage of boron fibers is implemented and/or considered for some other application types such as space structure components for optical imaging and satellite components business, armor, U.S. Space Shuttle, F-14 Tomcat fighter aircraft, F-15 Eagle fighter aircraft, Predator, the new F-15EX fighter aircrafts and hypersonic etc. With the introduction of new technologies and techniques into the production sector with different usage angles and the coming to life of new material combinations, it can be expected that the usage area and usage amounts of boron fibers will increase in the future.

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SUSTAINABLE NATURAL WOOL DYEING WITH RUBIA TINCTORUM

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ABSTRACT

It is common knowledge that natural dyes are fit for textile dyeing since ancient times. Basically, natural dyes are elements derived from natural resources, and classified as plant, animal, mineral, and microbial dyes based upon their source of origin. Natural dyeing is a very important part of the old Portuguese tradition which is, currently, regaining awareness due to sustainability and health issues that has arisen from the massive application of synthetic dyes in textile coloration. In this study we sought to optimize the extraction of Rubia Tinctorum (Alizarin and Lucidin) using a design of experiments (DOE) methodology and to develop an analytical method by high performance liquid chromatography-diode array detector (HPLC-DAD) for their quantification. Dyes extracted and isolated were then used to dye 100 % wool jersey knits by way of the exhaustion process. The color strength and fastness properties of the dyed samples against washing, and rubbing were evaluated. Our findings proved that meta-mordanted samples dyed at 80 °C for 4h obtained the best strength and color fastness results.

Key words: Natural Dyeing; Rubia Tinctorum; Extraction of Natural dyes; Wool; Fastness properties.

INTRODUCTION

Natural dyes have been known since ancient times, they are dyes derived and removed from plants, invertebrates, or minerals. Most of the natural colorants are vegetable colorants, extracted from different parts of plants: roots, fruits, bark of trees, leaves and wood; there are other biological sources that produce dyes such as fungi and lichens. Archaeologists have found evidence of fabric dyeing dating from the Neolithic period. In China, dyeing with plants, barks and insects has been traced to being more than 5,000 years old. [1] The essential dyeing process has changed little over time. Typically, the dyeing material is placed in a pot of water and then the fabric to be dyed is placed in the container, which is heated and stirred until the colour is transferred. Textile fibers can be collected before spinning ("wool dyeing"), but most textiles are dyed on the yarn or in "pieces" after weaving. Many natural paints require the use of chemicals called mordants to fix the ink on textile fibers; gall tannins, salt, natural alum, vinegar, and urine ammonia were used by the first dyers. Many mordants, as well as some dyes, produce strong odours, and dyeing sites were often isolated in their own districts.

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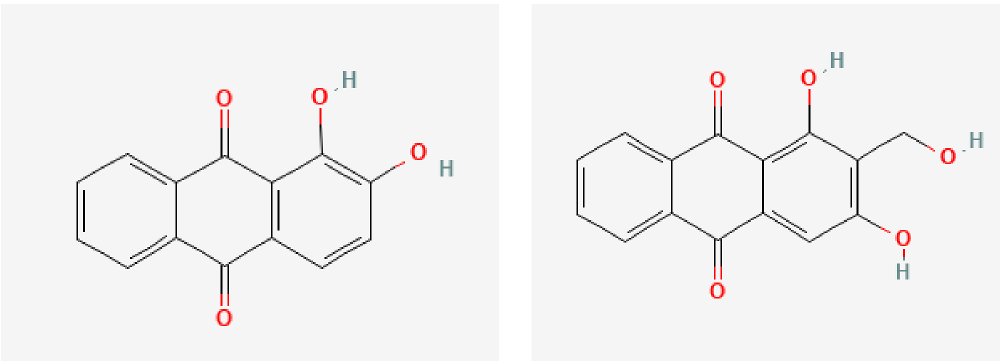
Throughout history, people have dyed their fabrics using common and locally available materials, but rare dyes that produced bright and permanent colors like natural dyes from invertebrates, Tyrian purple and kermes carmine, have become luxury items in the ancient and medieval world. Herbal dyes such as pastel (Isatis tinctoria) and indigo were important commercial items in the economies of Asia and Europe. Throughout Asia and Africa, printed fabrics were produced using techniques to control color absorption in part-dyed fabrics. Paints like cochineal and logwood (Haematoxylum campechianum) were brought to Europe by the Spanish, and European dyes were taken by the colonizers to America.
The discovery of synthetic dyes in the middle of the 19th century triggered the decline of the large-scale market for natural dyes. Synthetic dyes, which could be produced in large quantities, and unlike natural dyes, could be used in the synthetic fibers created next. Artists from the Arts and Crafts Movement preferred pure hues and a subtle variety of natural dyes, which ripen over time but preserve their true colors, unlike the first synthetic paints, [1] and helped to ensure that ancient European techniques became dyeing and printing with natural inks were preserved. Natural dyeing techniques have also been preserved by artisans and traditional cultures around the world. At the beginning of the 21st century, the natural paint market is experiencing a resurgence in the fashion industry. [2] Western consumers have become more health-conscious about the environmental impact of synthetic dyes in the manufacturing process and there is an increasing demand for products that use natural dyes. [3]

RUBIA TINCTORUM

Rubia tinctorum is a perennial plant related to lady's bedstraw and goosegrass or cleavers, which are common wild flowers in Europe. It produces an array of fast colors from its roots, ranging from pale pinks and violets, through deep reds to oranges and browns. This is uncommon, as red dyes are scarce both from natural and synthetic sources, and as such madder is considered a valuable commodity. The most significant of the madder dyes are alizarin (Fig1 A) and lucidin (Fig1B. [4] It has been used since ancient times as a vegetable red dye for leather, wool, cotton and silk**.**



A **B**

Figure 1 - Chemical structure of Alizarin Lucidin.

MATERIALS AND METHODS

Chemicals and Materials

Rubia Tinctorum was purchased from CRITT Horticole (France). Alizarin and Lucidin analytical standards were obtained from José Manuel Gomes dos Santos, (Odivelas, Portugal). The working solutions of both compounds were pre-pared by proper dilution of stock solutions with methanol to the final concentrations of 1mg/mL. All stock and working solutions were stored at -20 ºC and protected from light. Trifluoroacetic acid (Panreac Química SA, Barcelona, Spain) and ethanol (Fischer chemical, Loughborough, UK) were pro-analysis grade. Methanol (Merck Co, Darm-stadt, Germany), and acetonitrile (Prolabo, Lisbon, Portugal) were HPLC grade. De-ionised water was obtained from a Milli-Q System (Millipore, Billerica, MA, USA).

The analytical grade Copper (II) sulfate pentahydrate ($CuSO4.5H2O$,) was used as a mordant and purchased from Merck company, Germany. A non-ionic wetting agent and detergent, Kieralon DS, was procured from BASF Portugal. All solutions were prepared with distilled water. The exhaustion dyeing process was carried in a laboratory machine Labomat BFA12 dyeing system from Mathis. A Jenway 6300 spectrophotometer model, from Keison, was used for the absorbance measurements whereas a spectrophotometer Spectraflash SF300 model, from datacolor Int, (D65 illumination and 10° observer) was used for color strength measurements.

The 100% wool yarn was supplied by a Portuguese spinning mill named Ecolã and the knits used in the experimental setup were produced in the knitting workshop of the University of Beira Interior.

Instrumental and Chromatographic Conditions

The quantification of main compounds present in *Rubia Tinctorum* was performed on an high performance liquid chromatography system coupled to a diode array detector (HPLC-DAD) 1290 model (Agilent technologies Soquímica, Lisbon, Portugal) (Figure 2). The mobile phase was composed of acetonitrile: 0.1% trifluoroacetic acid (42:58, v/v). The elution was carried out in isocratic mode. The chromatographic time was 10 minutes. The flow rate was 1 mL/min, and the injection volume was 50 µL. The stationary phase consisted of an YMC-Triart PFP (5 µm, 4.6 i.d. × 150 mm) analytical column coupled to a Guard-c holder (4 ×10 mm) and a Triart PFP (5 µm, 3 ×10 mm) pre-column, all from YMC Europe GMBH (Solítica, Lisbon, Portugal), being maintained at 25 °C.

Figure 2 - Chromatographic system

Dyeing process

This investigation was focused on the ability of an aqueous and alcoholic extract of S.vulgare, acting as a natural dye, to carry out the dyeing of 100 % wool jersey knit samples under the influence of

different conditions [5,6,7]. The color strength and washing fastness were then thoroughly investigated.
The jersey knit was produced in a rectilinear knit machine (model SVR123SP from Shima Seiki) and can be characterized as follows (Table 1):

Table 1 – Knit sample characterization.

Composition	100 % wool
Yarn linear density (Tex)	115
Loop length (cm)	0.7
Wales per (cm)	4.7
Courses per (cm)	6.6
Stitch density per (cm^2)	29.04
Tightness factor (K)	15.3
GSM (g/m^2)	325
Knit structure	Jersey

Upon their production the knit fabric was scoured with a 3 g/L non-ionic detergent and 1 g/L sodium carbonate (Merck Company) at 70 ºC for 30 min. Then, it was thoroughly rinsed and air dried at ambient temperature.

The mordanting, with a concentration of 1% owm, and dyeing, took place in a simultaneous process (meta-mordanting). The samples were dyed at 80°C, with various concentrations of the *Sorghum spp.* extract: 10, 20, 30 and 40 g/L, and different durations: 1, 2, 3 and 4h. Dyeing was carried out in pH 4, adjusted with glacial acetic acid, purchased from sigma Aldrich, and with a liquor ratio of 50:1. Upon dyeing samples were thoroughly rinsed, washed, and dried at room temperature.
The color strength and color depth of mordanted and dyed samples were determined calorimetrically (colourspace: CIELab (1976)/D65) by light reflectance technique. The color strength (K/S) of all the samples was assessed by the Kubelka-Munk equation:

$$K/S = \frac{(1-R)^2}{2R}$$

With R being the observed reflectance at the wavelength of maximum absorption (λ_{max}= 420 nm) of the dyed wool samples, K is the absorption coefficient and S the light scattering coefficient. The colors are given in CIELab coordinates (L*, a*, b*), which refers to the three axes of the color space, in which L* indicates the perceived brightness (the scale runs from 0 = black to 100 = white); whereas a* denotes the red (+a*) and green (-a*) value and b* specifies the yellow (+b*) and (-b*) coordinate. Other values normally measured are C* which stands for the saturation value calculated from the reflectance data and h° which is the hue angle.

Washing fastness properties were evaluated in accordance with ISO 105-C06 standard method. The washing operation was carried out in the Linitest apparatus at 60°C for 30 minutes. Upon washing, samples were rinsed with tap water and air dried at room temperature. We repeated the procedure for 5, 10, 15, 20 and 25 cycles. Subsequentially, and in order to find out the washing effect on dyed samples, we measured the color strength and CIELab coordinates for all the tested samples, for a more objective comparison.

Statistical Analysis

Statistical analyses used for optimization were carried out with Minitab Statistical Software version 17, and SPSS version 25.

Sample Preparation

From the *rubia tinctorum* plant, 25g of powdered root material were weighed and dissolved with 500 mL of ethanol in an erlenmeyer and then submitted to an extraction process on the stirring plate, for 24 hours at 30 °C. After that, the product resulting from the plant was filtered with the aid of the buchner funnel, for an erlenmeyer and paper filters. The solution was then placed in the rotary evaporator, in order to evaporate the solvent added to the plant and to obtain the precise amount of dye in a 100 mL flask. Upon the dye extraction, the weight of the extract obtained was approximately 200 mg. After the extraction procedure, a 20 mg extract was obtained, which was dissolved in 1 ml of ethanol and filtered using 0.20 µm cellulose acetate filters before being transferred to the automatic sampler for injection in the HPLC-DAD system.

RESULTS AND DISCUSSION

Identification and quantification of Alizarine and Lucidin.

The column and autosampler temperatures were set at 30 and 4 °C, respectively, and the analytes were detected at 254 nm. The retention times were 5.27 min for lucidin and 7.19 min for alizarin (Figure 3).

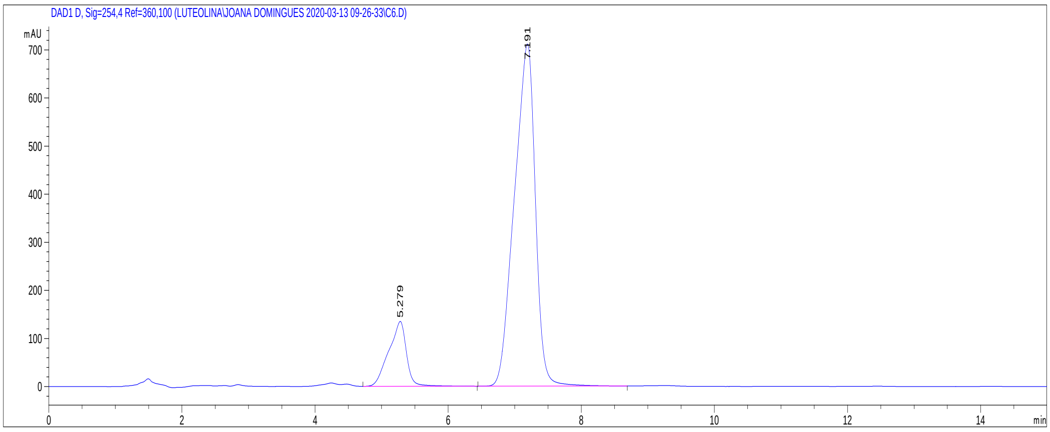


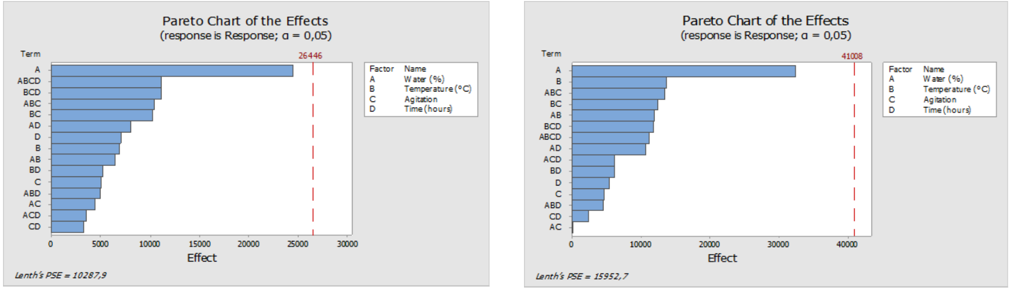
Figure 3: Chromatogram of lucidin (5.27 minutes) and alizarin (7.19 minutes) at 10 µg/mL

Optimization of the extraction procedure

In order to maximize the extraction procedure, a study was designed using the design of experiments tool (DOE) where the main parameters that affected the extraction procedure were studied. DOE rapidly evaluates, in a multivariate fashion, the critical factors that may have a significant impact on compounds' extraction. A central point (n=3) was added to the design matrix for precision evaluation.

The evaluation was performed with 25g of powdered roots of Rubia tinctorum dissolved in 500mL of ethanol. A two-level full factorial design with four factors (24) was developed in order to study the effect they had on the lucidin and alizarin recoveries. The studied factors were extraction time (6 to 24h), percentage of water (0 to 100%), stirring (yes or no) and temperature (30 to 80ºC).

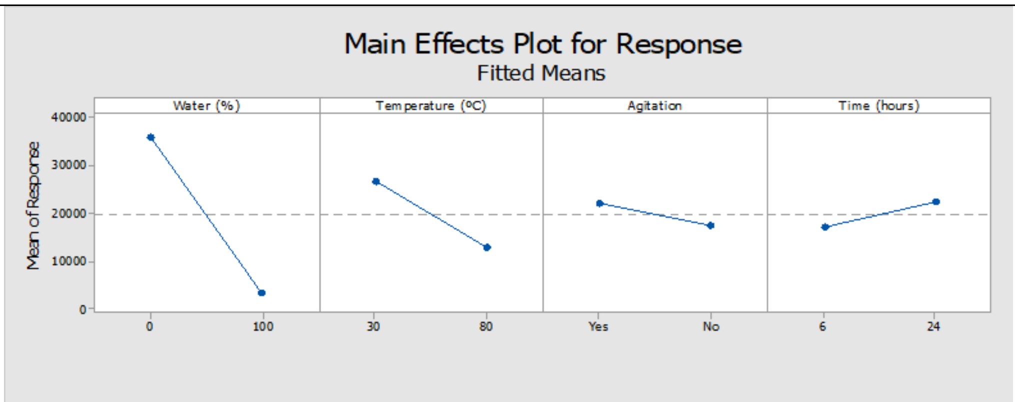
According to the pareto charts obtained from the experimental design (Figure 4A and 4B), no factor revealed a significant influence on both lucidin and alizarin recoveries.



A **B**

Figure 4: Pareto chart for lucidin extraction process (A) and alizarin (B).

Through the main effect plots (Figure 5A and 5B) it is possible to observe a greater response when a lower percentage of water, 30 ºC with stirring for 24h were used. Therefore, those conditions that originated an apparent better response (considering the main effects plots) were chosen: extraction with 100% of ethanol at 30ºC and stirring for 24h. The monitoring of the experimental design through the central point resulted in relative standard deviations (RSDs) of 18.5 and 18.4% for lucidin and alizarin, respectively. After the optimization and according to the results the final procedure to extraction the roots of Rubia tinctorum was obtained.



A

B

Figure 5: Main effects of the inputs in the lucidin (A) and alizarin (B) extraction process.

Quantification of Lucidin and Alizarin from Roots of Rubia tinctorum

The method was validated according to the guiding principles of the Food and Drug Administration. The calibration curves were established between 0.16 and 10 µg/mL for both compounds, seven calibrators evenly distributed (Table 1). The limits of detection and quantification were considered the same as the limits of quantification, 0.16µg/mL for lucidin and alizarin. Table 2 summarizes the data related to linearity.

Table 2: Linearity data

Analyte	Weight	Linear range (µg/mL)	Linearity Slope*	Intercept*	R^{2*}
Lucidin	Linear	0.16-10	236.15 ± 11.845	-7.508± 0.0899	0.9992 ± 0.0017
Alizarin	Linear	0.16-10	1443.6 ± 107.25	-94.965 ± 0.0976	0.9997± 0.0028

* Mean values ± standard deviation Using this method, it was possible to determine the concentration of the compounds in the extract. These concentrations were 13.6µg/mg and 0.18µg/mg for lucidin and alizarin, respectively.

Experimental dyeing

Based upon the extracted material four dyeing batches were carried out in accordance with the experimental framework defined in table 3.

Table 3: Dyeing conditions

Dyeing	**Rubia Tintorum extract**
Raw-material	100% wool Jersey knit
Mordent	Copper sulfate (II) $CuSO_4.5H_2O$ 1% o.w. Meta-mordant processe
Dyeing machine	Mathis Labomat
Dyeing process	Exhaustion
Concentration	10, 20, 30 e 40 g/L
Liquor ratio	1:50
Wetting agent	Kieralon [1g/L]
pH	pH 4 adjusted with acetic acid
Time	4h, 3h, 2h, 1h
Temperature	80°C
Finishing	Washing, rinsing, and drying at room temperature

Table 4: Visual aspect of dyed samples with mordant

Table 5: Visual aspect of dyed samples without mordant

Concentration g/L	WITH MORDANT											
	80° 4h	80°3h	80° 2h	80° 1h	60° 4h	60° 3h	60° 2h	60° 1h	40° 4h	40° 3h	40° 2h	40° 1h
10												
20												
30												
40												

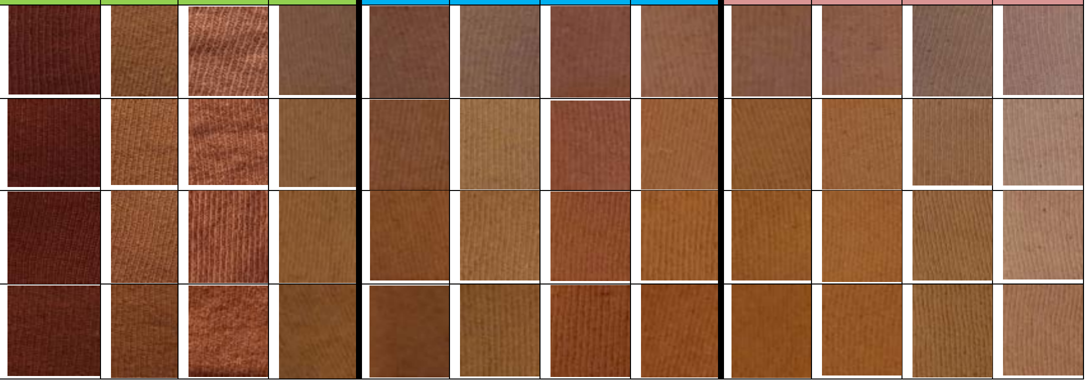


Table 6: Color strenght and CIELab values for samples dyed without mordant

With Mordant g/L	K/S	L*	a*	b*	K/S	L*	a*	b*	K/S	L*	a*	b*	K/S	L*	a*	b*
	80°4h				80° 3h				80° 2h				80° 1h			
10	23,46	34.54	23.13	26,42	15,56	33,52	19,74	21,15	13.02	36.31	18.19	21.08	8.66	43.44	20.76	24.96
20	34,75	25.59	18.91	20,38	25,77	28,71	22,41	22,83	22.52	31.73	22.95	24.78	11.91	39.71	19.30	24.91
30	37,66	24.06	23.10	20,87	29,99	28,22	23,93	24,32	26.98	29.28	23.59	24.25	16.19	37.77	23.15	28.22
40	39,34	23.34	24.13	20,84	32,84	25,06	21,13	20,57	31.03	25.47	21.10	20.39	23.39	33.63	25.84	29.00
	60° 4h				60° 3h				60° 2h				60° 1h			
10	10,10	44.11	23.80	28,86	10,01	43,81	24,22	28,36	9.44	44.65	24.44	28.37	8.29	45.11	20.24	25.80
20	17,51	39.34	27.93	32,4	17,44	39,26	27,29	32,02	15.87	40.17	27.04	31.80	14.28	41.13	26.38	31.07
30	24,02	35.99	28.97	32,91	23,63	36,48	29,73	33,39	22.13	37.39	29.87	33.71	19.52	38.00	27.79	32.10
40	26,85	35.50	31.23	34,25	26,39	34,25	29,13	31,88	25.72	35.51	30.57	33.48	24.35	36.58	30.60	34.15
	40° 4h				40° 3h				40° 2h				40° 1h			
10	8,18	47,10	22,52	28,79	8,06	46,46	21,51	27,33	4.09	55.32	19.38	26.19	3.63	55.76	15.86	23.71
20	14,28	41,93	28,26	32,62	13,97	42,17	27,89	32,60	6.64	50.78	23.84	30.82	3.97	55.33	17.49	25.90
30	19,19	39,54	30,50	34,60	18,64	39,62	30,14	34,25	8.80	48.09	26.03	33.00	5.30	53.48	20.36	29.57
40	23,02	36,11	28,79	32,24	21,39	38,00	31,01	34,26	10.88	45.68	27.42	33.46	7.05	51.57	23.76	33.32

Table 7: Color strenght and CIELab values for samples dyed with mordant

Without Mordant g/L	K/S	L*	a*	b*	K/S	L*	a*	b*	K/S	L*	a*	b*	K/S	L*	a*	b*
	80°4h				80° 3h				80° 2h				80° 1h			
10	20,58	27,82	17,45	17,13	9,92	41,68	13,26	20,89	8.18	44.54	12.23	20.90	5.95	47.32	11.38	18.13
20	30,31	25,75	18,60	21,16	16,08	38,51	14,74	25,88	12.13	41.05	13.01	24.12	7.77	44.97	11.99	21.21
30	32,66	26,21	18,04	23,07	20,32	37,04	15,11	28,00	14.25	40.45	13.55	26.51	9.74	43.61	12.63	24.16
40	36,66	30,71	16,48	25,27	20,99	36,84	15,64	28,34	17.93	40.83	14.24	31.20	11.75	43.46	13.18	27.56
	60° 4h				60° 3h				60° 2h				60° 1h			
10	6,55	41,71	14,08	14,21	6,38	41,97	13,45	13,51	6.20	41.89	13.30	13.00	5.98	46.32	11.94	17.95
20	9,79	39,12	14,85	18,51	8,83	42,51	14,44	20,97	8.82	40.01	14.47	17.43	8.23	44.81	13.26	22.98
30	11,66	40,20	15,63	23,48	11,94	40,21	15,19	23,34	10.66	40.85	14.95	22.13	9.74	43.61	12.63	24.16
40	13,94	38,83	15,56	24,83	12,96	41,57	15,51	26,89	13.78	40.43	15.41	26.10	12.40	43.28	14.60	28.76
	40° 4h				40° 3h				40° 2h				40° 1h			
10	5,26	47,85	11,04	17,59	5,09	47,92	11,07	17,06	2.64	56.20	6.24	12.13	2.44	56.14	6.05	9.49
20	7,77	46,73	12,28	24,18	7,21	46,42	11,95	22,66	3.95	52.58	8.32	16.84	2.51	56.78	6.77	10.64
30	9,62	47,22	12,64	28,96	9,36	46,51	12,93	28,03	4.90	51.88	8.89	21.08	3.00	54.69	8.04	12.48
40	12,33	47,47	13,88	34,27	11,20	46,08	13,11	30,70	5.64	51.44	9.03	23.77	3.30	54.59	8.84	15.32

The global analysis of the color strenght (K/S) and CIELab values attained for the different experimental conditions allows the following inferences:
In all dyeing batches carried out (with and without mordant), for the three temperatures considered (80°C, 60°C and 40°C) and for the different durations of the dyeing processes (4h, 3h, 2h and 1h) the value of color strength increases, consistently with the increasing of dye concentration in the dyebath;
The K/S values are always higher – for any value of concentration and temperature – when the mordant is added to the dyebath (except for three cases with very similar values that can be neglected);

Dyeings carried out at higher temperature and with longer duration tend to have higher values of color strenght, which means that temperature and duration have a critical effect on the migration and fixation of the dye in the wool fiber.
The L* tend to be lower with dyeings performed with higher concentration values and higher when lower concentration values are used. This effect is particularly noticeable when using mordant in the dye bath.

This behavior agrees with the respective color strenght variation. Thus, for higher values of K/S we have a lower value of L* and vice versa.
Consistently, also the samples dyed at higher temperature have lower L*values for higher dye concentrations and when the mordant is added to the dyebath.

CONCLUSIONS

The application of *Rubia Tincorum* extract to act as natural dye onto wool jersey samples was carried under two different sets of experiments in which we sought to assess the effect of the dyeing time. All the experiments were carried out in the presence and absence of a metal mordant, copper (II) sulphate pentahydrate, so as to ascertain his contribution for the dyeing outcome. From the results it can be postulated that wool jersey knits can be successively dyed with *Rubia tinctorum* extract. This may attributed to fact that *Rubia Tinctorum* is rich in Alizarin and Lucidin that can form hydrogen and ester bonds with the carboxyl groups in the protein fiber. In the overall, samples dyed with 80 °C and long dyeing duration – 4h – yielded the best color strength and fastness properties.

ACKNOWLEDGMENT

The authors gratefully acknowledge the funding by Ministério da Agricultura, under grants ID Grupo Operacional 303, Operação N. º PDR2020-101-031956. This work was partially supported by CICS-UBI, which is financed by National Funds from Fundação para a Ciência e a Tecnologia (FCT) and by Fundo Europeu de Desenvolvimento Re-gional (FEDER) under the scope of PORTUGAL 2020 and Programa Operacional do Centro (CENTRO 2020), with the project references UIDB/00709/2020 and UIDP/00709/2020.

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MUSICAL INSTRUMENT DESIGNS MADE FROM TEXTILE FIBERS

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ABSTRACT

Music is an indispensable part of most of our lives. We now see the use of textile fibers in many different musical instruments, as well as in classical fields such as clothing and home textiles. For this purpose, recently, composites reinforced with textile fibers have attracted attention in the production of musical instruments. Indeed, textile fibers used in musical instrument making are truly new material for environmental sustainability, technology, and art. The superior performance characteristics of textile fibers used in musical instruments offer ease of use. It is therefore an alternative material to conventionally used materials. In this paper, we examined the musical instruments made from textile fibers. With this object in my mind, several musical instruments such as guitar, ukulele, cello, violin, violin bow, piano, drum, flute, banjolele, trumpet, harp, harp guitar, didgeridoo, mandolin and musical instrument cases made from various textile fibers such as carbon, flax, glass, hemp, Kevlar, and their some combination usages are reviewed in detail.

Key words: Fiber, Musical instrument, Composite, Guitar, Harp, Piano, Hemp, Flax, Carbon, Kevlar, Glass

INTRODUCTION

Music is another form of showing our joy and sadness. It is also one of the important elements of our dream world that takes us to the past and the future. And it is widely accepted that the music is an indispensable part of most of our lives. We now experience the utilization of textile fibers in many different musical instruments apart from their usage in classical fields such as apparel and home textiles. The technology of making musical instruments containing textile materials is a new technology [1,2]. Many instruments have been invented and used in the process of introducing music and art to human beings and especially into their lives. Due to their superior acoustic properties, different woods and metals have generally been preferred in the production of musical instrument. With the advancement of technology and increasing environmental problems, the search for different materials has started to be used in the production of musical instruments [1,2]. The acoustic properties of wood make it ideal for its use in guitar, violin, clarinet, oboe, and drumsticks. Spruce woods of exceptional resonance quality are used in sound reflectors on the tops of violins and cello. For instance, poplar, walnut, and beech wood are widely used in the construction of Iran's traditional musical instruments called Santour, Tar and Barbat. Despite the unique acoustic characteristics of different types of wood, there are disadvantages. The desired sounds cannot be produced under humid conditions. Also making a musical instrument from wood is a time consuming and costly process. Its characteristics are not always of the same quality [2]. Research shows that utilizing polymeric composites instead of wood is a solution to such problems. Among these composites, high performance fiber reinforced composites are preferred because of their high physical and mechanical characteristics during their service life [2]. For this reason, textile fiber reinforced composites are used in the production of musical instruments [1,2]. Textile fibers reinforced composites are fatigue resistant. It provides design and production flexibility [1]. It is also resistant to extreme temperatures, corrosion, and abrasion. This increases the useful time of the product. Particularly, epoxy-resin matrix composites are used in musical instruments or parts of the musical instruments. In this way, the necessary mechanical properties are provided for musical instruments to produce appropriate sound. Composites reinforced with textile fibers used in the production of musical instruments increase vibration damping and impact resistance. It also reduces tensile strength, percent elongation at break and stiffness [1].

In some studies, conducted in the literature, acoustic parameters of composites reinforced separately with carbon fiber, glass fiber and hemp fiber were examined and compared with traditionally used wood based musical instruments. Acoustic features such as acoustic quality, sound quality factor, acoustic conversion factor were tested. The outcomes showed that glass fiber reinforced composites may be an alternative for some types of wood. It has also proven that carbon fiber-reinforced composites can be used in the manufacture of musical instruments with outstanding acoustic properties [2]. Natural fiber reinforced composites have attracted attention in the recent years due to renewable and environmental awareness. Flax fiber reinforced composites and hemp fiber reinforced composites were used instead of sound reflectors. Famous musical instrument manufacturers such as Blackbird have used flax fiber composites as well as carbon fiber composites in their musical instruments. They have successfully produced musical instruments that are very close to the properties of wood, with both natural and wooden appearance with flax fiber reinforced composites [3].

In this paper, we examined the musical instruments made from textile fibers. With this object in my mind, several musical instruments such as guitar, ukulele, cello, violin, violin bow, piano, drum, flute, banjolele, trumpet, harp, harp guitar, didgeridoo, mandolin and musical instrument cases made from various textile fibers such as carbon, linen, glass, hemp, Kevlar, and their some combination usages are reviewed in detail.

MUSICAL INSTRUMENT MADE FROM TEXTILE MATERIALS

The development of musical instruments depends largely on the production materials [4]. Therefore, it is important to what extent the materials used in the production of musical instruments increase or decrease the performance of the instrument [4]. In the recent years, scientists have been trying to make or develop musical instruments with new materials. Today, the most important material used for this purpose is textile fiber [5]. Of course, carbon fibers are the most important for use for this purpose among a wide variety of textile fibers. [6]. Carbon fiber yarns are composed of carbon element. These strands are woven together to form fabric layers, typically about 5-10 micrometers in diameter. When grafted with certain types of resin, carbon fiber woven fabric becomes hard leading to ultra-durable material [6]. The use of carbon fiber in the making of musical instruments is of great importance in environmental protection [5]. Traditional cello making uses all pieces of wood that have a great burden on the environment, along with demanding crafts. The annual wood consumption of the violin family in China was calculated. The annual wood consumption of the violin family was approximately 24,000 m^3. A 10-year-old tree makes up about 0.27 m^3 of timber and the annual tree used for violin family construction is 88,888 [5]. In addition, carbon fiber instruments eliminate the use of varnishes, which have a major impact on the environment. Making a traditional wooden musical instrument requires a large amount of colorants, paints and glaze, while virtually no varnish or colorants are needed to make carbon fiber musical instruments [5]. The most significant advantage of carbon fibers compared to wood is that it is resistant to atmospheric substances such as moisture, heat or cold. In addition, a carbon fiber composite provides three times faster sound transmission and is less damped when compared with wood. In terms of density, carbon fibers are much heavier than wood, but much more rigid. It is recognized that a high-quality musical instrument should be as light and thin as possible while having basic mechanical features. Carbon fiber composites, accepted as the materials of the future, are light, strong, and very durable [7]. Carbon fiber is only one of the preferred textile materials for modern musical instrument design. Apart from carbon fiber, Kevlar, glass, flax, and hemp fibers are also used in many different musical instruments. Natural fiber-reinforced composites give an extra advantage for musical instruments because they display the appearance of wood and exhibit wood-like properties along with their ecofriendly, sustainable, renewable, and biodegradable nature. In the next sections of this paper, musical instruments made from textile fibers were examined one by one.

Guitar

The guitar is a stringed instrument played with a finger or a pena, essentially similar to eight shapes, with oval sides and sound frets on the handle. Apart from wood, guitars can also be made from carbon, glass, flax and hemp fibers (Figures 1-4). Even though, guitar production from wood is common, carbon fibers with basic mechanical properties and light weight are also used to make a high-quality guitar. Carbon fibers are lighter than ¼ steel. The tensile elastic modulus is between 230-490 GPa and higher than steel. Carbon fibers are therefore a preferred fiber for making guitars and many other musical instruments. In November 1994, a carbon fiber guitar was exhibited at the largest musical instruments exhibition in the UK. The use of carbon fiber reduces the weight of the instrument, increases its mechanical strength and allows it to produce resonance [5]. Problems with warp necks, sharp pitch ends, unsuccessful glue joints, lifting bridges, sound strips, voice notes, cracks in wood and moisture should not be part of an acoustic guitar [8,9]. The use of carbon fibers for this purpose is advantageous. Most of the timber shows frequent damping. It cannot make the highest notes clear. The damping of carbon fibers is almost constant in the acoustic spectrum, resulting in a full sound range and crystal-clear notes are obtained. Due to its smooth stiffness, it perfectly balances acoustics and very loud sound [8,9].

Figure 5. Carbon Fiber Guitar [8]

Guitars can also be produced from composites reinforced with different textile fibers [10]. The most popular one is Ekoa. Ekoa is a natural bio-composite found in dry fabrics, pre-lubricants, cores, and resins. El Capitan is the first Ekoa® natural composite guitar. Flax (linen) fiber and bio resin (industrial waste resin) were used in this guitar. Thus, a wood-hard like guitar was obtained for a lighter, louder and more dynamic guitar then a sound reflector. Moreover, a guitar which is more resistant to moisture and temperature can be produced [10].

Figure 6. El Capitan, the first Ekoa® linen fiber composite guitar [10]

Another textile fiber used in guitar production is glass fiber. Glass fiber is practically preferred by designers because it can be molded in any way. The bodies of the formed guitars consist of two molded fiberglass body halves joined by a plastic seal. It is thought that the glass fiber used in guitars can make the production process cheaper. In addition, since the color can be mixed into glass fiber, it does not require extra dyeing process [11].

Figure 7. Glass Fiber Composite Guitar (Resoglass) [11]

Hemp fiber has an incredible power as a building material and, at the same time, resonance makes it possible its use in guitar production [12]. It is noteworthy that it is sustainable and renewable. Moreover, the resulting solid basses and very warm, smooth, softer medium and high tones prove their suitability to the instrument structure [12].

Figure 8. Hemp Fiber Composite Guitar (Canadian Hemp Guitar) [12]

Ukulele

Ukulele is a 4-string instrument belonging to the family of stringed instruments. Textile fibers such as flax, hemp and carbon fibers can be used as an alternative to wood in ukulele production [10] (Figures 5-7). In order to combine the tone of wooden instruments with the durability of the composite instruments, ukulele was first produced from ekoa, a natural composite [10]. Materials such as carbon fiber, glass fiber are also used to provide durability. However, flax (linen) fiber reinforced composite structures are used to produce a wood-like tone [10]. Ukulele is produced not only from flax fiber reinforced composites but also from hemp fiber reinforced composites [13]. Blackbird Clara concert ukulele was the first instrument produced with natural fiber composites and won the Composite and Advanced Materials Fair (CAMX), JEC America, and the American Industrial Designers Association IDEA Award. The guitar format was introduced later [10, 14]. Linen fiber composites were used instead of wood sound reflectors of ukulele. Properties such as material density dynamics, high specific modulus in the grain direction and low internal friction are important for sound reflections. These values were used as a guide when developing a layer sequence for the linen sandwich panel [3]. Ukulele Wires are usually made of nylon.

Figure 9. Linen Fiber Composite Ukulele [15]

Figure 10. Carbon Fiber Composite Ukulele [16]

Figure 11. Hemp Fiber Composite Ukulele [13]

Cello

Cello is a four-stringed instrument with a bass sound. Spruce, maple, and ebony are generally used in the production of this instrument, the first of which was produced in France [5]. However, cello types made from carbon and Kevlar fibers can also be found (Figure 8). It was reported that the sound quality and musical sound criteria of cello successfully produced using carbon fibers were tested with Fourier analysis. Accordingly, it was concluded that the cello produced from carbon fiber had a richer sound than the cello produced from wood. Cellos produced from carbon fiber provide deep and soft sound. Low frequency top tones play a more important role in carbon fiber cello. This allows for a new artistic combination [5]. In addition, carbon fibers are light. It has high strength and modulus [5]. This provides ease of transport for cello made of carbon fiber. The cello produced from wood is 4.0 kg, while the carbon fiber cello is 2.1 kg. In addition, carbon fiber weighs less than 1/4 steel and has elongation strength of more than 3500 MPa, which is 7 to 9 times that of steel. It is insoluble in organic solvent, acid and alkali and does not swell. In other words, the use of carbon fiber also provides protection for the cellos. Technically, carbon fiber cello is easier to produce than wooden cello. The production time is shorter, and the cost is lower [5]. Bridge Draco has a hollow body made of electric cello, carbon fiber and Kevlar composite [17]. Enclosed air can resonate to provide a rich amplified cello sound while maintaining the strength and durability of a solid object instrument. Bridge Draco electric cello utilizes an encapsulated collection system integrated into the bridge, which takes the full advantage of a traditional bridge and captures the warmth and tone of acoustic cello [17].

Figure 12. Cello Made of Carbon and Kevlar Fiber Composites [17]

Violin

Carbon fiber composites are also used in the production of violin which is the smallest member of the Violin family that plays the highest tone [18]. Not only violin but also violin bow can be made from carbon fibers (Figures 9-10). This material, woven from carbon yarns and produced by combining with an epoxy polymer, is used in violin manufacture. Thus, 5 times stronger than wood, 2 times harder and lighter instrument can be produced. It is also 33% of the steel weight. The use of carbon fibers, often used in advanced technology and aviation applications, in violin and similar musical instruments is also an advantage in outdoor concerts [18]. Carbon fiber fabrics and fine fabrics are placed in the mold according to a sophisticated plan during production [7]. Fiber direction, quantity and fiber type are important in here. The material structure can be further improved by the use of core materials or other fibers. Aramid combs, hard foams, wood coatings and a wide range of fibers and fillers are used in the mold [7]. Belgian instrument producer Tim Duerinck is currently conducting a research project that explores the possibilities of violin making from flax, carbon, aramid, and more other fibers [20]. Some materials, such as the Carbon-Nomex sandwich, seem to be more suitable for creating a higher violin instrument. Whereas the violin made of flax fiber has a warmer and more rounded sound. Mezzo-Forte has been careful in using carbon fibers in all traditional elements that make up the instrument's sound [21]. They have sought to remain true to the original designs for bridges, sound poles, fingerboards, tail pieces, chin rests and end pins. In this way, it reaches the right violin and cello sound. Adhering to the traditional shape and architecture of classical violin, designers can create instruments that produce a rich, warm, and perfect sound that can compete with even the most expensive Stradivarius [21].

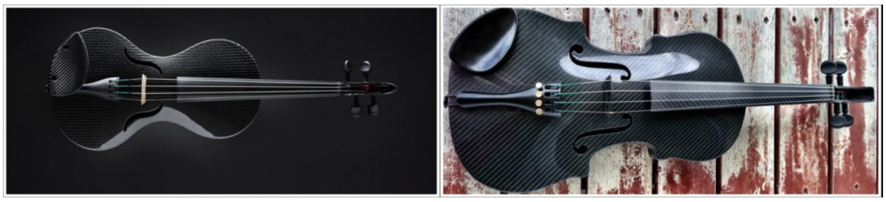

Figure 13. Carbon Fiber Violin [18,21]

Pernambuco or Brazilian wood is often used in the production of violin bows [22]. However, wooden springs can easily swell, hit, and even crack when exposed to different environmental conditions. One of the most common problems (as well as hair that extends beyond its usefulness) is that the tips tend to break. Therefore, the use of carbon fibers in violin springs is advantageous (Figure 10). Durability, long life, bending, and swelling are the most important advantages. In addition, carbon fiber composites are preferred in violin springs for making loud sound [22].

Figure 14. Carbon Fiber Violin Bow [22]

Piano

The piano, which is a clavier, is usually made of hard and durable wood [23]. Nowadays, pianos can also be made from textile fibers such as carbon and glass etc. (Figures 11-13). For instance, the award-winning pianist Gergely Bogányi has developed a new type of piano that includes carbon fiber composites. In developing this, he wanted the piano to be sharper and less susceptible to fluctuating humidity and temperatures. Thus, the usage of carbon fiber composites in piano construction has been increased to achieve a stronger and more balanced sound than traditional models of similar size. Because of an intricate mechanism, the strings apply minimal pressure on the sound board, produced from over 20 carbon fiber composite layers. The carbon fiber composite material soundboard endows numerous benefits over wood: it is resistant to temperature alteration and offers greater resonance, vibration and sustaining power than conventional models [23]. Generally, carbon fiber reinforced composites are used to reduce the weight of the piano and improve acoustics [24]. At the Composites Engineering Show, carbon fiber piano attracted massive attention. An innovative design, carbon fiber reinforced pianos stand out with their weight, performance, sound quality, and stability. The use of carbon fiber in the piano's sound panel disproportionately reduces the loss of acoustic energy in the material of the device in favor of high frequencies [24].

Figure 15. Space age piano designed by Gergely Bogányi, carbon fiber composite piano [24-26]

There is also a special high-tech piano supported by advanced carbon fiber reinforced composite materials [27]. The resonance of the specially designed piano, which combines the electronic, mechanical, and acoustic aspects of both acoustic and digital pianos, is provided by carbon fibers. In addition, the piano is much more resistant to environmental influences thanks to its carbon fiber content. The unique properties of the carbon fiber used allow the sound to be preserved for a longer period of time, resulting in a rich and strong tone [27].

Figure 16. Carbon fiber custom design piano (EXXEO) [27]

Figure 17. Glass fiber reinforced grand piano gravelli [30]

The ivory used to make piano keys was eventually replaced by galatite, a thermoset polymer made from milk casein. Instead of very expensive ebony used in black keys, phenolic compounds can also be utilized [28]. Acrylic resins have been used to cover traditional wooden keys of classical pianos or to produce 100% plastic keys of many electronic keyboards [28]. In addition, textile materials are used in some parts of pianos [29]. For example, felts are used in hammer heads. The impact force of the felt hammers on the pressure sensors determines the sound level. The main body (chassis) of the pianos can be made of glass fiber reinforced plastic or aluminum [29]. Carbon and glass fiber reinforced composite materials are also in use in the piano cover because it is durable, light and strong. In addition, the main parts of the Gravelli piano are designed from a mixture of concrete reinforced with tiny glass fibers. It combines a classical piano with modern materials [30].

Drum

Carbon or glass fibers reinforced composite materials are also used in drum production which is a percussion instrument (Figures 14 and 15). The carbon fibers used in the inner floors add clear and high frequencies to the drum. Its use on the outermost floor makes it strong and durable [19].

Figure 18. Carbon Fiber Drum [19]

Besides, glass fiber reinforced composite materials are also used in drum production. It is ensured that the shell thickness of the drum is thinner by using glass fibers. This results in a thinner shell with increased durability. Drum made of a layer knitted with glass fiber is shown in Figure 15 [31].

Figure 19. Glass Fiber Drum [31]

Flute

Composite flute made of carbon fiber is an innovative instrument [32] (Figure 16). With this double whistle made of carbon fiber, tone, fine adjustment, and sound adjustment can be made. The channel body of the flute is also made of carbon fiber. In this way, the flute is very light, extremely hard, and stable. Also flute made with carbon fiber offers a lifetime guarantee. It also provides grip comfort. The sound is quite warm and strong enough not to get lost in the community [32].

Figure 20. Carbon Fiber Composite Flute [32]

Banjolele

Banjolele, having an interesting appearance, is a four-stringed musical instrument with a small banjo-type body and fretboard ukulele neck [33]. Banjolele also can be made from carbon fibers (Figure 17). There are models made of carbon fiber composite polycarbonate with radial reinforcement and built-in stainless steel head tensioning system [33].

Figure 21. Carbon Fiber Banjolele [33]

Trumpet

Trumpet is a wind instrument consisted of a mouthpiece and a curled pipe, usually made from copper [34]. But in collaboration with Carbo AG, Musik Spiri in Winterthur, the Technical University of Rapperswil and the Institute for Music Acoustics at the University of Vienna, Nägeli Swiss AG have developed a trumpet bell made of carbon fiber-reinforced plastic. The trumpet bell was produced utilizing RTM (Resin Transfer Molding) technology. The dry fibres in the formation of braided bands were preformed and placed in a mold and the resin was injected into the closed and heated mold. Then, a vacuum was applied, and the resin was injected at high pressure, and afterwards the curing cycle was employed. The major advantage of DaCarbo devices lies in the measurable and noticeable low blowing energy required to play a sound (Figure 18). Because of the high hardness of the instrument panel and the good damping characteristics of the composite materials, the percentage of inaudible vibration of the bell is reduced, thereby enhancing the reflection component of the sound. Blind tests have displayed that DaCarbo instruments correspond to the tone characteristic of the typical traditional trumpet sound and can easily be accepted and used in professional orchestras [34].

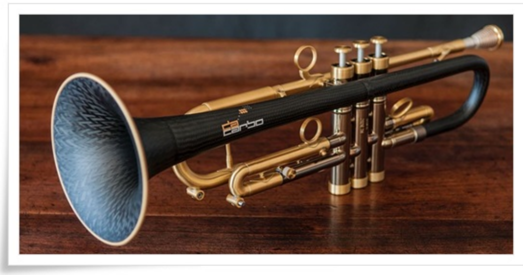

Figure 22. Carbon Fiber Composite Trumpet (Da Carbo) [34]

Harp

Harp is the oldest stringed musical instrument mostly used in classical western music [35]. Different materials have been used in harp production with the meeting of technology and design. Carbon fiber reinforced composites are the most widely used textile material for harp production (Figure 19). Thus, a lighter harp can be obtained than wood [35].

Figure 23. Carbon Fiber Reinforced Harp [35]

Harp guitar

The harp guitar produced under the name Synergy is made of carbon fibers (Figure 20) [36]. This instrument is a modern design and combining the best materials and technology. This innovation, which is a guitar-based stringed instrument, produces both light and durable instruments with very good sound characteristics [36].

Figure 24. Carbon Fiber Reinforced Composite Harp Guitar [36]

Didgeridoo

Didgeridoo is a wind instrument that has been developed by native Australians in northern Australia in the last 1,500 years and is still widely used nowadays both in Australia and around the world [37]. It is sometimes described as natural wood trumpet or "drone pipe". It can be produced from carbon fiber reinforced composites (Figure 21). The three-piece sliding didgeridoo is made of high-quality carbon fiber and is therefore not only very light, but also it is almost indestructible in normal use. Sliding adjustability makes it possible to play specific chapters in a full ninth (high A to low G) range. Didgeridoo can be pushed together to a length of about 75 cm [37].

Figure 25. Carbon Fiber Didgeridoo [37]

Mandolin

Carbon fiber composites were also used in the production of mandolin, a stringed instrument similar to the oud. However, it is expected to be improved to optimize tone and operation [38].

Figure 26. Carbon Fiber Reinforced Mandolin [38]

As clearly seen from above sections, many different musical instruments are produced from textile fibers. Not only the musical instruments but also the musical instrument cases used to carry or protect musical instruments can be made of textile fibers.

MUSICAL INSTRUMENT CASES

Musical instruments are sensitive to environmental factors such as extreme heat, cold, humidity and dust [39]. It causes expansion and shrinkage of musical instruments made of extremely hot and cold brass. Humidity damages wooden instruments such as acoustic guitars and pianos. The dust can be filled into the electric switchboards of electric guitars, amplifiers, and electric sound mixer boards. This is why it is important to store instruments for long-term use. Carbon fibers, a durable and strong fiber, are also used in the construction of instrument cases (Figure 23). Its superior performance characteristics against climate conditions provide an advantage not only in production but also in storage of its instruments [39]. These cases provide maximum protection and provide professional quality comfort and versatility. It is therefore possible to find not only carbon fibers but also aramid, glass fiber instrument cases. This makes it possible to obtain a lighter sheath which is more durable [39].

Figure 27. Carbon Fiber and Glass Fiber Reinforced Musical Instrument Cases [40]

CONCLUSIONS

In conclusion, several musical instruments such as guitar, ukulele, cello, violin, violin bow, piano, drum, flute, banjolele, trumpet, harp, harp guitar, didgeridoo, mandolin and their musical instrument cases now can be produced from different textile fibers such as carbon, linen, glass, hemp, Kevlar and their some combination usages. Indeed, recently, fiber-reinforced composites used in musical instruments play a major role in the development of the musical instruments manufacturing industry. Textile fiber composites are new materials for measuring, adjusting, and improving the density, vibration frequency and sound transfer characteristics of musical instruments. Textile fiber composites are preferred in many musical instruments due to their prominent performance characteristics. Especially carbon fiber reinforced composites are used in various instruments. What is more, natural fiber (such as flax and hemp etc.)-reinforced composites give an extra advantage for musical instruments because they display the appearance of wood and exhibit wood-like properties along with their ecofriendly, sustainable, renewable, and biodegradable nature. The use of textile fiber composites in musical instruments undoubtedly provides a suitable idea for improving sound and further studies. In addition, the use of long-lasting textile fibers composites in musical instruments contributes to the protection of forests from brutal exploitation. Textile fibers are expected to be an alternative to materials traditionally used in musical instruments. It is expected that the use of textile fibers in musical instruments will increase, and other musical instruments can also be produced from textile fibers. It can be expected that, in the near future, textile fibers may be used in different application types not only in the field of musical instruments, but also in many other different nonconventional fields.

ACKNOWLEDGEMENTS

Authors would like to thank to Pamukkale University Scientific Research Project Unit, PAU BAP Project No: 2019KRM004096 and PAU BAP Project No: 2020KRM004096 for their support.

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THE EFFECT OF THE DIFFERENT AGING CONDITIONS ON TENSILE STRENGTH AND ELONGATION UNDER LOAD PROPERTIES OF PLA/PET WOVEN FABRICS

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ABSTRACT

Due to the increase in environmental concerns, the determination of new legal obligations by governments and the European Union due to climate change, and also the unsustainability of the plastic waste problem, important steps are taken towards the use of biomaterials in many important sectors. Detailed studies were carried out by scientists on the production, development and use of biobased and biodegradable polymers within the scope of sustainability. The textile and automotive industry is at the forefront of the sectors that cause plastic waste generation. In this research, a study was conducted to use biobased and biodegradable PLA fibers instead of petroleum-based polyethylene terephthalate (PET) fibers used as basic raw material in automotive seat fabrics in order to reduce CO_2 emission, plastic waste problem and dependence on petroleum-based products, especially in the textile and automotive industry. In this context, the effect of elongation and tensile analyzes on the dimensional stability performance was investigated in accordance with automotive specifications on 100% PET and weft 100% PLA / warp 100% PET woven fabrics exposed to different aging processes. While PLA/PET fabrics provide the necessary standards and specifications, their special applications can be evaluated by taking into account the holistic requirements of the place of use.

Key words: Polylactic acid (PLA) fibers, biopolymers, automotive textiles, woven fabric, tensile strength, elongation

INTRODUCTION

In latest years, significant research effort has been devoted to the use of biodegradable polymers in plastic materials applications, such as packaging, textile. It is most important to reduce the ecological impact concerned to the accumulation of plastic wastes from daily applications of plastic materials based on conventional polymers, such as polypropylene (PP), polyethylene terephthalate (PET), polyethylene (PE), etc. (Hamad L. et al., 2014; Kaseem M. et al., 2012). Biobased materials and biodegradeble materials represent two of the most attractive fields of material science, in which scientists are contributing to human health care, improving life's quality, securing ecology from pollution, and decreasing dependence on fossil fuels. The most of biopolymers have been improved as potential biobased and biodegradable packaging materials due to their different compositions, specific structures, and unique features that cover a wide range of applications (Okada M., 2002; Cava D. et al., 2006; Lee S.G. et al., 2007).

Polyhydroxyalkanoates (PHA) and polylactic acid (PLA) are in the first place among biopolymers in terms of total biopolymer productions and usage areas (Lim L.T. et al., 2008; Europen bioplastics conference, 2020). PLA was first synthesized by Carothers in 1932, and high molecular weight PLA was synthesized and patented by DuPont in 1954 (Holten H., 1971; Lunt J., 1998; Lowe E., 1954; Carothers W.T. and Arvin G.A., 1929). Synthesized lactic acid monomers can be converted into PLA polymers using a number of polymerization processes, including polycondensation, ring-opening polymerization, and dehydration condensation reaction (Figure 1) (Hamad L. et al., 2015). Since lactic acid is a chiral molecule, it has three different optical isomers such as L-lactide, D-Lactide, and DL-lactide. The stereochemistry of PLA can be arranged to meet the requirements. Stereoregularity is the main reason why poly(L-lactic acid) is a highly crystalline polymer (Huang J. et al., 1998;

Casalini F.R.T. et al., 2011). The physical properties of high molecular weight PLA depend on transition temperatures for common properties such as density, heat capacity, and mechanical and rheological properties. PLA biopolymer can have an amorphous or semi-crystalline structure depending on factors such as stereochemistry and thermal history. For semi-crystalline PLAs, both the glass transition temperature (Tg~58°C) and melting point (Tm=130–230°C) are important to determine the temperature of use in various applications (Henton D. et al., 2005). The density of solid amorphous PLA is ~1.25 g/cm^3. The density of pure crystal PLLA is estimated to be 1.37-1.49 g/cm^3 (Henton D. et al., 2005; Witzke D.R., 1997).

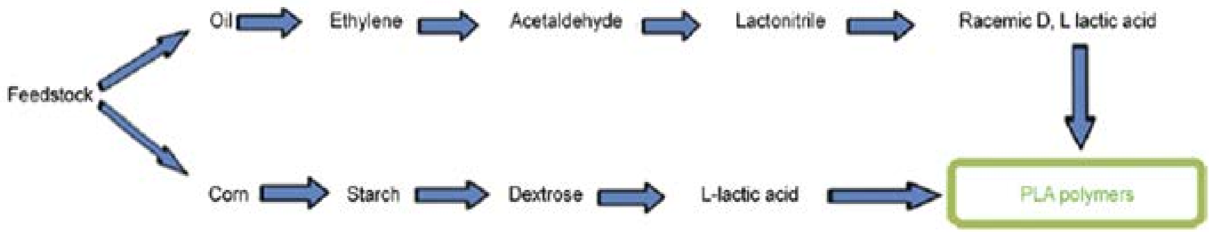

Figure 1. Polylactic acid production pathways (Hamad L. et al., 2015)

Most of the PLA fibers currently on the market are produced by melt spinning method due to its high speed production, economic and environmental friendliness. Some researchers have studied the properties of PLA fiber under various drafting parameters such as processing temperature, extrusion speed and winding speeds (Gupta B. Et al., 2007). Cayuela et al. studied the false-twist texturing process of PLA filaments. False twist texturing was applied to PLA filaments at different temperatures and with different draw ratios. Dimensional stability, mechanical properties and crystallinity of PLA textured fibers were investigated (Cayuela D. et al., 2013a,b). PLA fiber has some advantages for textile applications compared with other fibers (Jacopsen S. et al., 1999). It has lower moisture recovery and better moisture transport similar to petroleum-based polyester fibers. In addition, PLA fibers have inherent biological resistance, good flame retardant and UV resistance (Yang Y. et al., 2020). According to NatureWorks, using PLA fiber for 10,000 sports shirts instead of the petroleum-based polyester can help save fossil fuels, which equates to 540 gallons of greenhouse gas emissions or 18,500 km of driving (Farrington D. et al., 2005).

Polyester fibers (especially PET) are the basic raw materials used in the production of textiles used in the automotive industry. Polyester and nylon are highly preferred because of their good physical properties, high performance, dyeability and cheapness (Table 1) (Matsuo M., 2008). PET is preferred as a basic raw material for textiles used in automobiles due to its high resistance to temperature, high strength, hardness, good chemical resistance and excellent sliding properties (Štrumberger N. et al., 2005). In addition to these properties, polyester fiber has been used as a basic raw material for 95% of seat covers since the 1990s due to its good aesthetic and thermal comfort properties. Also, the very good abrasion resistance of PET fibers offers these fibers a significant advantage in terms of their use in car seat fabrics (Fung W. and Hardcastle M., 2001; Yao G., 2015). Because of the increasing environmental awareness towards the conservation of resources, reuse and recycling of products has gained importance in the manufacture of auto parts. Polyester fiber can be used in recycled form in car upholstery, especially in automobile carpets and seat covers (Atakan R., 2014; More ride comfort, 2017). Although recycling and reuse of automotive textiles is an option for the environment and waste management, the use of biodegradable polymers from renewable resources should be made mandatory instead of conventional polymers based on petroleum and non-biodegradable. For this reason, there are some legal obligations determined by governments and the European Union.

Petroleum-based and non-biodegradable polyesters cause serious damage to nature, as not only they are the most widely used polymer raw material in the automotive sector, but also in many other sectors. It is observed in literature reviews that few studies have been conducted on the use of biobased and biodegradable polymers in the automotive sector (especially in seat fabric). In this study, it is aimed to examine the tensile strength and elongation performances of 100% PET woven fabric and 100% PLA / warp 100% PET fabrics according to automotive standards by associating them with polymer and yarn properties. In this context, tensile and elongation tests will be applied to 6 different samples obtained after heat aging and after humidity aging, and the results will be evaluated in terms of automotive textile standards.

EXPERIMENTAL

PLA (PLLA) and PET polymer raw materials used in this study were supplied by Polyteks Textile A.Ş. The production of multifilament PET and PLA POY yarns, texturised yarns, textile analysis of POY and texturised yarns such as elongation, tenacity, dtex and the production of woven fabrics from textured yarns were made using the technical infrastructure and equipment of Polyteks A.Ş. The aging process of woven fabrics and the tensile and elongation tests of woven fabrics were performed using the technical infrastructure and equipment of TOFAŞ R&D Materials Engineering.

POY Yarn Production and Analysis

Partially oriented (POY) yarns were obtained from PLA and PET polymers by using 48 filament round section nozzles with the melt spinning method, which is more environmentally friendly and economical compared to other yarn production methods. Crystallization and drying processes of PLA and PET polymers in the form of chips (granules) were applied in order to absorb the workable moisture value. Dteks 167f48 PET and PLA multifilament POY yarns with different extruder and draft values were produced in Barmag industrial yarn production machine. Analyzes were made for textile values such as dtex, tensile elongation and tenacity of the obtained multifilament POY yarns. Textile values of PET and PLA POY yarns are as in Table 1.

Texturized Yarn Production and Analysis

High intermingled process was carried out with dtex 500f144 (167f48x3) on Barmag brand eAFK model texturing machines. Analyzes were made for textile values such as dtex, tensile elongation and tenacity of the obtained PET and PLA textured yarns. Textile values of PET and PLA textured yarns are as in Table 1.

Table 1. The textile analyzes of PET and PLA yarns

Yarn Analyzes	PET POY Yarns	PLA POY Yarns	PET Texturized Yarn	PLA Texturized Yarn
Dtex (gr/10000m)	270	304	500	470
Elongation (%)	130	100	22	23
Tenacity (cN/dteks)	2,2	1,7	3,8	2,1

Weaving Process

In this study, two different type of fabrics were produced from PET fibers in the form of dtex 500f144 high intermingled and from PLA fibers in the form of dtex 500f144 high intermingled that were produced by using the same weave parameters. 3/1 Twill weave construction was preferred in the weaving process (see also Table 2).

It is expected that the car seat fabrics will exhibit higher mechanical strength properties due to the mechanical stress they will be exposed to both during the fabric production processes and throughout the car life. The tests were carried out on unlaminated fabrics after natural state, heat aging and humidity aging processes. Firstly, the fabric was waited to condition for 72 hours at 23±2 ˚C at room temperature. A part of the fabric, which was conditioned at room temperature, was processed for heat aging in an oven for 100 hours at 80˚C. Another part of the fabric, which was conditioned at room temperature, was processed for humidity aging for 250 hours in the climatic cabin at 40˚C 95% RH condition. In the climatic cabin was set temperature variation with ±5˚C/min.

Table 2. Construction of woven fabrics from PET and PLA yarns

Woven fabric	Weave pattern	Warp density (threads/cm)	Weft density (threads/cm)	Comb width (cm)	Warp yarn	Weft yarn
%100 PET Woven Fabric	Twill 3/1	19	23	175	Dtex167f48 PET Texturized High Intermingled	Dtex500f144 PET Texturized High Intermingled
PLA/PET Woven Fabric	Twill 3/1	19	23	175	Dtex167f48 PET Texturized High Intermingled	Dtex500f144 PLA Texturized High Intermingled

Tensile and Elongation Tests

Tensile and elongation test measurements were made with Zwick brand test device according to Fiat standards (standard sample, standard holding space and tensile speed parameters). For each aging in two fabric types, 5 samples were tested in the warp and weft directions. The schematic representation of the samples of PLA/PET and 100% PET fabrics in their natural state, after heat aging and humidity aging for the tests is as in Figure 2. First of all, after the fabrics were cut to 200mm length and 100mm width, they were folded in half right in the middle of 100mm width. Five repetitive tests were carried out for the fabric types in each condition from the folded fabrics. The tensile test continues until the sample breaks and the value of the applied load is taken as soon as it breaks. The elongation test is terminated when the applied load reaches 10 daN and the amount of elongation at this load is calculated as a percentage.

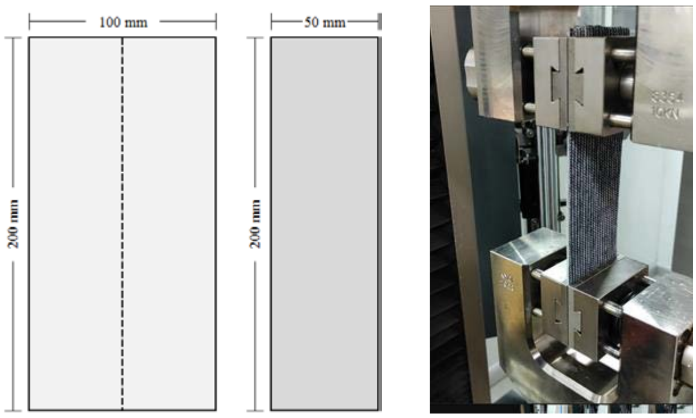

Figure 2. The elongation and tensile test sample (fabric opened and folded) and test device

RESULTS

The comparative tensile and elongation test results of warp/weft 100% PET and warp PET/ weft PLA woven fabrics in natural condition and after different aging processes are as in Table 3 and 4.

Tensile Test Results

Firstly, if the results of the tensile tests in the weft direction are evaluated; there is a 45% decrease in the tensile strength value of the natural PLA/PET fabric compared to natural 100% PET fabric. It is thought that the main reason for this decrease is that the tensile strength value of PLA texturized yarns used in weft is lower than PET texturized yarns. It has been observed that tensile strength of the %100 PET fabric the increase for 3% after the heat aging process, while it decrease for 7% after the humidity aging process. While the tensile strength of PLA/PET fabrics hasn’t changed after humidity aging, a slight decrease has been observed after heat aging.

If the tensile test results in the warp direction are evaluated; the tensile strength values of 100% PET fabrics in natural state and after aging processes are the same. It has been determined that tensile strength of the PLA/PET fabrics increases for 19% after the heat aging process and for 5% after the humidity aging process.

Table 3. Tensile strength of PET and PET/PLA fabrics in natural state and after aging processes

			Natural State	After Heat Aging	After Humidity Aging
Sample	**Test Direction**	**Yarn**	**Tensile Strength (daN)**	**Tensile Strength (daN)**	**Tensile Strength (daN)**
PET fabric	Warp	PET	105,7	106,3	105,6
PET fabric	Weft	PET	373,6	383,6	347,3
PLA / PET fabric	Warp	PET	103,6	122,9	109,1
PLA / PET fabric	Weft	PLA	206,0	202,7	207,2

Elongation Test Results

Firstly, if the results of the tensile tests in the weft direction are evaluated; it has been observed that the elongation value of PLA/PET fabric in natural state is 15% less than PET fabric. It is thought that the main reason for this decrease is that the elongation value of PLA texturized yarns used in weft is 23% less than PET texturized yarns. It has been observed that the elongation value of 100% PET increases by 67% after the heat aging process and 39% after humidity aging process. On the other hand, it has been observed that the elongation value of PLA/PET increases by 132% after the heat aging process and 39% after humidity aging process.

If the elongation test results in the warp direction are evaluated; it has been determined that the elongation value of the natural PLA/PET fabric is 14% less than the PET fabric. Although the same yarn is used in the warp direction in both fabric types, it is thought that main reason for this decrease is that the elongation value of PLA texturized yarns used in weft is lower than PET texturized yarns. The elongation values of PLA/PET and 100% PET fabrics increase by 27% after heat aging process. After the humidity aging process, the elongation value of 100% PET fabric increases by 12%, and the elongation value of PLA/PET fabric increases by 4%.

Table 4. Elongation of PET and PET/PLA fabrics in natural state and after aging processes

			Natural State	After Heat Aging	After Humidity Aging
Sample	**Test Direction**	**Yarn**	**Elongation (%)**	**Elongation (%)**	**Elongation (%)**
PET fabric	Warp	PET	8,1	10,3	9,1
PET fabric	Weft	PET	3,3	5,5	4,6
PLA / PET fabric	Warp	PET	7,0	8,9	7,3
PLA / PET fabric	Weft	PLA	2,8	6,5	3,9

CONCLUSION

One of the most important features for automotive components and materials is meeting durability requirements which mean keeping same level of test results in different conditions according to aging parameters defined. Even though the vehicle is exposed to different climate, temperature, humidity and phatic conditions throughout its lifetime (10-12 years), the mechanical performance of the fabric must maintain certain standards. In this context, tensile and elongation tests were applied to PLA/PET and 100% PET fabrics and the performance evaluation was analyzed. The results obtained with the unlaminated state of the fabric in the detailed tests and analyzes carried out by considering the relevant automotive permanence conditions, provide the minimum automotive requirements and standards in terms of tensile strength. The elongation values of PLA/PET fabrics under load meet the specified range for seat fabrics. Special applications of these fabrics can be evaluated by considering the holistic specifications in the using place.

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Textile Science and Economy
12th International Scientific-professional conference
10th December, 2021, Zrenjanin, Serbia
Technical faculty „Mihajlo Pupin", University of Novi Sad

MOTORS OF INDUSTRIAL LOCKSTITCH SEWING MACHINES

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ABSTRACT

The article describes different kind of motors used on lockstitch sewing machines, their advantages and disadvantages in garment manufacturing process. The clutch motors are long time used traditional kind of motors. They are efficient for long and simple seam processing and good on heavy duty machines. However, they are inefficient processing short and complicated seams, use a lot of energy, create noise and vibration. The servo motors are new generation motors which ensure lower energy consumption, better work condition for an operator, and with it, higher seam quality and productivity of the work process. Stepper motors are used to control separate parts of the advanced sewing machines and ensure their very precise motion. To increase stitching quality and ensure wider application, the latest sewing machines use several stepper motors on a single machine, such us, stepper motors for fabric feeding, thread trimming and presser foot lift, needle bar, take up lever and hook movement.

Key words: lockstitch sewing machines, clutch motors, servo motors, stepper motors, fabric feeding mechanism, thread trimming

INTRODUCTION

Many producers of sewing machines offer the same model a sewing machine with a clutch and a servo motor (see Fig.1). The clutch motors are long time used traditional kind of motors for sewing machines. The servo motors are new generation motors which ensure lower energy consumption, better work condition for an operator, and with it, high seam quality and productivity of the work process. There is one more type of motor used in advanced machines - a stepping/pulse motor. It can ensure very precise movement and speed control of the separate mechanisms of the sewing machine.

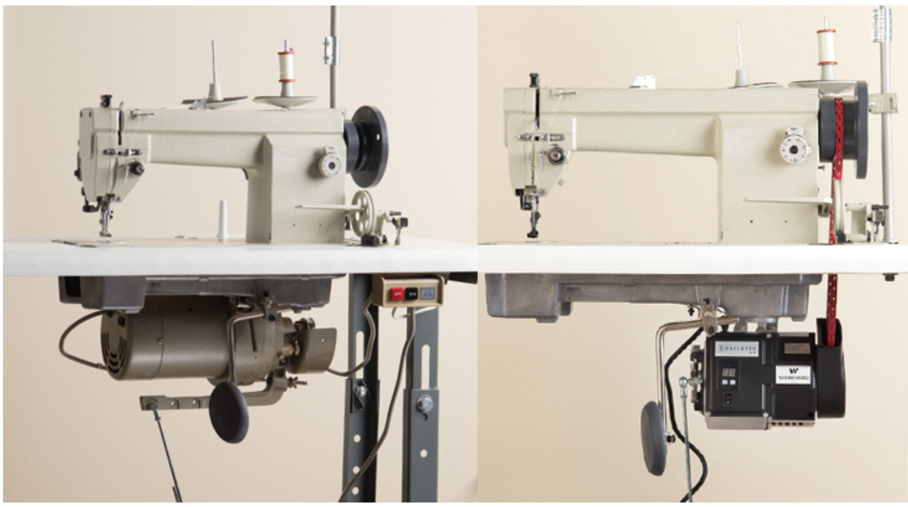

Figure 1. Clutch motor (a) and a servo motor (b) on a sewing machine

CLUTCH MOTORS

Clutch motor (see Fig.2) has three main parts: tri-phase induction motor, a clutch and a belt pulley. The motor is connected with the main shaft of the sewing machine by help of a V-belt (it creates noise and vibration).

They are two types of clutch motors [1]:

- low speed motors (1425-1725rpm) - used on heavy duty machines and machines which do not work in high speeds;
- high speed motors **(**2850-3450 RPM) - used on high-speed garment sewing machines for straight seaming and overedging.

The clutch motors can reach full speed in few seconds. When they gain this speed, they keep it, even releasing the speed pedal. However, during a sewing operation, an operator has to speed up or slow down the machine in accordance with the requirements of the certain seam. Only an experienced operator can achieve other desired speeds. When only 1 to 2 stitches are required on the seam corners or end, the operator has to rotate the machine's shaft manually, while the motor is still running in full speed.

Figure 2. Clutch motor

It means that the clutch motors consume maximum electricity all the working day round - during sewing process when the needle is running in high or low speed, during handling of sewn components/articles, during expected an unexpected short brakes while the machine is switched on. As typical needle time (the time when the needle is running and machine is sewing the seam) use to be less than 3th part of the all working time, energy losses are serious. Because of worn out parts, bad lubrication and other reasons, the clutch motors can get overloaded switching them on and in running status. The clutch motors heat up, with temperature rise they used more energy, reduce the service life and increase the cost of maintenance.

The machines with clutch motors are the efficient for long and simple seam processing (for example, long overedge seams) when needle running time is maximal. They are also good for heavy duty sewing as they are very powerful [2,3].

Advantages of the sewing machines with clutch motors:

- currently widely available on different kind of sewing machines;
- lower price comparing with servo motors;
- efficient for long and simple seam processing;
- good on heavy duty machines.

Disadvantages of the sewing machines with clutch motors:

- high energy consumption;
- inefficient processing short and complicated seams,
- creates high noise and vibration;
- hits up;
- heavy (20-30kg).

SERVO MOTORS

Servo motors (see Fig.3) are directly coupled with a main shaft of the sewing machine. The power is transmitted from the motor to the machine and there is no transmission energy losses. As the servo motors do not use a belt pulley, the sewing machine works without noise and vibration [2,3,7].
Servo motors use to be called direct-drive motors as sewing machine does not have a separate external motor attached to its table. The maximum speed at which servo motor can run is over 4000 RPM. By help of electronic controllers it is possible to adjust the start and stop speed, as well as, different sewing speeds, depending on the seam requirements.

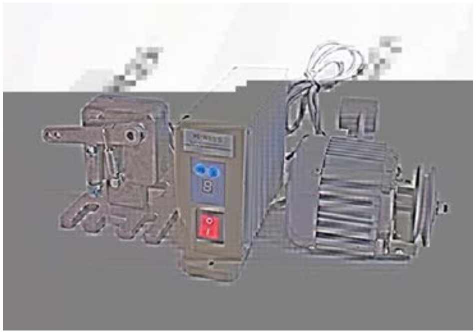

Figure 3. Servo motor

The servo motor consumes 550W energy when the machine is running at the maximum speed (4000 RPM). When the machine slows down to the half speed (2000 RPM), the motor consumes electricity at half rate - only 275W. When the needle is not running, and with it, the shaft of the machine is not moving (as it was mentioned before, this condition the machines has 3th part of the working time) the servo motor goes in stand-by mode and consumes energy 1W only! As the result of these advantages, sewing machines with servo motors consume 65-70% less energy than the machines with the clutch motors [5].
Servo motor can be equipped with a synchronizer. By help of it several additional devices can be mounted on the machine: auto needle positioning, presser foot lifting, thread cutting, backtacking or backlatching, others. Start and end speed of a sewing cycle can be adjusted and used without interference of an operator. All these additional advantages reduce fatigue of the operator, helps to keep his maximal attention to the sewing operation, and with it, raise seam quality and work process efficiency. However, if the extra devices are added to the servo motor, its price is higher.
Advantages of the servo motors comparing with clutch motors:

- ensure 15-30% higher work efficiency, labor efficiency 20%~30%;
- 65-80% lees energy consumption (electricity bill reduced for 2/3);
- reduced noise level, (noise is created only by a feeding mechanism);
- motors does not require any maintenance (no parts to wear out or adjust);
- low heat generation;
- better work conditions for an operator;
- light weight (5-15kg).

Disadvantages of the servo motors:

- more expensive than clutch motors.

STEPPER MOTORS (STEPPING/PULSE MOTORS)

Typical industrial sewing machines use one motor (clutch or servo motor) which drives its main shaft and subsequently drives also other parts of the sewing machine: a needle bar, a take up lever, a feed dog and a hook shaft. In digital feed machines, the feed dog movement is separated from the main drive as a distinct ***stepper motor*** independently drives the feed dog [6,7].

A ***stepper/pulse motor*** is an electric motor whose shaft rotates performing steps, that is, moving by a fixed amount of degrees. This feature allows to know the exact angular position of the shaft in every moment counting how many steps have been performed. These stepping motors are controlled by numerical control systems, which generate pulses - signals to cause very precise and quick movements.
Separating the feed dog movement from the needle movement the advanced machines ensure: precise reverse feeding, different stitching patterns (see Fig.4), simultaneous condensing and backtacking at the beginning and end of the seam [7].

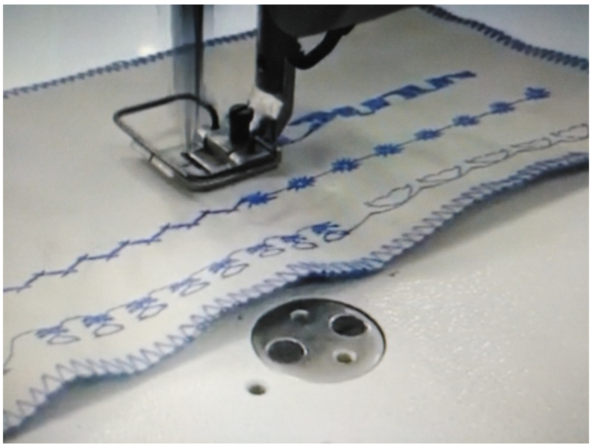

Figure 4. Decorative stitches created with needle movement
left - right and *forwards- backwards* using stepping motors

There are also available lockstitch sewing machines which use ***three-motor technology*** (Juki, Typical, Duma, others) when all mechanisms are driven by different stepper motors (see Fig.5):

- one stepper motor ensures the fabric feeding motion,
- the second stepper motor ensures thread trimming and presser foot lift;
- the third stepper motor drives the main shaft controlling needle bar, take up lever and hook movement.

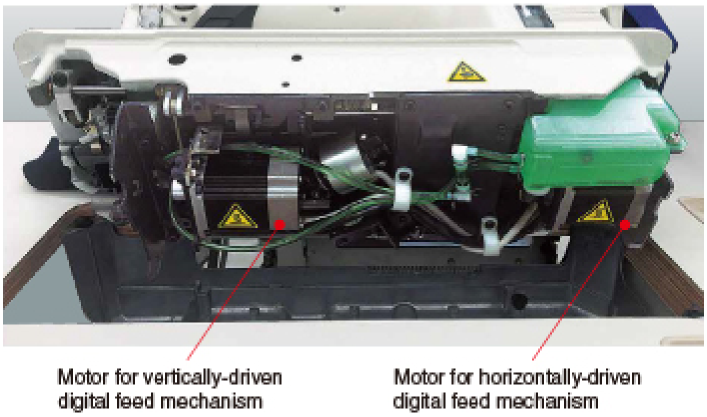

Figure 4. Two motors driving digital feed mechanism of the machine

CONCLUSIONS

The old generation clutch motors can be easy replaced with servo motors to continue the exploitation of existing sewing equipment with much higher efficiency[4]. However, garment producers are not yet using this opportunity widely. As it was mentioned before, in the current market new sewing machines are already offered with servo motors. Buyers can choose the type of motor fixed on the machine on the bases of their production needs. The advantages of the servo motors are much more important than the price difference between a clutch and a servo motor. Last generation intelligent sewing machines use computerized systems and stepper motors to control precisely different mechanisms of the machine and with it to ensure highest stitching quality, work productivity, as well as, reduce fatigue of the operator and his responsibility for work process. Currently these machines are option for large and strong garment manufacturers. They are also the future offer for other capacity producers as competition in the fashion market is very high, and the work process will have to become highly effective for everybody in this business.

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QUALITY CONTROL IN THE PRODUCTION OF TIGHTS

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ABSTRACT

In order to improve quality management is needed. Quality management is a part of application of statistical methods defining of the all processes in the organization as well as their interaction. Statistical process control in each phase of the production, using statistical methods (Pareto chart, Ishikawa chart, control cards, the correlation coefficient, check lists etc.) can obtain necessary evaluation and grading of the quality, can determine options for eliminating nonconformities, increase the productivity and decrease the costs. The mass production brings the problem of monitoring and maintaining the quality of the products, which stresses the need for the application of selected statistical and mathematical methods in process control. The standard ISO 9001 quality management system requires establishing of the criteria's and methods for process- measuring and monitoring in order to improve its functioning and control. Effective functioning of the process implies the realization of the process with minimal variability caused by random factors and achievement of required quality output. The paper investigates the occurrence of defects in the production of ladies tights. The Pareto chart is applied for investigating the type of defect and its frequency.

Key words: quality, statistical process control, check list, Pareto chart

INTRODUCTION

There are several methods and techniques used to measure quality, assess the stability of processes and to detect and prevent defects. Some of them are used to: detect the location of defects and their percentage; to discover the causes (of defects); to monitor the course of the processes; to assess the stability and capability of the process and to investigate the correlation between the properties [1]. The basic statistical methods that are also called seven quality control tools are Pareto chart, cause and effect diagram, histogram, control chart, correlation analysis, checklist, and flow chart [2].

The Pareto chart is very useful for maintaining the cooperation of all interested parties, because at a glance, it reveals where the irregularities occur, i.e. who is responsible for them. There are usually two or three highest pillars referring to the heaviest irregularities, while the lower pillars are easier cases [1]. This tool is used to systematize the problems starting from the most important ones. It is estimated that 20% of the causes cause 80% of the problems [3]

The application of science today is obvious and inevitable in all industry branches, including the textile one. Undoubtedly, the textile industry is one of the oldest ones with a long and rich tradition. Thus, over the years and the progress in all fields, it came to the use of electronic assemblies and computers in all stages of production in the textile industry [4]. Modern knitting machines require high productivity, satisfactory quality of the final product and complete automation of the knitting process, which requires simultaneous monitoring of a number of parameters during this process [5].

For centuries the production of socks has been a major concern and task of the knitting industry. Today, this production is realized mainly on circular machines with small diameter. Most of the latest achievements in this technology are located in Italy [6]. Modern single-cylinder or two-cylinder machines are computerized, pneumatic, having 2 to 4 systems, speed up to 6 times higher than the standard, and if they are well maintained and the work is organized - they offer cheap production [7].

The weaknesses in the process must be identified, so measures of their elimination or reducing their recurrence will be taken. If mistakes are just identified and corrected, without removing the cause of their occurrence, we will constantly have scrap and large losses. When a breakdown occurs, the knitting machine must be stopped and the error corrected, which leads to a waste of time and inefficiency, as confirmed by studies [8].

The goal of this paper is to investigate the possibilities of improving the quality by introducing statistical methods for quality control in the production of women's tights. The process of production of women's tights was monitored and analyzed during 2 week period. Based on the obtained data, the state of the operating processes was analyzed and the number of defects and its occurrence was investigated and the actions needed were considered.

EXPERIMENTAL PART

Production process and monitoring plan

The company has not implemented a quality system and has no specified procedure of operation. The existing documentation refers only to the number of manufactured pieces, sales, and the need for yarns, without noting the defective products, their percentage, or the reason for their occurrence. For that purpose, the first task was to make a current diagram of the production process, the phases through which it takes place, as well as to determine the holders of operations, inputs, and outputs.

Next step is the determination of the types of non-conformities that occur at each stage of production. For this purpose it was necessary to prepare appropriate checklists, which were filled in by the employees. Based on the data obtained, an overview of the production situation in the company is given, and we possibilities for improving the processes, is pointed. The reduction of the percentage of non-compliant products will influence the increase of productivity and reduction of costs caused by defects.

Raw material

Every production process begins with the purchase of the necessary raw materials, in this case the yarn. The procurement of the yarn is from a well-known supplier and it is based on trust gained through many years of experience between the two parties, but it is not accompanied by appropriate documents and quality analysis of each submitted lot. Only catalogs are submitted stating following characteristics of the yarn: linear density (dtex), gloss, color (dyed, glossy and matte), type of yarn (textured, piled, filament) and a usage recommendation for: knitting, weaving, for socks. Although so far there have been no major problems in the procurement of raw materials, this is not a guarantee that the situation will not change in the future. Immediately after purchase and delivery, the yarn is storage in a separate room.

The fineness of the polyamide and lycra yarn is 22 dtex and it has a white shiny color. This combination is the most common for making this type of products. Like lycra, polyamide is a synthetic yarn with high wear and tear resistance and is easy to use [9,10]. The quality of the raw materials always plays a major role in the production process. That is why filament yarns from synthetic fibers are most often used for making tights because they enable greater productivity of knitting machines, and at the same time these are requirements of the buyers.

Production process

The production process of this model includes the following processes: knitting, sewing, dyeing, folding, and packaging. The first stage of the production process is knitting, and we will focus solely on this process, as one of the main stages of obtaining a semi-finished product. The experience has shown that this is the stage characterized by the largest number of defects, due to the complexity of the process, which depends on several factors. It is necessary to knit the so-called pipes (two of them are assembled to form a pair of tights and an additional piece - "rhombus" is inserted in the middle) on computerized machines from the company Lonati, type 421 (circular knitting machine). The pattern (tangle) of the tights is previously prepared and through the computer that is connected to the machine, the knit function is given. Before starting, the most important thing is that the machine is set up correctly. All parameters are prepared before knitting begins, namely: setting the knitting speed, knitting density, sinking depth, yarn tightness and selection of knitting needles. All this is achieved by the help of the knitting program of the corresponding model.
Lonati 421 is a two-cylinder sock machine designed for making fine women's socks with the possibility of weaving very elastic filament threads. The machine knits with 4 knitting systems. The double edge of the socks can be made in different interlaces with a single electronic selection of needles. The cylinder is 102 mm (4"), which houses 400 tabbed pins; i.e. the machine has E32 fineness [11]. The machine is equipped with modern knitting devices so that each knitting system can be individually selected. This makes it possible to make a pattern shaped only by interlacing (transfer of half-loops) or interlacing of colored threads.

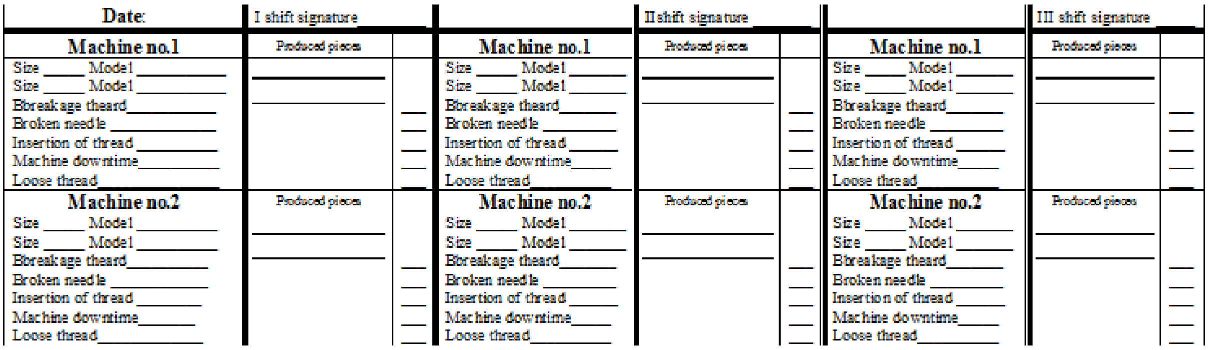
When making socks with simple weaves, the working speed of the needle cylinder is 650/min, and when making complex samples the working speed is in the range between 500 and 550/min. Two control rollers and computer programs are used for the mechanical-electronic control of the machine. A novelty is that the machines can regulate the tension of the braid depending on the structure of the yarn, i.e. from the amount of entanglement of highly elastic filaments.

Usually on the screen of the machine are presented all the data about the control commands, executive functions, and errors at work. The working memory of the machines is large, and several dozen different designs can be stored. The machine manufacturer usually supplies the basic types of interlacing programs, to different models, with appropriate types of yarns, as well as programs for adjusting the parameters of the machine, depending on the type of the weave and the type of yarn.

The tight are consisted of several parts that need to be knitted in different ways. Of course, there are local (Macedonian) standards for making socks with panties [12]. The memorized program provides an order of execution of the process in the knitting cycle of the product. In addition, the correct order of operation of the mechanisms in each phase must be ensured. If this is provided by a previous program entry, then the machine can start making the tights. The sequence of knitting stages is as follows [6]: Knitting the product and knitting the edge (patent), Knitting sheet, Knitting toes (top of socks), Knitting of the processing part.

RESULTS AND DISCUSSION

Due to the large production volume, the production of the order for this type of product is realized on two machines. Figure 1 shows the created checklist, which will monitor the defects (their type and number) that occur. This information can later be used to determine the causes of their occurrence, which will help in reducing or eliminating them.



Date:	I shift signature ____			II shift signature ____			III shift signature ____	
Machine no.1	Produced pieces		**Machine no.1**	Produced pieces		**Machine no.1**	Produced pieces	
Size ____ Model ____	____		Size ____ Model ____	____		Size ____ Model ____	____	
Size ____ Model ____	____		Size ____ Model ____	____		Size ____ Model ____	____	
Bbreakage theard ____		___	Bbreakage theard ____		___	Bbreakage theard ____		___
Broken needle ____		___	Broken needle ____		___	Broken needle ____		___
Insertion of thread ____		___	Insertion of thread ____		___	Insertion of thread ____		___
Machine downtime ____		___	Machine downtime ____		___	Machine downtime ____		___
Loose thread ____		___	Loose thread ____		___	Loose thread ____		___
Machine no.2	Produced pieces		**Machine no.2**	Produced pieces		**Machine no.2**	Produced pieces	
Size ____ Model ____	____		Size ____ Model ____	____		Size ____ Model ____	____	
Size ____ Model ____	____		Size ____ Model ____	____		Size ____ Model ____	____	
Bbreakage theard ____		___	Bbreakage theard ____		___	Bbreakage theard ____		___
Broken needle ____		___	Broken needle ____		___	Broken needle ____		___
Insertion of thread ____		___	Insertion of thread ____		___	Insertion of thread ____		___
Machine downtime ____		___	Machine downtime ____		___	Machine downtime ____		___
Loose thread ____		___	Loose thread ____		___	Loose thread ____		___

Figure 1: Checklist for collecting data during the process of knitting

The collected data from the checklists, filled in on a daily basis are summarized and presented in addition.

Table 1: Production, defects and percentage of defects, machine 1, I, II and III shift (06.03-15.04)

	I shift			II shift			III shift			Summary all shifts		
Date	**n**	**d**	**%**	**n**	**d**	**%**	**n**	**d**	**%**	**n**	**d**	**%**
06.03	100	9	9	120	5	4,2	100	12	12	320	26	8,1%
09. 03	140	3	2,1	160	4	2,5	100	9	9	400	16	4,0%
11. 03	120	30	25	40	10	25				120	30	25,0%
12. 03	16	1	6,3	160	15	9,4	100	11	11	260	26	10,0%
13. 03	100	13	13	160	12	7,5	160	13	8,1	420	38	9,0%
14. 03	100	11	11							100	11	11,0%
16. 03	140	15	10,7	140	16	11,4	100	9	9	380	40	10,5%
17. 03	120	12	10	160	8	5	140	8	5,7	420	28	6,7%
18. 03	160	7	4,4	160	12	7,5	140	8	5,7	460	27	5,9%
19. 03	120	10	8,3	140	14	10	140	10	7,1	400	34	8,5%
20. 03	140	10	7,1	140	16	11,4	120	12	10	400	38	9,5%
23. 03	140	2	1,4	100	5	5				240	7	2,9%
01.04	160	13	8,1	160	10	6,3	160	10	6,3	480	33	6,9%
02. 04	160	12	7,5	160	11	6,9	120	12	10	440	35	8,0%
03. 04	120	11	9,2	160	9	5,6	160	9	5,6	440	29	6,6%
04. 04	120	11	9,2	180	9	5	160	10	6,3	460	30	6,5%
06. 04	160	8	5	180	5	2,8	180	7	3,9	520	20	3,8%
07. 04	100	8	8	120	5	4,2	100	8	8	320	21	6,6%
08. 04	180	4	2,2	160	5	3,1	90	9	10	340	9	2,6%
09. 04	80	25	31,3	60	14	23,3						
10. 04	40	9	22,5	140	17	12,1	120	11	9,2	260	28	10,8%
11. 04	100	9	9	140	11	7,9	150	12	8	390	32	8,2%
13. 04	120	11	9,2	60	8	13,3				120	11	9,2%
14. 04	100	17	17	110	18	16,4	120	12	10	330	47	14,2%
15. 04	140	9	6,4	160	6	3,8	180	5	2,8	480	20	4,2%
Total	**2840**	**235**	**8,3%**	**3110**	**213**	**6,8%**	**2550**	**188**	**7,4%**	**8500**	**636**	**7,5%**

n- number of produced pieces, d- number of defects

The data whose values are excluded from the calculations are marked in red. These days (or in certain shifts) the production is below the set minimum limit of 100 pipes. It remains to be seen what the reason for this small production is, with a significantly increased number of defects.

For the completion of the further analyzes, will cover the defects that occur with the following markings:

A. Thread breakage (if any of the threads breaks in the knitting area of the tights sheet);
B. Loose thread (if one of the guides does not lay the thread and the knitting continues);
C. Machine downtime (may have run out of lubrication or due to a malfunction);
D. Insertion of thread (breaking thread 2, any thread in the panties area. The positive in this case is that the thread in this part can be inserted and knitting can be continued, but this product stands out and it goes to the second class, which means it is sold at a lower price);
E. Broken needle

Table 2 shows the recorded types of defects per day.

Table 2: Daily production and type of defects, per day, machine 1, (06.03-15.04)

Date:	No. of produced pieces	A	B	C	D	E	Total defects	% of nonconformity vs. produced pieces
06.03	320	6	5	6	9	0	26	8,1%
09.03	400	3	5	2	6	0	16	4,0%
11.03	120	12	6	0	12	0	30	25,0%
12.03	260	10	5	2	9	0	26	10,0%
13.03	420	13	7	3	15	0	38	9,0%
14.03	100	2	3	2	3	1	11	11,0%
16.03	380	9	8	4	19	0	40	10,5%
17.03	420	7	4	2	15	0	28	6,7%
18.03	460	10	2	1	14	0	27	5,9%
19.03	400	11	5	1	17	0	34	8,5%
20.03	400	12	3	1	22	0	38	9,5%
23.03	240	2	0	0	5	0	7	2,9%
01.04	480	8	2	1	22	0	33	6,9%
02.04	440	5	4	1	25	0	35	8,0%
03.04	440	3	5	1	20	0	29	6,6%
04.04	460	8	2	1	19	0	30	6,5%
06.04	520	5	2	0	13	0	20	3,8%
07.04	320	4	5	5	6	1	21	6,6%
08.04	340	3	5	0	1	0	9	2,6%
10.04	260	8	6	5	9	0	28	10,8%
11.04	390	14	4	2	12	0	32	8,2%
13.04	120	3	2	1	3	2	11	9,2%
14.04	330	12	9	5	21	0	47	14,2%
15.04	480	7	2	2	9	0	20	4,2%
Total	**8500**	**177**	**101**	**48**	**306**	**4**	**636**	**7,5%**
% per type of defect		**27,8%**	**15,9%**	**7,5%**	**48,1%**	**0,6%**		

From the checklists get a realistic picture of the condition of the first machine, the achieved production, the type, and number of defects that exist. Based on these data, designed a Pareto chart (Figure 2) from which it can be seen that the largest percentage of defects is of the type D - thread breaking 2 (thread insertion), followed by: thread breaking 1, missing thread, machine downtime and broken needle.

The condition of machine 2 in the same period, with the same workers as in the first machine is given in Table 3.

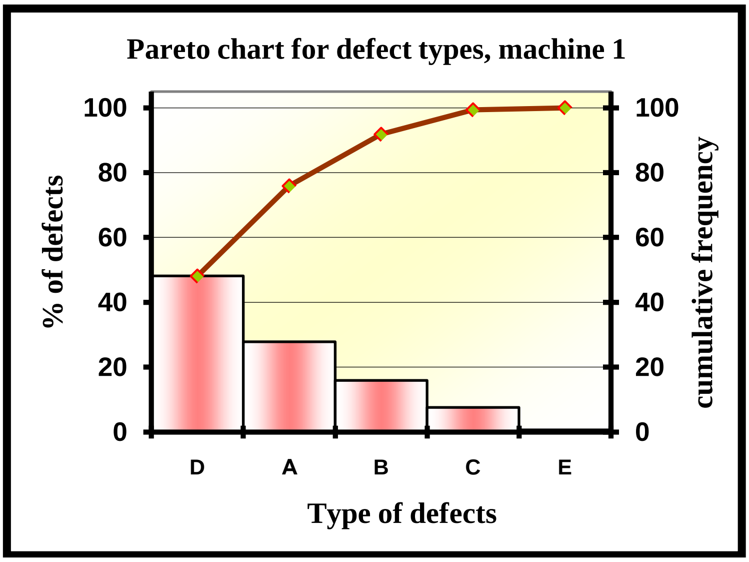


Figure 2: Pareto chart of machine 1

Table 3: Production, defects and percentage of defects, machine 2, I, II and III shift (06.03-15.04)

	I shift			II shift			III shift			Summary all shifts		
Date	**n**	**d**	**%**	**n**	**Date**	**n**	**d**	**%**	**n**	**Date**	**n**	**d**
06.03	140	7	5%	190	7	4%	140	10	7%	470	24	5,1%
09. 03	100	8	8%	60	11	18%	120	7	6%	220	15	6,8%
11. 03	100	18	18%	140	17	12%	140	17	12%	380	52	13,7%
12. 03	120	23	19%	160	18	11%	140	13	9%	420	54	12,9%
13. 03	140	16	11%	140	14	10%	80	10	13%	280	30	10,7%
14. 03	20	10	50%	120	6	5%	60	8	13%	120	6	5,0%
16. 03	26	6	23%	160	6	4%	160	8	5%	320	14	4,4%
17. 03	160	11	7%	160	14	9%	160	12	8%	480	37	7,7%
18. 03	180	5	3%	180	6	3%	180	11	6%	540	22	4,1%
19. 03	180	10	6%	80	11	14%	140	11	8%	320	21	6,6%
20. 03	140	10	7%	180	10	6%	160	9	6%	480	29	6,0%
23. 03	160	9	6%	120	8	7%	120	1	1%	400	18	4,5%
01.04	180	7	4%	180	9	5%	180	6	3%	540	22	4,1%
02. 04	140	7	5%	160	6	4%	140	8	6%	440	21	4,8%
03. 04	160	13	8%	160	11	7%	140	10	7%	460	34	7,4%
04. 04	16	7	44%	180	4	2%	180	7	4%	360	11	3,1%
06. 04	180	7	4%	120	4	3%	46	9	20%	300	11	3,7%
07. 04	140	8	6%	160	7	4%	80	11	14%	300	15	5,0%

08. 04	180	3	2%	160	8	5%	160	6	4%	500	17	3,4%
09. 04	140	10	7%	140	6	4%	160	5	3%	440	21	4,8%
10. 04	140	7	5%	140	9	6%	40	16	40%	280	16	5,7%
11. 04	20	11	55%	140	6	4%	120	8	7%	260	14	5,4%
13. 04	140	6	4%	160	7	4%	140	8	6%	440	21	4,8%
14. 04	120	11	9%	160	9	6%	140	11	8%	420	31	7,4%
15. 04	140	9	6%	160	6	4%	180	5	3%	480	20	4,2%
Total	**3080**	**205**	**6,7%**	**3570**	**198**	**5,5%**	**3000**	**173**	**5,8%**	**9650**	**576**	**6,0%**

Table 4 shows the types of defects per day on machine 2.

Table 4: Daily production and type of defects, per day, machine2, (06.03-15.04)

Date:	**No. of produced pieces**	**A**	**B**	**C**	**D**	**E**	**Total defects**	**% of nonconformity vs. produced pieces**
06.03	470	7	7	2	8	0	24	5,1
09.03	220	2	6	3	4	0	15	6,8
11.03	380	13	12	2	25	0	52	13,7
12.03	420	18	16	2	16	2	54	12,9
13.03	280	10	7	3	10	0	30	10,7
14.03	180	5	3	2	3	1	14	7,8
16.03	320	3	2	1	8	0	14	4,4
17.03	480	13	5	1	18	0	37	7,7
18.03	540	8	3	2	9	0	22	4,1
19.03	320	7	3	1	10	0	21	6,6
20.03	480	9	5	1	12	2	29	6,0
23.03	400	4	4	2	8	0	18	4,5
01.04	540	8	4	0	10	0	22	4,1
02.04	440	2	5	1	11	2	21	4,8
03.04	460	4	7	2	17	4	34	7,4
04.04	360	1	1	1	8	0	11	3,1
06.04	300	2	0	0	9	0	11	3,7
07.04	300	4	5	3	3	0	15	5,0
08.04	500	4	6	2	5	0	17	3,4
09.04	440	6	4	5	6	0	21	4,8
10.04	280	4	4	5	3	0	16	5,7
11.04	260	5	3	3	3	0	14	5,4
13.04	440	5	5	5	6	0	21	4,8
14.04	420	8	9	3	11	0	31	7,4
15.04	520	4	2	3	5	0	14	2,7
Total	**9690**	**153**	**127**	**54**	**226**	**10**	**570**	**5,9**
% per type of defect		**26,8%**	**22,3%**	**9,5%**	**39,6%**	**1,8%**		

The Pareto chart for above-mentioned information is designed on the Figure 3.
From the Pareto chart, Figure 3 is noticeable the same sequence of defects on machine 2 just like on the machine 1. The major percentage of defects on both machines is type D and is participates with 48.1% (machine 1) and 39.6% (on machine 2). The next more frequent defect is type A and is 27.8% on machine 1 and 26.8% on machine 2. From marked five type of defect the three of them are with frequency of 91.8% (machine 1) and 88.7% (machine 2).

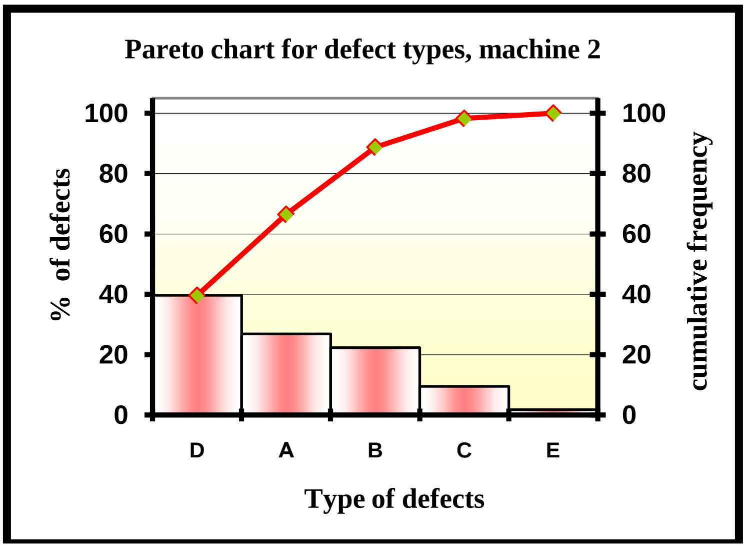


Figure 3: Pareto chart of machine 2

CONCLUSION

From the presented Pareto chart, for both machines it is determined that the highest percentage of defects occurs from breaking thread 2. It is the thread break in the panties area of the tights that actually affects getting second class products. This means that efforts should be directed towards the elimination of this largest percentage of defects.

Thus, the Pareto chart can be the first stage in making improvements. This tool helps the team to select the goal, to create enthusiasm for teamwork, to give a clear visual representation and to serve as a stable measure of progress. The Pareto chart helps to analyze and identify the main field where energy and knowledge for better condition can be directed.

The obtained results should be presented to the workers in this way. The goal is for them to understand the meaning of these methods and techniques and not to look with distrust, but in the future to advocate for this way of control and work.

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MODELING AND SIMULATION OF THREE-DIMENSIONAL KNITTED PATTERNS COMPUTER GRAPHICS

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ABSTRACT

This paper introduces a system with three-dimensional computer graphics in the design of knitted garment. Quick physically correct visualization of macro-structures of clothing is of crucial importance in the textile industry because it allows rapid and less expensive product development. For a real look of virtual textiles may be used by computer graphics as part of the rapid production of flat knitting machines. The paper pays particular attention to the process of knitting and not exceed the visualization as it is done (E. Gröller and others, 1995).

Other authors (M. Meißner and B. Eberhardt, 1998) presented a new approach that is able to produce a sample of simulated data produced by the original designer, and knitter must intrepetira this data and to produce the final sample, which is quite time consuming and expensive. Simulation of knitting as a system to fully simulate the entire process of knitting, and as a result, images of samples of knitted products can be generated without using the actual knitting machines. This is not just a new step for the industry, but also the demanding process that must include the physical. mechanical properties of materials and yarns.

To understand the model and basic data about the structure of knitted fabrics are given a basic knitting patterns that contain only simple loops, but the author (V.Gljigorevic, 2010 and 2011) think that it is necessary to take twists and structures that are experiencing other than ordinary loops and snare (not processed lock loop), long loop, yarn and other flotation, which would enable the production of clothing items of interest to the world market.

Key words: physical modeling, modeling of textiles, computer graphics, simulation, 3D- models

INTRODUCTION

After looking at the history of mankind, we have evidence that there are textiles for thousands of years. We have many different ways to produce garments made of one row or a series of loops and braids, knots, weaving, knitting, etc. However, two main methods, in relation to the amount of building materials, the weaving and knitting. While the simple weaving and crossing weft warp yarn, knitting has interlacing loops.

Four centuries ago, the first knitting machine was invented William Lee, in 1589, from the village of Calverton near Nottingham. Since then, knitting has advanced in the areas of products that require flexibility, comfort and insulation. In fact woven garments have found their way into daily wear-time, even in high fashion. A large number of fabrics produced on flat knitting machines for knitting that are very diverse in the production of almost arbitrary kind of knitted patterns. At the same time there are advantages and disadvantages produced yarn. There are countless ways to combine inter-knit net working.

There are both advantages and disadvantages of knitwear. There are countless ways to combine the abstraction of each loop and each year, designers have come up with four different collection of new fashion models. This work needs to be faster and more intense at lower costs. Access via computer graphics must exist as part of the rapid production of virtual and real appearance textiles. So, expensive knitting machines available to produce various patterns designed to cut costs and simulation of production. Visualization textiles have already made their place in the history of computer graphics. Draping textiles was thoroughly investigated by several authors. One of the first was (J. Weil, 1986). He used a purely geometric approach catenary (curve, which idealizes a higher range) surfaces. Researchers group with N. Thalmann (M.Courshesnes at el., 1995) had thrown cloth-modeling to high elongation. Moreover, (D. Breen et al., 1994) proposed a particle system approach with the power minimized process to simulate the draping of fabrics. All these works are sophisticated and together participate in a simulation to calculate the trajectory of particles. In addition, collision detection algorithms were developed and are suitable for screen-modeling.

A good survey of cloth modeling technique can be found in (Hing N.Ng et al., 1996). Visualization of micro-structure of textiles, fabrics, has not caught a lot of attention within the computer graphics community. But it is a micro structure which is of vital importance for the textile industry.
In this paper, attention is paid to the process of knitting, not to exceed that visualization is presented for example in (E.Groller et al., 1995). Here we want to present an application that allows almost instant visualization of the newly designed knitting patterns. So time visualization techniques, such as light-modeling in (E.Groller et al., 1995) does not apply. But we want to calculate the natural impression of specimens based on knitting data and physical properties of the twisted yarns. To achieve this, the authors (M.Meibner et al., 1998) took the knitting machine with all the technical data of the tables of the Company, with the generated data structure to represent it, and apply a system of particles to simulate the natural behavior patterns. For visualization purposes, used the simple technique of drawing routine s'open GL library.

SIMULATION OF KNITTING

The authors (M.Meibner et al., 1998) presented a new approach that is able to produce a sample of simulated data produced by the original designers. Usually, the knitter must intrepretira this data and to produce the final sample, which is quite time consuming and expensive. Simulation of knitting is a system that fully simulates the whole process of knitting. As a result, images of samples of knitted products can be generated without using the actual knitting machines. This is not just a very innovative step for the industry, but still very demanding process that must include the physical mechanical properties of materials, or yarn.
Input data for the system are the same as the data will besent to the right machine for knitting. In our case it is a form of data table of the company, which is the largest machine manufacturer (Figure 1).

a) b)

Figure 1. The modern knitting machine ADF (Stoll, Germany) (a) and MACH2®SIR® (Shima Seiki, Japan) (b)

Simulation of knitting has been implemented in an objective-oriented framework using C ++. The system is equipped with an intuitive graphical user interface (GKI). It was developed using a fast turn and open App invent or (display) for viewing to enable three-dimensional overview of the knitwear and interactive handling. GKI system is shown in Figure 2.

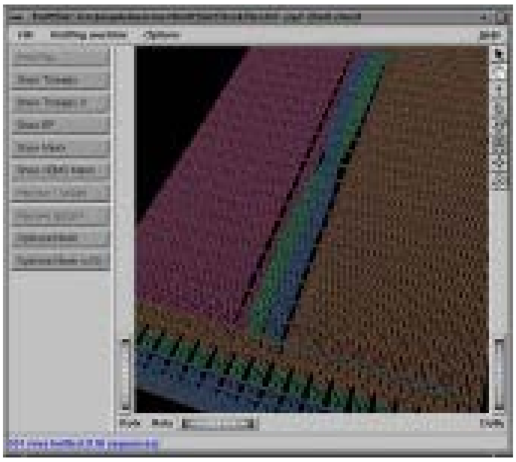
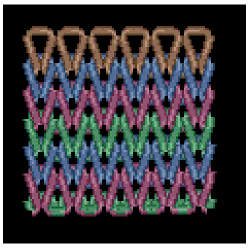


Figure 2. Graphical user interface system for simulating knitting (M.Meibner et al., 1998)

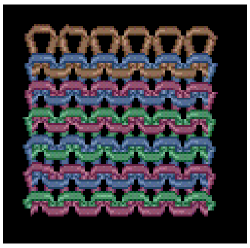
Global parameters of knitting machines and needles for a number of English-Cola, or the number of needles in the bar, the number of yarn, and so on, are considered for simulation. The physical advantage on the basis of simulations is the fact that knitting can be replaced or introduced into any knitting yarn from those that are available. In contrast, the system allows easy replacement of yarn and simulation can be restarted. As of machine knitting, knitting simulation has two bar that can be equipped with any number of needles. In addition, virtual knitting machine is equipped with several facilities needed for the simulation process.

DATA STRUCTURE

Representation of knitted samples to the appropriate data structure requires a very flexible approach. Today, there are almost no limits to design patterns, using modern machines for knitting, and every day a new and highly complex patterns generated. This is very important, knowing that the machine can knit a few operations, although in recent years appeared more sophisticated machines. A data structure that can store all necessary information about the specifics of knitted samples must meet a huge number of unstable conditions. We'll mention some of the most important: information regarding the composition of the raw yarn; wind yarn into 3D space; intreraction points yarn.
In addition, all information required for physical modeling must be available, or is exposed to the forces of knitting and must be stretched. The authors (M.Meibner et al., 1998) developed a model that can play all kinds of knitted patterns in the manner described above. To understand this model and basic data structures, it is necessary first to take a closer look at some examples of knitted patterns. Figure 3 (a) and (b) shows a simple knitted samples containing only a knitted loop. Some more sampled samples are shown in Figure 4.



a)



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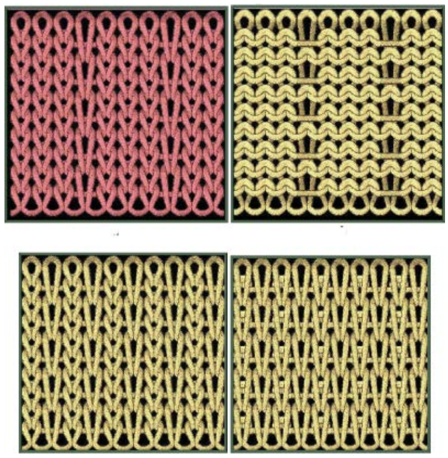


c)

Figure 3. An example of knitted samples:
(a) view of the front-right side and (b) rear-left side, derived fabrics (c)

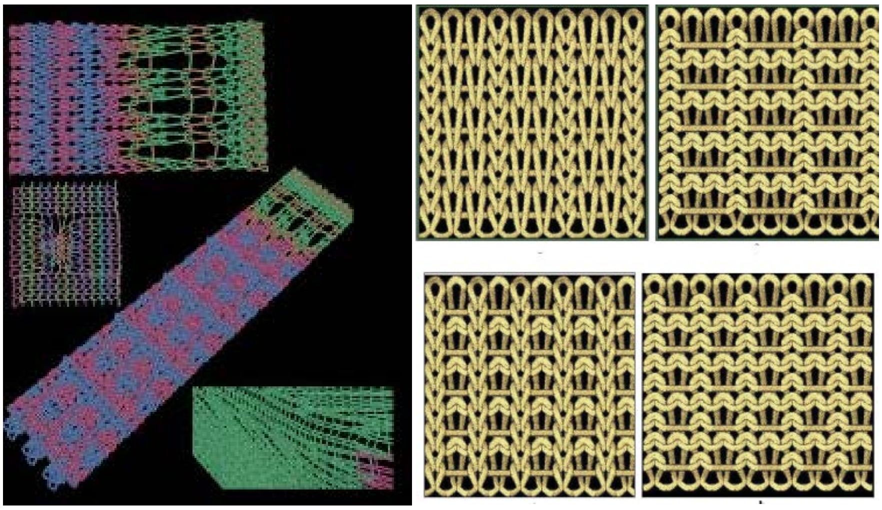


Figure 4. Typical specimens sampled knitwear

How to move 3D curve effect? Is it really necessary to keep the whole curve in explicit function or parametric representation? It would be very expensive, and happiness is easier solution to this problem is viewed from an abstract point of view only in terms of power, yarn can be seen or viewed as a polygonal line. In places where the yarn is subjceted to deformations or forces, given bending. In the context of knitted patterns, such pointsare called deformation bonding points (DVT), they are linked together and cross the interactive, ie, pushing each other.

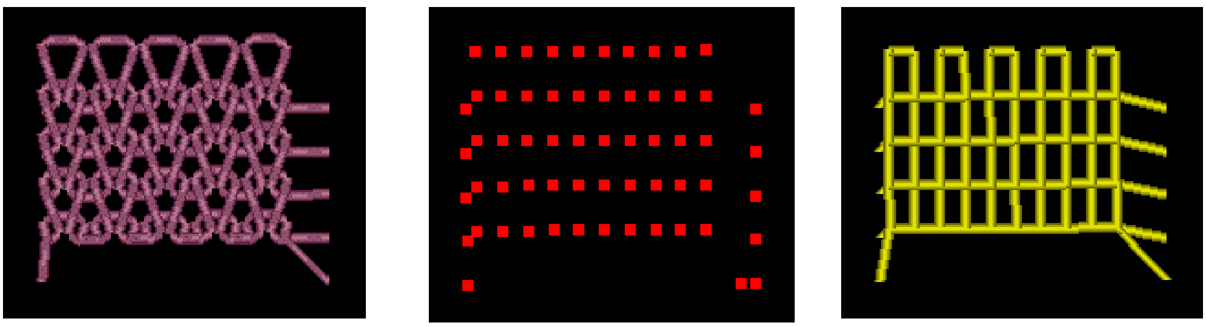
DVT DVT of the yarn is not exposed to any other forces except gravity. Gravity does not cause cross to hang and get lost in the framework of the braided pattern due to the following reasons: yarns are light-weighted; distance between DVT is low.
As we all know from everyday experience, the yarn can be drawn from the fabric and hang loosely. Fortunately, this does not happen during the creation of the sample and the same should not be included in the simulation.

The model is simple, but close to reality. In reality knitwear mesh, cross slip is only observed between the two loops. So can not ignore the yarn friction yarn. So we can only consider the touch points in the binding loop. However, the lines we distribute free amount of yarn around the neighboring yarn loops. Yarn can be viewed as a chain of connected points (LPT). From an abstract way of seeing, the basic structure of the knitted sample is primarily independent of the actual location of individual points in space. There is a strong dependence on distant points when it comes to physical modeling to look at the forces within the knitted sample. But especially for mid level based on the structure of the curves cross depends on the binding of abstract points. Binder yarn from different points share the same coordinate space, but it is stored only once and shared by the different binding points. This is an override duplicate information on the structure of data. The total representation of knitwear patterns in mech structure is composed of connective points and edges formed between the binder yarn counts. Figure 5, shows a braided pattern, that is the binding point, and the resulting mesh structure knitwear pattern. It is obvious that the yarn it self can draw by simply connecting the bonding points. More polygon segments need to be better approximated curve linking the points that can also be seen in Figure 5, a. In addition, the true direction of yarn will not go through the bonding point, but the movement around them forming a loop. However, the polygonal method is used to simulate the physical interaction as a valid pass.

How samples should be kept in a flexible way of using linked list structure, we have implemented our list template class C and C list container. For example, C provides a list of doubly linked list entity-list with a number of methods allowing quick access to the head and the last element of a list of lists as well as further necessary search methods.

This is a pretty small part of the knitwear pattern, just two loops, but it is enough to demonstrate the basic structure.

The two loops in this example are dull spots in the the connective structure that contains a list of two yarn (binder course points). Each of the directional bonding points is just a list of binding points. The first line of binding points to two, and one of the four directions of binding points. As mentioned earlier, each binding point is an abstract object of providing information and history from the creation of bonding points. For example, is the point made binding on the front or back of the bar machines, whether up, down, right and left connective point? This information is necessary for the schematic view of yarn on the basis of the data structure. Each item has aconnective point to their spatial coordinates. These coordinates are stored in the connective points of tables that are essentially sorted linked list of binding points standings. Each entry has the spatial coordinates of binding points. As noted earlier, there are bonding points are divided along the lines connecting points of the same coordinates.



a) b) c)

Figure 5. The data structure of knitted samples:
(a) knitwear pattern, (b) the corresponding binding points, (c) the corresponding mesh structure

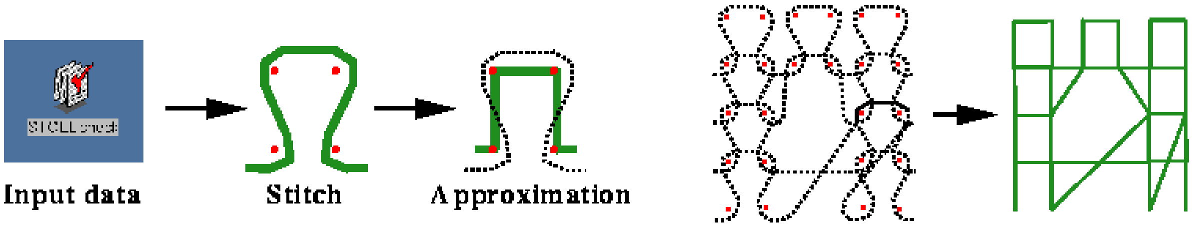


Figure 6. Approximation of the direction switch to the network

Thus, they point to the same table binding points entered in the table of binding points by passing unnecessary storage mentioned earlier. In this case, the bonding points table consists of four inputs. To speed up search operations, we keep a table of binding points for each class. Storage knitted sample is an approximation. Instead of saving for every wrong move in 3D, we store the edges of a network linking all the neighboring points that represent the simplified structure of knitted patterns.
Figure 7 shows the repetition of the inputs to the final structure of the network for a simple pattern. As mentioned earlier, we must be able to present sample is based on data structures. This requires some additional information that we have not mentioned so far. For example, each item gets its binding information in its creation, indicating that it was created on the front or rear bar machine, whether the loop on the left or right side, and soon. This allows us to show the direction of yarn in a quick and easy way.

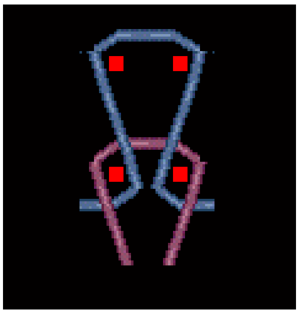


Figure 7. Knitted pattern which contains two knitted loop-half loop

TOPOLOGY CREATION

Generation of the previously described data structure from the given data input format is very demanding format is very demanding process. Topology is the relationship between yarn that has to be generated. To better understand this process we will describe a machine for knitting and possible surgery. Yarns from the device to add and move out of the zone to the zone where the knitting is interwoven into the loop. Depending on the machine model and its construction machine can perform three operations basics: knitting, transfer loops from one bar to another or from one needle to another bar and turn.

KNITTING. In order to create knitting needles must be from their needle channels run up to create a loop, a snare, flotation,elongated loop and more. The process of creating the loop is described in detail in the book Professor Gligorijevic "Knitting technology with theoretical and experimental analysis" .

Figure 8 is given a flat pattern for knitting machine son which to knit not only the most basic knitting, but alsoleft - mesh left and right-right cross-interlock knit that until recently could only get the interlock machines and circular left - mesh left the flat left-left-machines.

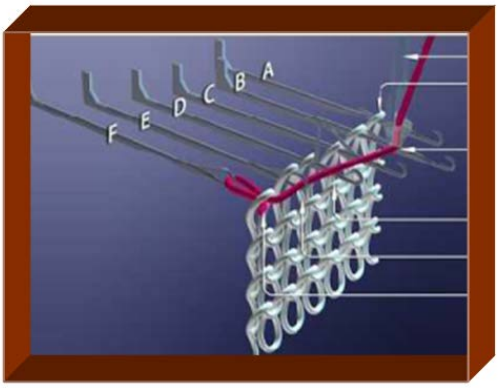


Figure 8. Generation-making loop

Each new row is inserted knitwear into the data structure. Consequently, each new order we create a new binding orientation points which are inserted in the inventory list-a list of targeted binding points. Related 3D coordinates are stored in a table of binding points in it self further linked list of tables of binding points.

Note, we must first check whether the registered binding points in the table already exist in order to prevent exc ess.

This operation is fast even for large samples that contain a lot of points because the connective inventory list is keep sorted and sequenced. Adding a new loop order can be entered only overlap the binding point in the table that arise during the process of knitting a new row. So, we have only to compare the binding points entered in the table with the Y coordinate if they are greater or equal to the previous row. In the event that there is no equivalent of a new insertion. Binding point simply share that entered the binding point in the table with one or more other binding points of the targeted binding points.

TRANSFER. Elements of the transmission loop transmit the same needle in the opposite bar. Two situations are possible: the opposite is empty needle or needles, but contrary to contain some elements of the-loop traps. In the first case, we simply modify the coordinates entered in the table of binding points in connection with bonding spots to be found in the other needle bar. This essentially leads to the addition or deletion of remote needle entered the bar at the binding point coordinates from a table. In the second case, we really have to get across any point from the previous bonding pins at the other pins, but retained the same binding point or other yarns.As a result, we get a reduction of binding points table of the four entered the merger in two.

TURNING BAR. This operation does not affect the individual pins, but the entire rear bar. Turning bar can be executed to turn the device left or right for one or more of needle-step process. In any case, it is added or subtracted out of the binding set of all points entered in the table are affected by this operation.
Grid orientation of our approach introduces a stretching or distortion that can be seen in figure 7. This is mainly due to the association coordinates in each row. When we create a new line, loop more on inacative needles and comes to stretching. Stretch loops or, more precisely, the corresponding element in the mesh data structure does not affect the topology in any way.

In the finishing stage topology, the loop stretching equalized by appropriate physical forces. This is possible because we store the actual amount distributed passes over each loop.
Therefore, stretching the loop (the upper two-point binding) results in a strong driving force of binding points that correspond to the following formula:

$$F_i xyz \sum_{k=0}^{ni} V_k xyz \quad ,$$

where i- index of network points;
Fi - force vector of i-th point;
ni - the number of neighbors of the i-point network;
Vk - k-vector of force and of the adjacent network point-and that is just super-ranking powers that occur.

Vk force vector can be determined by empirical data yarns (used in our system), or approximated to:

Vk (x y z)=Ck distance between k-default distanceα.

where Ck is again a material (yarn), always dependent on size, and an integer 1, 3, 5.

Indeed, the topology change may also affect the operation of the turning bar and a transmission loop. A very simple example of a sample containing two loops inside the front bar. Transfer one loop to another loop in the back bar, is detrimental to the other side of the second loop, and transfer back, there is a collision because of the crossing yarns that are in the same plane. This has to be protected during the turn and transfer operations. For these operations we have included a test segment exceeds the crash and was bending corres ponding to a collision is resolved, or to introduce new binding points.

CONCLUSION

For faster production and real appearance of virtual textiles require access by using computer graphics as part of the production. To gather the available knitting machines to produce different patterns designed to reduce production costs.

Visualization and simulation of textile has found its place in the history of computer graphics.
(J. Weil, 1986) is one of the first to use a purely geometric approach catenary surface. The authors of (D. Breen et al., 1994) proposed a particle system approach with the power minimized process to simulate the draping of textile. Visualization of micro-textile structure within the computer graphics community is of vital importance for the textile industry.

Simulation of twists as a system to fully simulate the entire process of knitting patterns and knitted products images can be generated without using the actual knitting machines.This is not only innovative steps for the industry, but also in an extremely demanding process that must include the physical mechanical properties of materials, and yarn.All the information needed for physical modeling must be a last resort because it is exposed to the forces of knitting and must be stretched.

In terms of power, yarn can be seen or viewed as a polygonal line. In places where the yarn is subjected to deformations or forces, given bending, such points are called deformation bonding points (DVT), they are linked together and cross the interactive and pushing each other.

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THE NEEDS FOR COMPRESSION SOCKS

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ABSTRACT

Different sock shapes and compression socks are described. Compressions of classic short socks in the sock body and cuff are analysed. The measuring was done on rigid cylinders of different diameters/circumferences which corresponded to leg circumferences in particular places. Special focus was placed on preventive and medical compression socks and amounts of compression on particular parts of the sock sleeve, as determined by an international doctors' agreement. The measuring of the sock sleeve compression in long compression socks was conducted on the wooden leg model in certain sizes. Sock compression up to 13 hPa (10 mmHg) is generally considered small and is not stated on the sock manufacturing label. In the German norm, the smallest amount of compression is 24 hPa (18 mmHg) and preventive compression socks are usually made below this compression area. A larger compression classifies the sock as a medical compression sock. Compression socks help people to perform their everyday or professional activities in a simpler, less painful, faster, more precise and happier way and to lead a more joyful life. The classic construction of the medical (therapeutic) compression sock follows the principle of the highest compression in the ankle area which gradually decreases towards the crotch. Depending on the purpose, it is possible to make a compression sock with specifically determined amounts of compression in particular leg parts.

Key words: compression sock, polyamide, elastane, elongation, compression

INTRODUCTION

Socks are an important aesthetic and functional part of dressing. In developed countries, they are worn every day, both on private occasions and in different occupations. Constructional shapes and functionality of socks are adapted to their intended use. Socks can be divided into different groups and are equally worn by healthy people, men, women and kids. They can be very short (ankle socks), short, knee highs, long stockings or pantyhose. Special-purpose socks have specific constructions and properties [1].

Short classic male and female socks are basically made in three material compositions. Ground yarn used to make the entire length of the sock usually consists of natural fibres, cotton or wool. Breaking elongation of these yarns is commonly 5 to 15 % and they cannot form a good-quality classic sock on their own. In order for the sock to have an adequate elasticity, apart from the already mentioned yarns, multifilament polyamide (PA) yarns with the breaking elongation 20 to 40 % are usually knitted in. They provide the sock with elasticity, acceptable fit on the leg and wearing comfort. This multifilament yarn is simultaneously knitted in with the ground yarn along the entire length of the sock. The third yarn used in the production of classic short socks is elastane and it is significantly coarser. It is knitted into the upper, open cuff of the sock and makes it self-supported. Such classic socks are most often mass produced for an unknown buyer [2].

Special-purpose socks have specific constructions, material compositions and tensile properties. For example, there are constructional differences among the so-called sports socks for athletes, skiers, alpinists, football, basketball and handball players, etc. Many professional athletes use socks which are made according to their leg measurements and have a specific construction. They use one kind in their everyday life, other during practice and third in competitions [3].

Some hosiery is used for medical therapeutic purposes in the treatment of leg diseases. Chronic venous insufficiency (varicose veins) is often treated by compression socks which press on the tissue, and thereby also the veins, thus restoring the right blood flow through the legs. Other medical therapeutic socks are used to cover wounds wrapped in bandages. These socks do not usually exert compression on the leg but keep the bandage in a certain position and keep the leg warm or protect it from cold [4,5].

HOSIERY COMPRESSION

In order to adequately fit on the leg, the sock presses the leg with a certain force, i.e., the moderately longitudinally elongated body of the sock comfortably fits on the leg, which is how the sock becomes self-supported. In classic socks, sock compression on the leg is not that significant and is not stated on the manufacturing label. The amount of hosiery compression is relevant in medical compression (therapeutic) stockings. The pressure that blood exerts on the artery wall is called blood pressure. With each heartbeat, the blood is introduced into the arterial system under pressure. At that moment, the blood pressure is the highest and is called systolic. In the period between two heartbeats, the blood pressure is lower and is called diastolic. The value of blood pressure is therefore expressed by two numerical values. The first value is always higher and represents systolic pressure, while the second is lower and represents diastolic pressure. In healthy people, the optimal value of blood pressure should be below 120/80 mmHg. The blood pressure above 140/90 mmHg is considered high blood pressure or hypertension. In people suffering from diabetes, kidney or heart disease and those who have had a stroke, the target blood pressure is below 130/80 mmHg [6]. Based on blood pressure measurements, doctors have accepted mmHg as a unit of measurement for the compression of compression hosiery on the leg. Some European countries made standards for measuring the compression of hosiery on the leg, and the compression is expressed in mmHg. [7-9]. In mechanics, especially fluid mechanics, pressure is measured in the pascals (Pa), which is a relation between force in newtons (N) and surface on which the force acts expressed in square metres (m^2), ($Pa = N/m^2$). Since the pascal is a small unit, we use kPa and hPa, (1 mmHg = 1.33 hPa; 1 hPa = 1 g/cm^2; 67 hPa = 50 mmHg). Depending on the intended purpose of the stocking, its compression is usually measured on the leg from the ankle to crotch. Doctors defined certain places (points) in which compression is measured [4,5]. Apart from compression stockings or leg sleeves, there are compression arm sleeves which are put on the arms, Fig. 1. They are used by professional athletes, typically basketball and handball players, but also volleyball players and skiers. The function of a compression leg or arm sleeve differs between sick and healthy people, i.e., athletes.

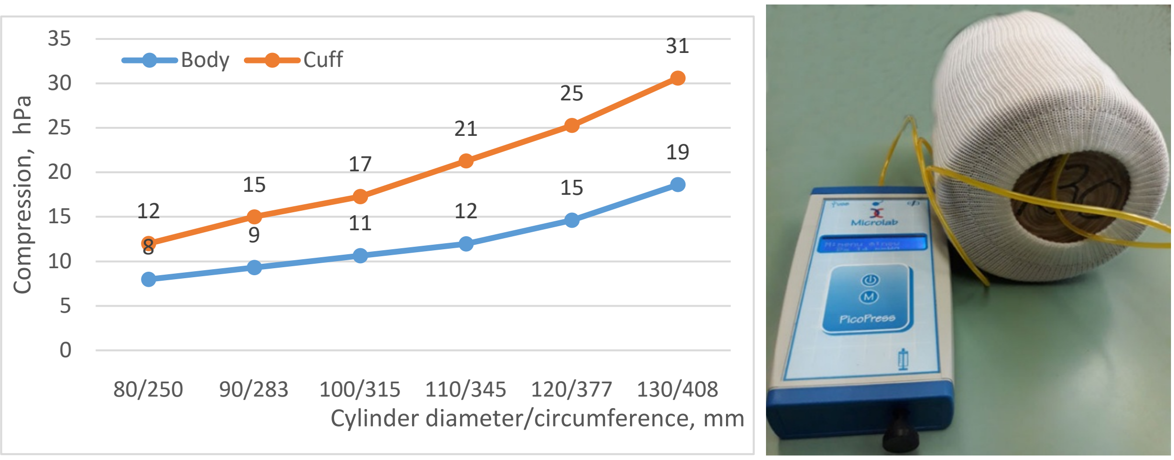
a) b) c) d) e) f)

Figure 1: Different types of compression hosiery: a) knee-high stockings, b) women's preventive pantyhose, c) preventive maternity pantyhose, d) sports short compression socks, e) compression leg sleeves, f) compression arm sleeves

COMPRESSIONS OF SHORT SOCKS

There are different constructional shapes of short socks. In the classic construction of short summer or winter socks, compression is irrelevant and is therefore not stated on the manufacturing label.

However, a coarser elastane yarn is incorporated into the upper sock part or the open cuff, and sometimes presses the leg more strongly and leaves a deformation on the leg. Since such sock is uncomfortable for everyday wear, its use is avoided. There are two reasons why the cuff pressure on the leg is too large. The first reason is to be found in the relation of the sock construction and the leg. The sock was probably made for the classic leg shape, while the leg on which the cuff lies has larger dimensions. The second reason is that the sock was really made with a smaller share of elastic elongation in the cuff area. In such socks, the compression of the sock body on the leg is 4 to 10 hPa (3 to 7 mmHg). A comfortable cuff compression on the leg is often twice as large as the compression of the sock body on the leg and ranges between 8 and 20 hPa, Fig. 2. Short classic socks are made for an unknown buyer and usually unknown market. Therefore, this sock group involves various compressions of the sock body and cuff on the leg. For this reason, the measuring of the short sock body and cuff compressions on the leg is simply and cheaply done on cylinders with the human leg diameter, e.g., 80 to 130 mm with the 10 mm spacing. By mounting the sock on the cylinder of a larger diameter/circumference, the elongation increases, and thereby the mounting force and finally the amount of the measured compression, Fig 2b.



a) *b)*

Figure 2: Compression of the body and cuff of the short classic sock: a) amounts of compression at a certain elongation, b) measuring compression on a stiff cylinder of a certain diameter [10]

Compressions of the body of short socks with various structures and purposes were measured. A representative sample of a light spring/summer short sock, with the mass of 15 g, made with a ground cotton yarn in the count 20 tex and PA multifilament yarn in the count 156 dtex, exerts the compression on a stiff cylinder from 4 to 13 hPa, Fig. 3, curve A, [10]. If the sock body is mounted on a leg circumference from 250 to 300 mm, the compression is the smallest and amounts 4 to 5 hPa. In the leg circumference from 300 to 360 mm, the sock body exerts the compression from 6 to 10 hPa, and in the largest circumference of 400 mm, the achieved compression is around 13 hPa. These socks are appropriate for the use in leg circumferences from 250 to 330 mm, where an acceptable wearing comfort is achieved. Objectively speaking, this sock is not comfortable to use if it exerts a compression larger than 10 hPa.

The second sock from this group selected for compression measurement has similar constructional properties. It is intended for winter use. It was made from a ground cotton yarn in the count 50 tex and PA multifilament yarn in the count 220 dtex, and had the mass 20 g. By mounting the body of this sock on cylinders with diameters/circumferences from 80/250 to 130/408 mm, the measured compression was from 6 to 20 hPa – curve B. In such socks, increased compression leads to greater comfort during use. As in the first sock, the compression linearly increases with respect to the increase in cylinder circumference on which the sock is mounted. The third sock is made from similar yarns as the second, except that it is made in the plush weave, and is featured on the market as a thermal sock. The sock is significantly more massive than the winter sock and has the mass of 26 g. It is also intended for use during winter. In winter, it is often worn by the young, but the old as well, during walks or in the house/apartment. The compression of this sock is similar to the compression of the winter sock. It tends to be more acceptable to wear with a smaller compression. The fourth in this group is the so-called sports sock. Unlike the previous ones, this sock is made from the ground cotton yarn in the count 34 tex and the elastane yarn 54 tex. The elastane yarn is knitted into each course together with the ground yarn. As a result, it significantly shrinks the tubular shape of the sock upon removal from the machine. Therefore, this sock elastically stretches during application and presses the leg more firmly. In some sock constructions, the body and foot are entirely made with the ground and elastane yarn, while in other constructions only partially. This sock in this sock group exerts the largest compression on the leg in the amount 8 to 35 hPa. Many users, especially amateur or recreational athletes, consider the compression 12 to 25 hPa as the most suitable for themselves. Recreational athletes who use such socks with an increased compression, i.e., 20 to 25 hPa, remove them from their legs after a practice or game because large compression causes discomfort in the resting position. During use and after a dozen washes, the compression in these socks slowly decreases, often up to 30 %, [3].

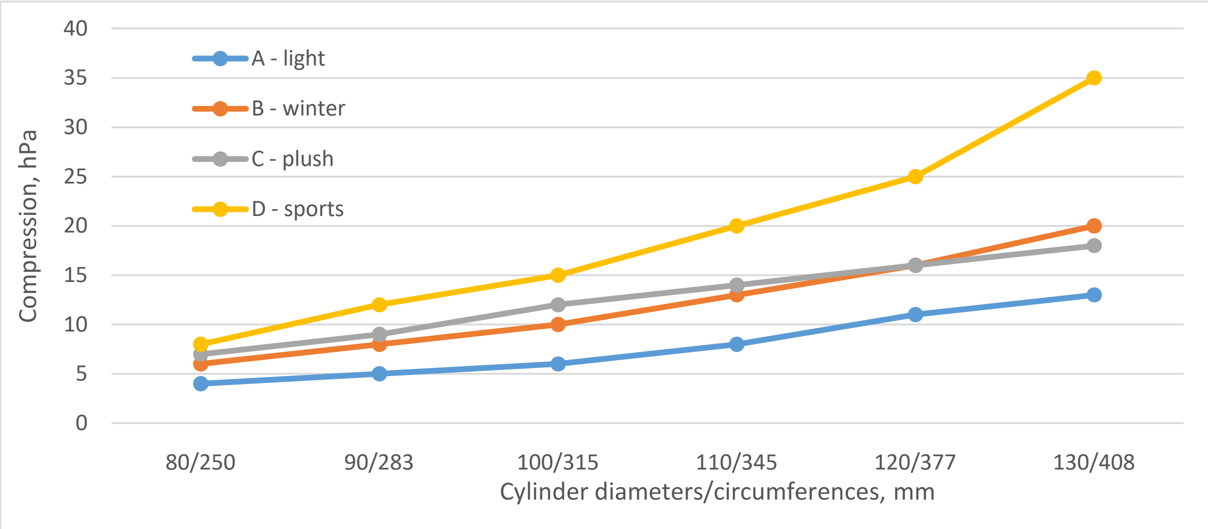


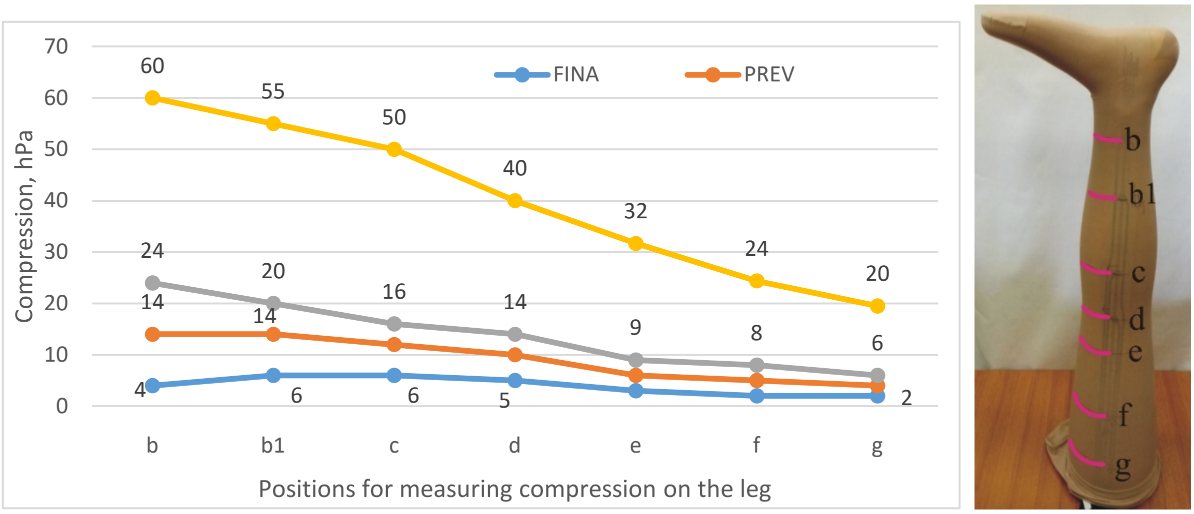
Figure 3: Compressions of the body of different short socks

There are various reasons why short socks with an increased compression are in high demand. They are happily worn by the elderly and sick as well as athletes and kids. In most cases, these socks do not cause health disorders during use. Special-purpose short or knee-high socks are custom made and exert the required compressions on certain parts of the lower leg.

MEDICAL COMPRESSION SOCKS

Classic fine women's pantyhose is made according to the principle where the sock sleeve is made from yarn in a single count with different sinking depths. The yarns used in the production of these socks are typically PA multifilament yarns in the counts 17, 22, 33, 40 or 60 dtex. The smallest sinking depth is applied in the sock part lying above the ankle (Fig. 4 – position b) and the width of tubular knitwear in this area is usually 80 to 90 mm. The leg circumference in this area is from 180 to 220 mm. When the sock is put on the leg, it elongates 30 to 50 % and exerts the compression from 5 to 8 hPa (4 to 6 mmHg). Leg circumference increases from the ankle towards the knee and with it also the width of tubular knitwear in the sock sleeve. The increased width of tubular knitwear is achieved by the increased sinking depth. In numerous fine women’s socks such as these, the compression on the lower leg (position c – diagram FINA) is around 20 % larger than the compression above the ankle. In the upper leg area, leg circumference is even larger, which means greater width of the knitwear. When the sock is put on this leg part, the compression decreases and is often around 2 hPa in the area below the crotch (position g). These are small amounts of compression which can be differently distributed along the sock sleeve and are therefore not stated on the manufacturing label. Girls or women who play sports often prefer to use socks which have the largest compression on the calf and around the knee. [11].

Preventive compression socks (Fig. 4. - curve PREV) are often worn by people who spend a long time in the standing position or on the go: stomatologists, nurses, postmen, recreational mountaineers, shop assistants and others. They are certainly more frequently used by women and without doctor consultation. These socks have a larger compression, especially above the ankle. The compression is often 14 to 18 hPa (10 to 14 mmHg) and gradually decreases towards the crotch, where it is around 4 hPa (3 mmHg). The socks are made in plated weave with two yarns being knitted into a single course: the ground is polyamide multifilament, e.g., in the count 33, 44 or 60 dtex, and the plated is single or double covered elastane in the count of, for example, 44 dtex. According to the German standard [7] the smallest compression of a compression sock is 24 hPa (18 mmHg). Therefore, preventive compression socks are often made below the given amount of compression and in principle, they can be used without doctor consultation. However, pregnant women who have given birth more than twice are happy to consult a doctor. During pregnancy, doctors recommend using preventive compression pantyhose with compression above the ankle of up to 24 hPa. In principle, the compression in these socks decreases 60 to 80 % towards the crotch, where it is only 6 hPa. These socks also come in different constructional forms and compressions. The demand for these socks on the European market has been increasing lately. In certain areas, these socks are supplanting classic socks, e.g., among mountaineers, firefighters, police officers, truck drivers, foresters, and others.



a) *b)*

Figure 4: Compression of sock sleeves of preventive and compression medical socks; a) measured compressions of certain socks in measuring areas, b) specified areas for measuring compression on the wooden leg model

Socks which exert a compression larger than 24hPa (18 mmHg) in the German standard are used as medical compression socks or medical therapeutic socks. Generally, they are recommended by doctors to treat certain diseases (varicose veins, oedema, ankle swelling, lipodermatosclerosis, ulcerations in the healed venous stasis, active venous ulceration, venous insufficiency, chronic venous insufficiency, etc.). Standards by certain countries usually include four grades or degrees of compression which are mutually different. In the German standard, the first class encompasses mild compression from 24 to 28 hPa (18 to 21 mmHg), the second class involves moderate compression from 30 to 43 hPa (23 to 32 mmHg), the third class includes strong compression in the amount from 45 to 61 hPa (34 to 46 mmHg) and the fourth class very strong compression which is larger than 65 hPa (49 mmHg). Depending on the disease type and stage, doctors recommend socks with a certain compression. In Fig. 4. – the curve OM-MA shows the amounts of compression in a medical compression sock with mild compression and the curve KOM-VE shows large amounts of compression in a medical compression sock belonging to strong compression, while the compression decreases from 60 hPa (position b) to 20 hPa (position g). Measuring of the sock sleeve compression is usually simultaneously performed in the seven given areas on the wooden leg model. Medical compression or therapeutic socks are worn for longer time periods under medical supervision.

As can be observed, in numerous compression medical socks, compression continuously decreases from the ankle (position b) towards the crotch (position g). Many professional athletes use compression socks which have customized and comfortable amounts of compression. Some basketball players have the largest amounts of compression in the lower leg and upper leg muscle because of mass amortisation during high jump and fall. Some handball players use compression socks with the largest compression around the knee, which suffers the biggest pressure. Such socks are custom made according to the measurements of a specific leg. Compression socks which exert a compression larger than 24 hPa are very often used by ex professional athletes who become recreational athletes. After active sports playing, their muscles lose flexibility and elasticity so compression socks strengthen their muscle tissue. They use such mild compression socks every day, and during practice or recreational matches, they use socks with a larger compression. They choose socks with a certain compression on their own, without doctor consultation.

CONCLUSIONS

In modern society, compression socks increase the joy of living by making it easier for people to perform their daily activities. In everyday life, compression socks are used by people of all ages. Some follow doctor recommendations while others use them on their own based on wearing comfort. In the world it is a generally accepted view that the socks which exert compression up to 13 hPa (10 mmHg) are not considered compression products. These socks are usually the kind that healthy people wear every day. People who do their activities in the standing position use preventive compression socks which exert the compression on the leg 13 to 24 hPa (10 to 18 mmHg). Medical compression socks exert the compression on the leg larger than 24 hPa (18 mmHg) and should be used based on doctor recommendation and control. Many compression socks are made on specially constructed hosiery automats and are made from PA multifilament and elastane yarns.

Acknowledgement:
This paper was financed by the Croatian Science Foundation in the project IP-2016-06-5278.

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THE PROCESS OF KNITTING BERETS ON THE EXAMPLE OF COMPANY "BEGEJ HAT"

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ABSTRACT

The paper describes knitting technology of the women's berets on the example of company"Begej hat". Production of the berets was made with a knitting technique. The technique is very demanding, which means working on special knitting machines like such as a circular knitting machine. The process of needle work on a circular knitting machine is described, as well as the method of placing a beret on a kettle machine. The company "Begej hat", as one of the most famous companies on our market is a symbol of the tradition of producing berets and woolen hats. The aim of this paper is to present the way of knitting a beret as one of the products that is very rarely produced in Serbia and other countries.

Keywords: *berets, wool, knitting, loop, needle*

INTRODUCTION

Berets are the most elegantly timeless style of hat – at once capable of being tidy and astute, feminine and intellectual, unassuming and intriguing. The beret's agelessness endurance comes from having a complex history; it was born out of necessity and existed long before it was even dubbed a beret. Despite the reputation it has now of French artsy-fartsy, cigarette-puffing pretention, this stereotype is not actually part of its origin story. In the 14th and 15th century, berets were simply referred to as felt hats and were specifically common among the poorest farming classes and artists (perhaps due to the hat's incorporation into the self-portraits of artists such as Vermeer and Rembrandt). Its practical construction allowed it to be adopted by many groups, from French and Spanish militaries in the 1800s, to the Black Panthers in the 1960s and 70s and endless film starlets in between. The beret creates unity and wholeness in a group of individuals – it's an additional layer to a uniform that symbolizes a strong alliance. [1]

The company "Capital group" from Belgrade was founded in 2006 with the idea to start the production of woolen sleeves, caps, berets and hats. Today, the production plant is located in the municipality of Ruma and consists of a production and warehouse part and office space. The facility is equipped with modern machines for the production of berets, which make up the additional production program of the factory.

This type of production is important not only because of foreign sales (distribution in the region, countries of the former SFRY, customers in Italy, France, Austria, Germany ...), but also because it initiates the development of domestic livestock - sheep breeding. , because natural wool is used as the basic raw material. [2]

Circular knitting technologies are the most productive methods in the knitting industry. Recently, renowned machinery companies have been developing modern circular knitting machines with a high efficiency production rate and the ability to create special properties in the produced fabrics. Circular knitting technology will lead the textile industry in producing special fabrics once the circular knitting machines are able to produce these fabrics at a high speed and of suitable quality, enabling competitive production of special and industrial fabrics for automotive and medical applications and elegant clothing. [3]

THE PROCESS OF KNITTING BERETS

Beret, a seamless hat made of wool, had originated in France. The beret is knitted on a single-needle flat knitting machine. The three-dimensional shape of a beret is formed by knitting a series of interlinked triangular sections. The full width of a beret is knitted at the beginning and is completed by course shaping. After knitting is completed, it is milled, dyed, dried, and blocked. Sometimes brushing may be applied to the finished hat. [4]

Circular knitting machine for fashioned products for example berets, hats and other related products with coloured patterns. The object of invention is a circular knitting machine with an oscillating movement of cylinder, with a fixed cam system, sinkers crown and jacquered type needle selecting device with selecting combs, the cam system consisting of three tracks of which one for needles in operation, the second for needles out of action for shaping, and the last one for needles out of action realizing the pattern. The controls for knitting, narrowing/widening, selecting and those for yarn guides are transmitted from a driving wheel with cam tracks of a suitable position for giving a synchronization of the mechanismus. [5]

The rim of the beret is knitted - with large needles
The middle of the beret is knitted - with small needles
The upper part of the beret and the tentacle - large needles

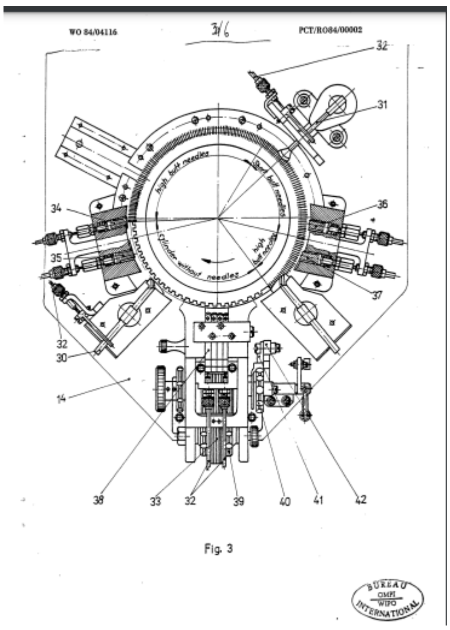
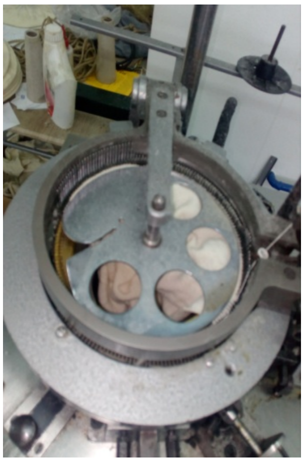


Figure1: Scheme of cynematic chain of the machine [5]

Yarn used - raw material composition 100% wool


Figures 3,4,5: Beret production process on knitting machines

Figure 6: Appearance of the beret after knitting

When the beret knitting process is completed, the beret is not completely closed, so the further production process continues on the kettle machine.

THE PROCESS OF ASSEMBLING BERETS ON A "KETTLE" MACHINE

After finishing the beret knitting, the beret is further assembled on the kettle machine. In the "ketting" process, the most important thing is to put each loop on one needle. The seams produced by the kettling machines must be imperceptible and elastic. This is achieved by the correct selection of the ketting equipment, which must correspond to the class of the knitting machine. The easiest way to choose is to match the density of knitwear. For this purpose, the number of loop rows is counted per unit length. Their number will correspond to the class of the machine. [6]

Putting the loops on the tocol is done manually, and the unification, cutting, cleaning and processing of the seam makes the machine in automatic mode. [6] The worker presses the foot pedal on the left side to start the machine. The beret placed on circular needles is rotated, the device with a knife cuts off the excess knitwear, the circular roller in the form of a brush cleans the cut remains, then the catcher pulls the yarn and adds it to the device that suppresses the yarn to obtain a sewn beret.

The opening (tentacle) of the beret is sewn by hand, depending on whether the tentacle remains protruding - which is the case with the female beret, while with the male beret the tentacle is retracted.


a)


b)


c)


d)

e)


f)

Figure 7: a)Appearance of a kettle machine, b)Magnified view of the loop through each needle, c) Cutting the excess, d) Cleaning after cutting, e) Yarn catcher, f) Splicing - yarn suppression

Figure8: The appearance of a closed beret

FINISHING PROCESS OF BERETS

After "ketling", the berets continue to:

a) hammering
b) painting
c) stretching on molds
d) drying

Figure 9: Picture of a beret after knitting (before finishing) and after finishing

In the case of a female beret, the process ends there. If it is a male beret, after drying it goes to the process of cutting and sewing the lining. The final look of the beret depends on the customer's order.
The example shows a men's beret with a leather rim, a strip inside the entire leather rim that has the possibility of tightening, drikers and an emblem.

Figure 10: Appearance of a female beret on the customer's order

Figure 11: Appearance of a men's beret on the customer's order

CONCLUSION

The paper describes the technology of knitting berets on circular machines on the example of the company "Begej hat". The paper also describes the process and operation of needles circular machine, as well as the method of placing a knitted beret on a kettle machine. Emphasis is placed on the company and the fact that the production of berets is very demanding and rare. With four years of operation, the company has managed to maintain quality in order to achieve a high level of placement in foreign markets.

ACKNOLEDGEMENTS

This paper is a part of the research project titled: Development of knitted textile materials for products of increased thermo physiological comfort, financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

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THE USE OF CARBON FIBERS MANUFACTURING COMPOSITE MATERIALS IN WORKSHOP CONDITIONS

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ABSTRACT

Composite materials with carbon fibers are increasingly used nowadays. They show significant advantages compared to common materials, such as plastic and metal. These materials are not as affordable as regular metals, but with the development of technology, new ways are found for their production and lower price, provided that the quality remains the same. Since carbon fibers has excellent mechanical performance in relation to its weight, they are used to achieve a certain strength in new composite materials. By mixing with certain resins, carbon fibers create properties that support their wide use. The paper describes the procedure of making a car component from carbon fiber composite material using simple techniques in a workshop. The experiments showed that in such simple conditions it is possible to obtain good quality composite material. The components from carbon fiber composite materials made is the workshops could be use in automotive industry for car, motorbike and helmet improvements and tuning.

Key words: Carbon fiber, resin, epoxy, polyester, workshop

INTRODUCTION

Nowadays people are living fast, and that leads to great risks, especially in traffic. Speed requires the attention of each individual and sometimes it happens that a moment of inattention occurs and then a serious problems can arise, especially in traffic. Car and motorcycle races are at a much higher speeds than they used to be, and thus it is becoming increasingly difficult to protect the driver in case of an accident.

Air pollution is one more important problem that occurs nowadays. The automotive and textile industries are some of the biggest polluters on the planet. The automotive industry use advanced filters and special fuels, as well as parts from certain composite materials that are lighter than classic metals, and yet have the same or greater strength. Reducing the weight of the car it is possible to reduce fuel consumption and thus less harmful gases produced by the engine.

This paper is describing one of the modern composite materials that is increasingly used in the production of cars, both in terms of protection of road users and in terms of reducing pollution.
Carbon fibers are, perhaps, the most successful new carbon product which is commercialized in the past 35 years. Their high strength and stiffness, combined with light weight, make these fibers very maluable for high-volume applications ranging from sporting goods to aircraft structures. Like other products, commercial carbon fibers must exhibit consistent mechanical and transport properties, however the optimum properties may differ for each application. [1]

PERFORMANCES OF CARBON FIBER

Carbon fibers are made from carbon atoms joined together to form a long chain. [2] These carbon atoms are linked between each other with a crystal structure, more or less oriented along the direction of the fibers. This alignment gives the fiber its high strength resistance for its volume (it makes it a strong material relative to its size and weight). [3] Creating carbon fibers several precursor fibers are combined by subjecting them to chemical treatment, heating, stretching and carbonization. [4] Different types of carbon fiber result in different properties of the composite part both in production and in the final product. [2]

Advantages and disadvantages

The properties of carbon fibers depend on the structure of the fibers. In general, the most important properties of carbon fiber are low density, high tensile modulus and strength, low thermal expansion coefficient, thermal stability in the absence of oxygen to over 3000°C, excellent creep resistance, chemical stability, biocompatibility, high thermal conductivity, low electrical resistivity, availability in a continuous form, decreasing cost (versus time).
Disadvantages of carbon fibers are anisotropy (in the axial versus transverse directions), low strain to failure, low compressive strength compared to tensile strength, tendency to be oxidized and become a gas (e.g., CO) upon heating in air above about 400°C, oxidation catalyzed in an alkaline environment. [5]

Carbon fiber vs. metals

When designing composite parts, one cannot simply compare properties of carbon fiber versus steel, aluminum, or plastic, since these materials are in general homogeneous (properties are the same at all points in the part), and have isotropic properties throughout (properties are the same along all axes). By comparison, in a carbon fiber part the strength resides along the axis of the fibers, and thus fiber properties and orientation greatly impact mechanical properties. Carbon fiber parts are in general neither homogeneous nor isotropic. The properties of a carbon fiber part are close to that of steel and the weight is close to that of plastic. Thus the strength to weight ratio (as well as stiffness to weight ratio) of a carbon fiber part is much higher than either steel or plastic. [2]

APPLICATION OF RESINS IN THE MANUFACTURE OF CARBON PRODUCTS

There are three main types of resins used today for use with carbon fiber.
The most often polyester resins are used because they are relatively cheap and about three quarters of them are used with some form of reinforcement. Only the resins with good mechanical and high temperature performance are used with the relatively expensive carbon fibers.

The epoxide resins are the next important class of resins. There were developed over 50 years ago. They are more expensive than polyester resins but have superior mechanical properties and good resistance to alkaline conditions. Epoxides are by far the most widely used polymer matrix for carbon fibers and currently constitute over 90% of the matrix resin material used in advanced composites.
The vinyl ester resins have properties that are intermediate between polyesters and epoxides, are easier to process than epoxides, coupled with a better chemical resistance than polyester resins. [6]

Polyester resin

The term "polyester resin" ("laminating resin" or "fiberglass resin") largely refers to "unsaturated polyester resin", unless otherwise indicated. [7] Unsaturated polyester resins are the product of an esterification reaction between dibasic organic acids (or anhydrides) and a dihydric alcohol (glycol) with the formation of H2O. One of these groups, generally the acid, contributes the unsaturation to enable cross linking to take place in the final cure. The most commonly used unsaturated acid is maleic acid. Saturated acids can also be used, which can contain an aromatic nucleus and have no pendant double bonds that would react with a peroxide catalyst. Ethylene glycol gives a product that tends to crystallize out. Therefore, propylene glycol is used for most polyester resins. [6]
Easy to use and economical, it is a major component in many industries, from construction to aviation. It is also used as an ingredient in special coatings and adhesives. [7]

Epoxy resin

Epoxy is the thermosetting matrix or resin materials, having at least one or more epoxide groups in the molecule. Most of the commercially available epoxy resins are oligomers of diglycidyl ether of bisphenol A (DGEBA). Epoxy resins usually require the higher amount of curing agent in the ratio of resin to hardener (1:1 or 2:1), compared with polyester or vinyl ester resins, where the resin is catalyzed with a small (1–3%) addition of a catalyst. The advantage and limitations of epoxy resins can be preset by the chemical structure of the resin and hardener, as well as by the network achieved after curing.
Epoxy resins have distinct advantages compared with other thermoplastic or thermoset resins, such as the following:

- Minimum shrinkage during curing.
- Improved mechanical and fatigue strength.
- High moisture resistance.
- High chemical resistance.
- Better electrical properties.
- Good adhesion with many substrates.
- Non-magnetic properties.
- No volatile organic compounds.
- Long shelf life.
- Impact resistant.
- Corrosion resistant (anticorrosive) [8]

The highly cross-linked structures that are formed determine the thermal and mechanical properties of epoxy thermosets. A higher cross linking density can also be a “downside” for epoxy thermosets which could lead to lower fracture toughness, loss of flexibility and difficulty in the recycling of processed materials. Due to its versatility from chemical and processing perspectives, the utility of epoxy resins is ubiquitous in industries that require high performing materials. [9] Epoxy resins have been widely used for coatings, electronic materials, adhesives, and matrices for fiber-reinforced composites because of their outstanding mechanical properties, high adhesion strength, good heat resistance, and high electrical resistance. [10]

Epoxy resin and carbon fibers

Composite materials have similar strength abilities as metals such as aluminum and titanium, and weigh less. They are formed by combining two or more compounds that retain their macrostructures after fusion. These combinations give materials with stronger combined physical properties than those of their individual parts.

When manufacturers use epoxy resins in composite production, they result in stronger, lighter components. Composite manufacturers combine epoxy resins and carbon fibers because these materials interact. Epoxy is one of the few materials that can be glued to carbon fibers, and many other composite production options do not offer the required bonding properties. Composites offer industry professionals several benefits that improve product quality, such as high strength and light weight, fatigue resistance, resistance to extreme temperatures, corrosion and wear, features that can be easily developed for specialized applications (vibration damping, low thermal expansion coefficient), flexibility of design and construction (composite materials can reduce the amount of parts needed for the project and translate to products that require less raw materials and assembly time). [4]

EXPERIMENTAL PART

It was decided to create a car mirror cover from a carbon fiber composite material (see Fig.1). As the experiment was done in an amateur workshop conditions, a small and simple shape component - a cover of car mirror was chosen. The experiment consisted of two parts:
● mold making,
● car component making from carbon fiber composite material.

Figure 1: Mirror cover used as a model

Mold making

The mold making process consisted of several stages:
● *Cleaning the disassembled mirror cover:* It was necessary to clean, degrease the cover, if necessary polish it so that the resin can stick evenly, during its application.
● *Cutting the appropriate size of glass fiber cloth.* At this stage it was necessary to cut and adjust the size of the piece of cloth according to the shape of the mirror cover.
● *Coating the cover with a protective lay* to avoid gluing the created mold to the original mirror cover.
● *Coating the cover with a resin*: The resin was applied to the cover by a brush. Then the piece of cloth was thinned and then resin coated again.
● *Drying*: After 15 minutes, the mold made of polyester resin was sticky. The mold dried completely after 2 hours and it was ready to separate.
● *Detaching the mold*: The mold was separated slowly by help of a thin sharp object.

Polyester resin is very sticky and tends to stick to the surfaces to which it is applied. To prevent the sticking of the mold, to the original mirror cover an inlayer have to be placed in between the mold and the original component. Polyvinyl alcohol (*PVA*) is a polymer which is used for film *coating* in such applications in industry. However, it has high price and it is not common in Serbian market. Therefore it was decided to find other kind of material which could be used as a interlay between the mold and the original component. Three different materials were tried as a protective lay to avoid sticking together the original mirror cover with its mold: *adhesive tape*, *lard* or a *cream*.

The *adhesive tape* had to be carefully applied to the mold to minimize creases. Unfortunately, the folds that appeared gluing the 2D adhesive tape on the 3D component, outlined on the ready mold. It was clear that the use of the tape was not the ideal solution. The tape can be used to make a mold, but after separation, the mold have be additionally processed and leveled.

One more mold was made using a *lard*. *Lard* melts very quickly at high temperatures. Polyester resin reaches high temperatures during drying and with it melted the lard. However, melted lard mixed with polyester resin and glued to the mirror cover. It was very difficult to separate the mirror cover and the mold. The mold became uneven and had a lot of cracks.

The third time a simple *hand cream* were used as a interlay. It showed the best results. The cream relaxed at high temperatures, but still remained stable enough. When the resin dried, the cream did not allow it to stick to the mirror cover. When the mold was separated, the part of the cream remained on its surface. It was enough to degrease the mold with soap to remove it (see Fig.2).

Figure 2: Ready mold

***Making a* mirror cover from a carbon fiber composite material**

The work procedure was similar to the mold making process. Carbon composite material was made using epoxy resin and a carbon fiber cloth in 3 different ways: not using protective interlay in between a mold and composite material, using lard as a interlay, using a adhesive tape as a interlay.

Without any interlay

To see how the epoxy resin react on the polymer resin which was used creating the mold, the first sample was made without any interlayer. The epoxy resin was mixed with a hardener in a ratio 100: 26. During 24 hour drying process, the epoxy resin heated up. Affected by heat two resins reacted chemically and stuck together. It was difficult to separate the carbon composite from the mold. The mold had to be fully damaged, but the newly created mirror cover from composite material was contaminated with small parts of the mold (see Fig.3).

Figure 3: Appearance of the carbon part I of the mold after separation

It was clear that some kind of a protective interlay had to be used to avoid gluing together the mold with the carbon fiber composite material.

Lard as a interlay

One of the samples was made using lard interlay. During drying because of high temperature the epoxy resin melted and absorbed the lard. The lard became sticky and therefore it was not possible to separate it from the mold not breaking it. The mold and created component from carbon fiber composite material were fully damaged (see Fig.4).

Figure 4: Appearance of carbon fiber and mold with lard as a pre-war material – front

Hand cream as a interlay

Hand cream also melted at high temperature, but unlike lard, it bond much less to the epoxy resin.
The cream started to boil at high temperature and because of it left tiny holes in the composite material. It was easy to separate the carbon component from the mold. However, the created carbon component had very bad quality - it was embossed and perforated (see Fig.5).

Figure 5: Appearance of carbon where hand cream was a pre-war material

Adhesive tape and vacuum

In previous experiments the resin was applied with a brush. To reduce the amount of resin used, it was decided to use the vacuum. This method was more complex and was performed in several steps:
● The mold was covered with an adhesive tape and a lay of carbon fiber cloth. The it was put into a proper size strong nylon bag (thin nylon burns during the drying phase).
● To create the vacuum in the bag, a vacuum pump with a power of 70W was used.

Figure 6: Appearance of creating a vacuum in a bag (Nylon) using a vacuum pump

● The epoxy resin was applied through a syringe and a tiny pipe to the carbon fiber cloth in the nylon bag (see Fig.6).
● The created composite material dried in the vacuum 3 hours. When it was taken out of the bag, it was still sticky. 24 hours were necessary to dry it fully.
● It was easy to separate the composite material created from the mold. However, as the 2D tape covered the 3D mold, folds of the tape left the marks on the carbon composite component.

Figure 7: Carbon formed from vacuum

At the end of the work process, the component was just to cleaned. The car component created at the last experiment had the best quality (see Fig.8). Obviously the adhesive tape as the interlay and the vacuum to apply the resin can be used in simple workshops creating such components from carbon fiber composite materials. To smooth the surface of the ready component and to create glass effect on its surface, the larger amount of epoxy resin should be used.

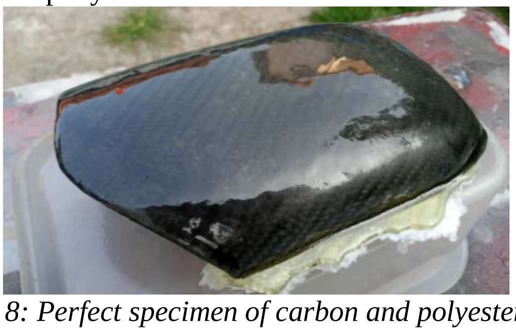

Figure 8: Perfect specimen of carbon and polyester resin

CONCLUSIONS

1. Several experiments were performed to create a small car component from carbon fiber composite material.
2. The experiments showed that it is possible to create qualitative components from carbon fiber composite material in simple workshop conditions.

3. It was established that the most important factors which influence the quality of the ready component are: the amount of the epoxy resin applied, work methods used to join the resin with the carbon fiber cloth and the type of an interlay placed in between the mold and the composite material.
5. It was found that the best conditions to apply the epoxy resin to the carbon fiber cloth is the vacuum. By help of the vacuum the amount of needed resin can be reduced and the quality of the created composite material can be increased.
4. It was tried to find the simple and easy available interlay materials which can be used in between the mold and the composite material. The acceptable quality was obtained using a adhesive tape as a interlay.
5. The advantages of the work process performed in the simple workshop conditions are: possibility to create unique components, possibility to make quick orders, possibility to reduce product costs.
6. To ensure high quality of the ready products in such simple work conditions, the experiments should be continued: to improve the technology of manual work process, to find the ideal interlay material, to find other simple equipment which could easy the work process and improve the quality of the ready products.
7. The unique components from carbon fiber composite material created in workshop conditions could be used for car and motorbike improvements and tuning, for motorbike helmet tuning, other.

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APPLIQUE AS A MEANS FOR MEN'S KNITWEAR DECORATION

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ABSTRACT

Todays to look stylish, to meet modern trends, to have a beautiful appearance are the tasks that are relevant not only for women but for men also. Men's fashion is much more conservative and therefore has remained faithful to the classic suit for a long time. But the reality makes adjustments. Men's wardrobe has got images for work, rest, meetings with friends. In the upcoming autumn-winter season, men's clothing becomes more casual: free-cut products, cozy soft knitwear, which differ in particular decoration. The most effective and unique clothes` decoration can be created by an applique that has a long history and has undergone a transformation from a means of repairing clothes to a contemporary type of creativity. The possibility of using different (by colors, structures, surfaces, etc) materials for applique opens up unlimited space for the embodiment of any fantasy, and therefore it is very popular with modern fashion designers. The paper presents a result of design work for creating a collection of men's knitted cardigans with unique abstract appliques.

Key words: applique, abstractionism, knitwear, men's clothing, cardigan

INTRODUCTION

Men's fashion is no less important segment of the clothing industry than women's one. It does not exist only but also is developing every year, offering men outrageous trends and laconic things. Today`s men, despite stereotypes, spend more and more time on appearance. Men's fashion clothing gives every man the opportunity to create their own style and image. Every year designers present exclusive trends that set the rhythm and offer men the best styles that emphasize character, individuality, charisma.

The unpredictable isolation of 2020, as well as the restrictions in 2021 due to the continuous pandemic, have changed our lives in many points. Fashion has also evolved, as evidenced by the trends of the autumn-winter season. Designers are experimenting with men's wardrobes, creating for example spacious oversize coats or cozy knitwear. Thus, in men's clothing for the autumn-winter 2021/2022 season, knitted polo shirts, vests, turtlenecks with geometric and abstract prints of gray, yellow, beige colors are relevant among traditional suits (Fashionable men's clothing, 2021-2022). In the collections of the upcoming season, designers have focused on creating abstract patterns in both leisurewear and casual wear. Both monochrome patterns resembling wide brush strokes on a canvas, and color blocks of various geometrical forms are used.

Any design collection originates from an idea. Anything from nature to humans themselves can be an inspiration. Designers look for inspiration in the fine arts often. Abstraction is one of the popular trends. It is one of the currents of avant-garde art. In the early XX century, Henri Matisse and several other young artists revolutionized the Paris art world with "wild", multi-colored, expressive landscapes and figure paintings that the critics called Fauvism. With his expressive use of color and his free and imaginative drawing, Henri Matisse comes close to pure abstraction. Irrationalism, a declination from the illusory-subjective image, an absolutization of pure impression, and artist self-expression through geometric shapes, lines, colored spots are the main characteristics. The raw language of color as developed by the Fauves directly influenced another pioneer of abstraction, Wassily Kandinsky. Kazimir Malevich, Piet Mondrian, Frantisek Kupka were founders of abstraction as well.

The Ukrainian market of men's knitwear is represented by sweaters, cardigans, vests, most often plain or decorated with a colored stripe, sometimes embossed pattern, and do not always correspond to current fashion trends. The development of men's knitted cardigans that meet modern fashion trends is the main goal of this work.

THEORY

People have long created various patterns and drawings, which allowed them to decorate and diversify clothing and household items. Today a wide range of technologies, methods, and technics are used for this purpose while bright, interesting, and unique textile products are created.

The knitting allows obtaining a pattern during the manufacturing without additional technological operations. The loop is the smallest element of the pattern, so it is possible to create patterns from the smallest ones to those that mimic handwork by changing the gauge of the knitting machine and the yarn's linear density. The patterns are resistant to mechanical action and weather conditions, and their quality largely depends on the quality of raw materials. Modern knitting equipment allows creating a pattern in a certain part of the items or along its entire length (Kyzymchuk O. et al., 2021). This method is mostly used for outerwear production.

Embroidery is the oldest way to decorate textiles, which has developed and improved over the centuries. It has got special traditions and many techniques (Susak K.R., Stefiuk N.A., 2006). Today, machine embroidery is widely used in the clothes industry. Drawings and inscriptions are high-quality, clear, resistant to external influences, durable. Modern embroidery machines could be used for two stitches types: smooth and cross-stitch. This is a separate technological stage with specialized equipment, additional labor and material sources.

Color printing is usual way to decorate knitted items especially T-shirts, blouses and tops. There are number of printing methods which could be used such as block, roller, screen, and heat transfer printing. These methods are used as a separate technological stage (Sharma E., Paul S., 2015) and requires additional technological equipment as well. The pattern resistance to external influences, their durability, brightness, and color saturation depend on the printing methods. Some of them allow creating large images.

Patchwork is another of the most ancient ways of textiles finishing (Wu X. et al., 2012). It appeared due to the presence of small pieces of material during the cutting of the fabric, the combination of which created unique compositions. It involves sewing together pieces of fabric into a larger design. The larger design is usually based on repeating patterns built up with different fabric shapes. These shapes can be different colors as well. They are carefully measured and cut, basic geometric shapes making them easy to piece together. Patchwork does not cost too much, as you can use various leftover fabrics and even old things that are out of fashion. With this technique, it is possible to use a traditional cut and to apply also folklore motives.

Quilting is a much broader concept than patchwork, as it complements the patchwork with stitching. Thus, the products made in this technique always consist of several layers and have got relief. Generally, quilting includes patchwork, embroidery, and applique. The sewing techniques of piecing, appliqué, and quilting have been used for clothing in diverse parts of the world for several millennia (Deacon, D.A. and Calvin, P.E., 2014) and a wide range of quilting styles and techniques have uniquely evolved around the globe.

Applique as a technology has a long way of its development, during which it was enriched with various means of fixing on various surfaces (for example, gluing, sewing, substitution, etc.). References and encyclopedias characterize the applique as a technique of plot or ornamental compositions on paper, cardboard, canvas by gluing or sewing colorful pieces, paper, fabric, leather, and other materials that create the image conceived by the artist. The textile applique occupies a proper place among many types of decorative and applied arts (Seiler-Baldinger A., 1994). It is ornamental needlework in which pieces or patches of fabric in different shapes and patterns are sewn or stuck onto a larger piece to form a picture or pattern. It is commonly used as decoration, especially on garments. The emergence and development of this art form were initially caused by utilitarian needs such as repairing clothes, but over time applique has transformed into an exciting form of creativity (Triston J., Lombard R., 2015). The applique is sewn ornaments that were applied to individual elements of already sewn clothes. Threads, ribbons, lace, velvet, ribbons, leather, fur were used as a material for applique. In contemporary applique, the emphasis is now on surface embellishment and decoration/ Wide ranges of colours, textures and materials can be innovatively combined to create individual and personal textile artworks.

The idea of using applique for the men's clothes decoration is embodied in the Master`s thesis of Valentyna Shahman. A collection of men's cardigans has been developed, which are decorated with a stylized applique based on the painting "Upward" by W. Kandinsky (Fig. 1). The use of geometric shapes in the knitwear decoration is always a win-win situation. The pattern of geometric shapes can both emphasize a particular part of the body and hide flaws. Therefore, geometry has been and will always be the most favorite ornament for clothes decoration.

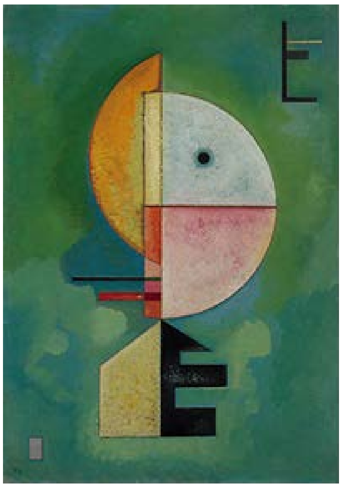


Figure 1: Wassily Kandinsky, Upward, 1929.

In general, a cardigan has the purpose of warming. Therefore, it is advisable to choose a cardigan length similar to the length of the coat or jacket. The maximum length of a classic men's cardigan can reach the middle of the thigh. Button cardigans are more of a classic style, and buttonless or/and hooded cardigans are casual. It is safe to say that a cardigan can be an integral part of a man's wardrobe.

METHODS

The applique was chosen as a decoration method for a collection of men's knitted cardigans. As mentioned above it allows creating a pattern from many parts, different by colors and textures. A unique and interesting effect can be achieved even by using textile remnants.

The invisible fleecy fabric was chosen for men`s cardigans manufacture. Invisible fleecy is a plain plated structure composed of a face and binding yarn with a fleecy backing yarn tucked into the technical back at every fourth wale to mesh only with the binding yarn (Spencer D., 2001). The face yarn prevents the arms of fleecy tuck been visible between the wales on the face, which would spoil its clean appearance. The characteristics of the fabric are given in table 1.

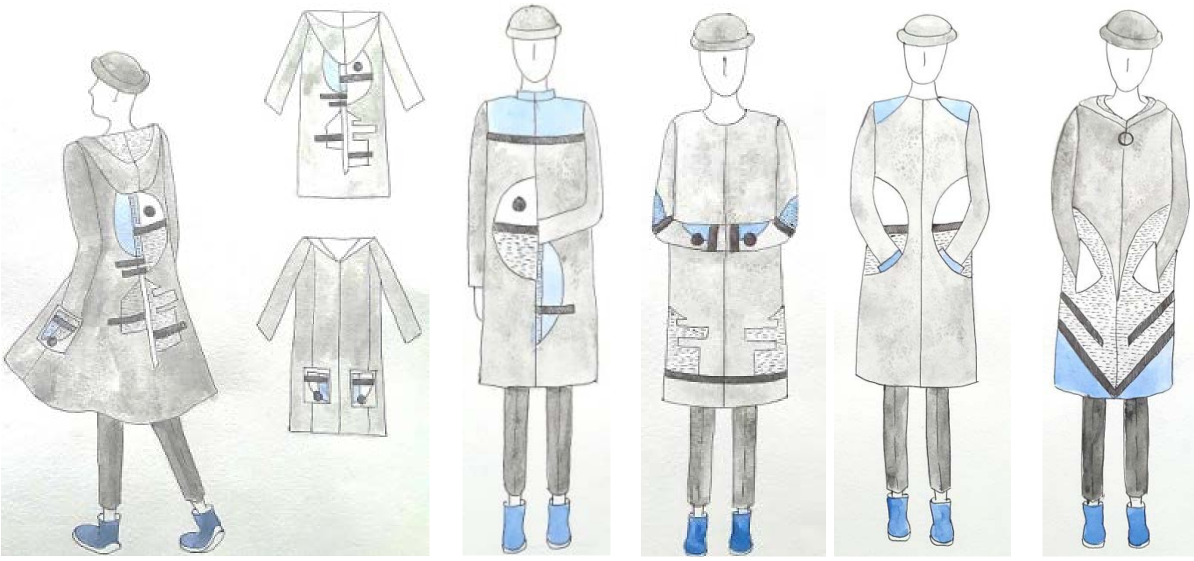
Table 1: Characteristics of knitted fabric

Interlooping	Raw composition		GSM, gr/m^2	Thickness, mm	Number per 100 mm		Shrinkage, %
	Cotton	Lycra			wales	courses	
Fleecy	95	5	260	0,70	148	218	1-2

Fleecy and plain knitted fabrics, as well as artificial leather, were used for applique.

RESULTS AND DISCUSSION

All models of the collection of men's knitted cardigans (Fig. 2) are offered with a straight silhouette without fastening - unbuttoned. A length is to the knee line, the sleeves are long. This silhouette allows creating the appliqués of different sizes: from smallest placed in different parts to those covering the whole product. The difference between the models is in the neckline design: hood, stand-up collar, without a collar; in presence or absence of pockets; in appliques shape and placement (Fig. 3): on the back or front, pockets or sleeves. A feature of the model 1 cardigan (Fig. 2.a) is the hood, which can be laid out as a shawl collar. While its front side is formed by the reverse side of the fleecy fabric different in color and texture from the main item and resonates with stylized ornaments.



a *b* *c* *d* *e*

Figure 2: Collection of men's knitted cardigans

According to Pantone, gray (Ultimate Gray) is one of the fashionable colors for 2021, so the collection is made in gray, as the most relevant in the coming season. It is symbolizing reliability, self-confidence and actions confidence. Light gray, white and blue colors are used for the appliques, which stand out and become accents on the main fabric.

Figure 3: Appliques on products

One of the most important tasks in the creation of this collection was the selection of knitted fabrics. Firstly, the main fabric must be stable, maintain its form and shape during using and not impede the movements of a potential consumer. Secondly, the fabric must have good heat properties. At the same time, the main fabric shouldn`t have reliefs at the surface, since this will interfere with the applique application. Thirdly, the fabric should not unravel easily. That is why invisible fleecy fabric with an elastomeric thread content (Table 1) was chosen as the main for the collection`s production. This is a single knitted fabric with a smooth surface on the front side. An elastomeric thread improves relaxation characteristics, namely, reducing residual deformation. In addition, the elastomeric thread increases the density of the knitted fabric, which improves the heat properties and reduces the unraveling. This fabric has got different textures and colors at the front and back fabric`s sides. This allows creating an additional decorative and color effect for example at the cardigan`s hood. In addition, decorative effects on the front parts of models 4 and 5 are also made through the use of the backside of knitted fabric.

The creation of the applique also deserves special attention. Its elements for different models have different sizes and complex shapes, and sections of applique details are placed not only along with courses and wales but also diagonally to them. It should be noted that knitted fabric is more stretchable compared to woven fabrics and areas with overstretched seams may appear during sewing on appliqué details. In addition, another problem arose during applique application, namely delamination and displacement of the backing yarn on the backside of the fabric. Two solutions were proposed to solve problems:

1. to use a doublerin for both applique details and product parts where applique will be placed but it significantly increases the rigidity of the product;
2. to use the third layer - thin non-woven fabric, which is sewn to the main fabric from the product inside in the places where the applique will be placed.

The men`s cardigans are decorated with stylized appliqué placed at different parts, that is, depending on the position, it could have different extensibility, during use. That is, the method of the applique attaching must provide good stretchability. Since these products are the subject for individual manufacturing, it is recommended to use the second method: to lay the non-woven fabric on the backside of the product part, and then after applique sewing to remove (to cut) it along the edges and, if possible, between the seams.

CONCLUSION

The creativity of a new range of products actuals not only for women's fashion. Every day, men are increasingly looking at new trends and demanding non-standard clothing solutions. For this purpose, the idea of creating the men's knitted cardigans of small batches, decorated with applique, is proposed. It allows the use of small pieces of cloth as well as inter-pattern waste of mass production. This work offers a collection of men's knitted cardigans decorated with appliques in the abstract style, inspired by W. Kandinsky's work. The main tasks solved during the development of the collection are the materials choice and the method of fastening the applique elements.

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HISTORY OF SCARVES IN THE 20TH CENTURY AND HER ROLE IN CONTEMPORARY CLOTHING

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ABSTRACT

The analyzed role of the headscarf, as a simple piece of fabric that has survived throughout the history of humanity, providing countless combinations and possibilities for wearing. In the social sphere, the role of the headscarf has changed slightly. It has never been neglected by design houses. Textile history provide us with editions of trends, current colors and materials. In the aesthetic sense, it gives us a creative approach in finishing the everyday look. Her simplicity in form is an advantage for obtaining complex shapes. Multifunctionality enabled her to survive on all levels throughout the history. Fashion on the scarf absorbed everything around it, customs, traditions, art and culture, style and identity.

Key words: scarf, history of the headscarf, style, globalization

INTRODUCTION

Today, the scarf is much more than a decorative textile detail. The way we tie it, wear it, the unlimited variations of colors, sizes, ornamentation, shape, style provides an opportunity to express our creativity, uniqueness or conservatism in clothing. Today, the scarf describes the style, a textile product that primarily reveals and emphasizes the attitude of the person wearing it. It can easily give a little formality and elegance to a casual look, but it can send a serious political message, mark social status or note the affiliation to a certain subcultural group ...

The headscarf is one of the rare clothing elements that reaches far from the beginning of the history of costumes and as such is an important document of every historical chapter. It changed its shape, texture, composition, colors, and yet it has survived to this day as a unique companion of style. Today, in the 21st century, it is a symbol of status, a refined element of elegance and a sign of belonging that explains the social and aesthetic criteria of a group or individuals. It is of great importance in the sociological, religious, ethnological, historical and especially in the psychological aspect of women's and men's clothing around the world. From the aspect of fashion design, the scarf has the power of details that should complement and strengthen the aesthetic component of the suit, but also to achieve the functionality necessary in modern clothing. Modern society can rightly be said to be a fashion society. Therefore, fashion as a mass social phenomenon is imposed on researchers of social life to explore it within the framework of culture and to build special theoretical concepts for its most adequate explanation.

What separates it from other accessories such as hats and caps is its multi-purpose use and transformation from one shape to another. It is this multifunctionality and ability to be easily repurposed from head to neck, from neck to shoulders and other parts of the body, that is the key to her durability and longevity. Her original role was primarily protection, to protect her head and face from adverse weather conditions, such as wind, rain and strong sun. On the other hand, from a religious and conservative point of view on the position of women in the community, she has the role of concealing and shielding a woman's face from undesirable views. To subdue a woman and make her humble. In the aesthetic sense, the scarf emphasizes the creativity of the individual and complements the clothing form with ornamentation, print, color or choice of material and manner of wearing. It descended from the head to the neck, then to the chest, worn like various robes, belts, bags, bundles around the waist like an apron, skirt, etc.

Scarf as an obligatory, lucrative accessory that becomes a design challenge and a "painting canvas" applied in the sense of clothing. It is a regular, richly illustrated companion of the collection, easily adaptable to the onslaught of modern fashion trends and never loses it’s popularity.

Scarves are a good communicator in the modern world where the media play a significant role, participating in a dizzying change of trends and messages. It is often used as propaganda material to promote various social movements, airlines, companies, banks, religious communities, as part of the school uniform. It is a powerful tool in the world of advertising, because it’s simplicity is hers advantage.

Scarf as a fashion accessory of the XX century in women's fashion

In the first decades of the twentieth century, the headscarf continued its journey through fashion styles. Women's suit becomes more natural, more relaxed, more comfortable and no longer tight. Despite the upcoming climate, women of the first years of the twentieth century find it difficult to separate themselves from corsets. The Bell Epoque period, with which we begin the historical exploration of the headscarf, and all possible variations of this fashion detail, retained the so-called "healthy corset" until 1910. With the "S" silhouette, layers of lace, embroidery and muslin, the scarf is spontaneously tied in a bow on a hat, worn over the shoulders and around the neck. The wide brims of the hat were complemented by rich folds of draped velvet and plush. Satin bows would be tied on straw hats, which were a favorite decoration among women. Bows were often defined by wire, so as not to "fall" when worn.

In the first years of the 20th century, women became more and more involved in sports, and competed with men in many disciplines. While driving the first cars, which were open, like cabriolet, suits for men and women were created. They were practical, and with the aim of protecting the driver from wind, rain, sun, various gases, etc. Female riders would usually wear a large breathable scarf, like a veil, that would be put on a fashionable hat during the day.[1] Women would wear glasses while driving.

Figure 1. Wearing scarves and shawls in the first decade of the twentieth century

Since 1910, there has been a mass liberation of the female body of rigid form and long twists. Corsets have gone into complete oblivion, offering greater freedom of movement. Women became more independent, the first fashion names appeared, so more and more designers began to participate in the fashion game. The French designer, known for the luxurious exoticism of Paul Poirier[2], subtly introduces elements of the orient into women's wardrobe, such as wide sleeves, kimono dresses, harem pants and long tunics. With the new style of clothing, the scarf has been transformed into a turban, which is an indispensable fashion accessory with the newly created oriental style.

Favorite designs created under the new influence are a stylized beam, feathers, white heron, etc.[3]
Figure 2 shows models of various headgear, such as hats, turbans and veils, which were gladly worn in the first two decades of the twentieth century.

During the First World War from 1914-1918. which has taken over the whole world, the space of entertainment is narrowing, the clothes have changed significantly. There were significant social, economic and political changes, women took over men's jobs and changed them in jobs they had not been in before.

War, haste and poverty have made wearing trousers popular among women, lace and silk have been replaced by cotton and wool, and luxury has subsided. It was rude indecent not to show solidarity with the sufferings of the people. This time, the scarf was given the main role in protecting the hair. Everyone wears it, nurses wear a headscarf-like scarf, and women in factories wear one type of turban.

Figure 3 shows Red Cross nurses during the First World War.

Figure 2. 1900-1920. Scarf, veil and turban

After the war years, during the second decade, women's skirts became narrower, shorter, and fashion adapted to a new lifestyle. Women are no longer a decoration for salons, they need activities and they want clothes in which they can easily move and play. Boys' silhouettes, straight lines, without emphasizing curves, were accepted by women of all social strata. The neckline for evening outings became narrower and longer, the silhouette was elongated with a low waist. Small square cotton scarves worn around the neck contributed to softening this contrast, in order to preserve modesty in ladies.[4] Although hats are still popular among the older generations of women, younger women prefer ribbons, scarves, bandana, and even luxurious combs, ostrich feathers and evening gowns. Bandana is a way of tying a scarf on the head, popular all over the world.


Figure 3. World War I - Red Cross nurses

In the twenties of the twentieth century, the headscarf is long, rectangular, worn like a scarf, like a ribbon around the head, like a detail around a belt that falls freely on the hips. Figure 4 shows wearing a scarf in several ways. It is like a long scarf loosely tied around the neck, while in the picture on the right we have a classic clothing combination of black and gold with a scarf tied on the head in a bandana.[5]

Figure 4. 1910.-1920.

Hers popularity has been significantly contributed by the film and music industry, jazz is listened to, it has been praised by players, dancers, Latino players and other artists. With reduced glamor, Coco Chanel achieved softness in the silhouette, emphasizing comfort and convenience in the foreground. The colorfulness of the twenties subsides with the arrival of the elegant thirties. Changes in modern industrial society were felt in all layers. This has led to the availability of fashion, regardless of profession and class. One of the novelties in the field of textiles is the appearance of new synthetic fibers, such as the rayon. It was one of the first artificial materials, which was used as a cheap alternative to silk. Scarves were made of cheaper fabrics, which were tied in a triangle on the neck, which is still one of the most common ways of wearing a scarf. Favorite motifs were like various polka dots and simple geometric solutions. Hermes is launching today's famous 36-inch square silk scarves with a horse print in 1937, on the occasion of the centenary of the opening of the first store. These scarves will become a status symbol among many conservative fashion companions including Queen Elizabeth II.[6] In the evening gowns, the women looked like Greek caryatids, with long and wide silk scarves wrapping around their arms behind their backs. Fringed muslin scarves and shawls were sewn with tassels or feathers at the edges, which was a luxurious detail along with ostrich feather fans.

The 1940s resulted in depression and the war years, which significantly affected all social spheres. It was considered indecent and distasteful to appear in clothes made of expensive and fine materials. The devastation and depression of the Second World War left consequences on the whole world and on fashion. Clothes became narrower and shorter, material was saved, and for these reasons the cuts became more reduced, more modest and freer of luxury accessories. Silk scarves have been replaced by cotton and synthetic fibers. National colors were forced, and prints with political symbols and patriotic messages were often decorated. In France, the favorite scarves with the image of Marshal Peten and other state symbols of New France. The new fashion is published by French magazines such as "*L'Officiel de la mode de Paris*" from 1941. These were scarves with a typewriter print bearing the message "Holy love of your country" and "Long live France!" [7]

The headscarf was worn more for practical than aesthetic reasons, as in the First World War. It was worn on the head and neck; the hair was shortened and there were no more curls. Turbans were a favorite on both day and evening occasions. They ideally covered the hair, the hairstyle did not matter, because they did not take off indoors, unlike hats. The film industry developed rapidly and was used as a powerful

propaganda tool during the Second World War. In America after the 1945-50 war twenty million people went to the cinema during the week, which gives us an idea of what a powerful influence and mechanism it is. Actresses of that time like Lauren Bacall, Ingrid Bergman, Rita Hayworth[8] were the main fashion role models for many women around the world. Music, the popularity of sports, trends in art and the influences of design in all areas also had a great influence. In the late forties, pin-up girls and Hollywood actresses became the face of cosmetic companies, their faces are present on various products. Photographs of them in bold poses on the beach in a bathing suit became a phenomenon of that time and their influence on women around the world was global. Glamor also settled on the beach, which brought the scarf into a new dimension. A large square scarf like a sarong and a pare has become an indispensable companion for bikinis.[9]

Jacqmar was a famous scarf company founded in 1932. “The firm was established by Joseph “Jack” Lyons with his wife Mary. The company had offices and a showroom at 16 Grosvenor Street in London’s Mayfair. The founders had, typically, “Frenchified” their names from Jack and Mary to create a sense of glamour suited to a high-class Mayfair fashion house. An advertisement for Jacqmar from VOGUE announces their “Spring 1942 Collection” and places their silk and tweed products as an alternative to the French designs that were no longer internationally available”[10]

Figure 5. Forties, turbans

During the 1950s, there was a serious economic recovery. Technological progress after the war became an imperative of the new age. The divas of this period, Marilyn Monroe, Audrey Hepburn, Elizabeth Taylor from the movie screen, influence millions of women around the world. Femininity returns to the big door again. Silk scarves gained notoriety and soon became a symbol of glamour, power and independence. In the words of Audrey Hepburn below 'When I wear a silk scarf I never feel so definitely like a woman, a beautiful woman.' Dior is creating a “New look”, a novelty that needed to erase the war drama and bring elegance and sophistication to the female silhouette.[11]

The automotive industry is gaining momentum and is very important for creating a personal style and popularizing the scarf. Scenes from movies in which enchanting actresses ride in convertibles with a silk scarf wrapped around their heads and big glasses have become a stereotype. Many fashion houses have aspired to creative graphic solutions on scarves, as an easy symbol of luxury and wealth. If it was impossible to buy a Dior dress, maybe buying a scarf could still achieve a bit of that luxury.

Cosmetic companies are often using their products as an aid to propaganda. The emergence of subcultures and anti-fashion in those years represents a new conception of fashion in general.

America's first lady, Jacqueline Kennedy, wore a headscarf with refined lines of dresses and coats, and her influence on women around the world was very significant. Phenomena in culture and art encouraged the creation of new styles in fashion in the 1960s.New social changes are taking place, which have especially affected the lifestyle of young people. This is a decade of new rhythms in music, the emergence of rock and roll, hippie style, sexual revolution, fashion designers and more. The female figure changes significantly, the body is slimmer and the clothes become shorter and narrower. The body is more revealing, wearing an "A" silhouette and very short skirts with the appearance of a mini length. There is a lot of experimentation with materials such as PVC and metallic fabrics, shiny nylons, lame. Small square scarves are worn around the neck or as a headband. Interesting textile designs inspired by the new social order come to the fore. Pete Mondrian, pop art, op art and other artistic directions have an aesthetic impact on the artistic design of scarves and shawls, textiles in general. The combination of pop culture and mass consumer culture takes us to decades where it is difficult to define a fashion style.

The seventies are famous for flower children, Hendrix, protests about Vietnam, punk music, bra rejection, LSD and other social phenomena. A strong floral influence came from the East, reflecting on the hippie fashion that the period. The hippie subculture was identified through a headscarf that they would like to tie around their head. Maxi fashion was a synthesis of colorful, patchwork skirts, gypsy style and long scarves that reached the platform. In the 1970s, all this would be framed by a large rustic, knitted triangle scarf, like a cloak. Crocheted and knitted kaftans and ponchos are worn with long skirts. This style is known as "Granny look" or grandma's style. Scarves are becoming an interesting social document of history.

The spirit of apostasy, characteristic of bohemia, the spirit of social exclusivity, which marked the phenomenon of dandies, was renovated in the seventies of the twentieth century, when, after the concept of flower children and their features - from leveling gender differences to ideology of disorder led to accentuating luxury as fashion details. This opened the door to scarves and enthroned them in the following years on the fashion platform.

In addition to floral, zoomorphic and geometric motifs from traditional Indian heritage, there has been a creative release when it comes to textile design. Designer Carol Osten[12] said: "The farther we can see, the more we will have a mixture of relaxation, fluidity and fantasy on textiles." Just a mix of different styles, experiments of the hitherto incompatible are coming to the fashion scene. During the Art Nouveau period, floral motifs stood out, while in the Cubist phase, geometric prints predominated. Fauvists, Futurists, Surrealists and other painters had a strong influence on textile design, which was also reflected in the design of scarves. As we approached the end of the century, the style of dress became more reduced, cleaner in the pursuit of a calmer atmosphere. Scarves, as a document of that time, were often one-color or with reduced graphics in the form of a logo of a certain company.

The eighties of the XX century are a decade in which luxury was placed through expensive pieces of clothing, fur coats, silk blouses, crocodile bags and on the other hand the emergence of street style where there is a style chaos. The hair was full of volume, richly soaked and for these reasons was not covered with a headscarf. It is worn on the neck, posing to see its full color, brand logo and the like. At the beginning of the eighties, turbans were worn again, which were formed from one or more scarves. Pop music dominates and has a great effect on the masses. Madonna, with her silly style, launched a trend that is copied by young women around the world who flirt with Christian elements. In addition to crosses, colorful bracelets, messy, taped hair on her head, a scarf is tied in a bow. Clothing is free of moral codes, which liberalizes women and personalizes them in an erotic sense.

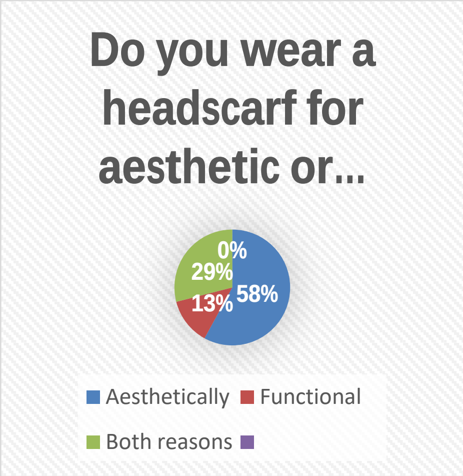
At the end of the twentieth century, with the emergence of new fashion styles such as: gothic, Lolita, new romance, hip-hop, rave, rock, grunge, sports and many others, there was a change in the approach and understanding of fashion.

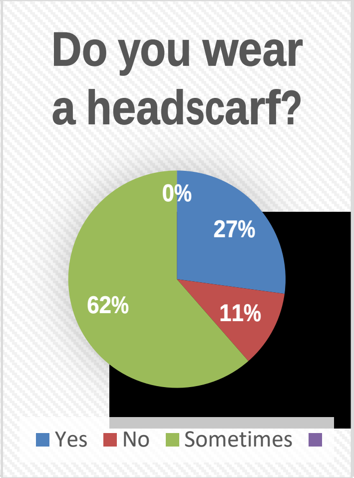
She experienced countless variations during the 1990s, which led her to the minimalist concept. For each of the mentioned fashion trends, the scarf has found its application, somewhere less, somewhere more. I would cite as an example in the rock manner the appearance of Axel Rose was unthinkable without a cotton scarf tied around his head. Silk scarves fell out of favor during the 90s and people flocked to buy accessories that were innovative and striking. This elegant, stylish accessory was no longer the must-have item in the woman’s wardrobe and soon disappeared from the spotlight. In the romantic edition, it is swaying, pastel with a floral print and tied at the hips or optionally released around the neck. Designer houses always try to make a collection of interesting accessories in their collections, such as scarves, shawls, jewelry ... The scarf is either a large square, like a long scarf, a thin scarf, a triangle with fringes, it is up to us to accept it as accomplices of new trends, with the help of which our clothes are always more interesting. Scarves have reached such a saturation and acceptance point that fashion companies, from Dolce & Gabbana to Dior, are now including them in their collections and advertising campaigns, signaling recognition of the purchasing power of scarf-wearing communities around the world.

The role and application of scarves in modern clothing

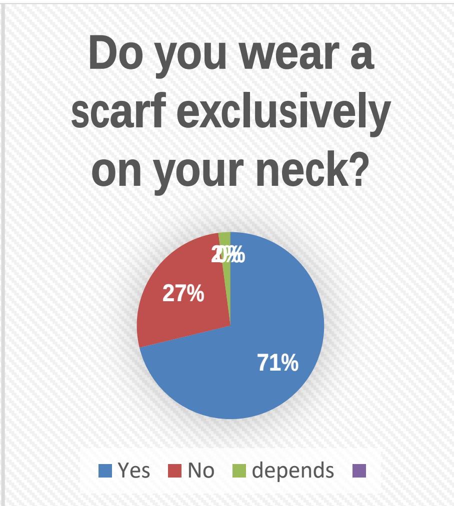
In the 21st century, the headscarf has become an indispensable clothing detail that can be worn either on the neck, around the head or at the waist. While during the Victorian period it was a symbol of luxury, today it is present and available as a new model of social communication. This geometric detail became a symbol of status recognition and a kind of social grouping. This commodification of the headscarf is perhaps most interesting in France. Since 1989, when a principal told three Muslim teenagers they wouldn’t be allowed at their high school if they didn’t unveil, the French government has had an increasingly fraught relationship with the headscarf. A memorandum was issued in 1994, noting the difference between “discreet” and “ostentatious” religious symbols in schools, with the hijab falling in the latter category and thus being considered off limits. Hundreds of French students who wore them were suspended over the years.[12]

Analyzing a group of 70 women, I came to the conclusion that the headscarf is an accessory that is worn mostly for aesthetic reasons. It is not an everyday fashion detail for the younger population of women. Most of them will mostly wear it tied around their necks. Quality of workmanship, raw material composition and design are more important than the brand and the name of the manufacturer. For religious purposes, it is worn in the Christian community only occasionally, during the stay in the church.





Today, the headscarf is a personal creation of each individual, because its versatility lies precisely in hers form. A square of canvas without buttons and zippers is an open space for various games on the body. Whether it is wrapped around the neck, slung over the shoulder or used as a belt around the waist, it will suit the purpose. Crossed over the arms, the rectangular scarf was supposed to be in line with the body. The ratio of proportions is very important when wearing, so that the ends that fall freely from the sides are in line with the height of the body. Also, if you were wearing a scarf around your neck, you had to take into account the size itself, so that there was not too much or too little material. The favorite style of the rich aristocracy is a triangular scarf draped over the back.



This model of scarf is very gladly worn even among the middle class. The lower strata of citizens and those from rural areas preferred a square scarf. the triangular scarf, thanks to its elegant shape, performed its function and subtly fell down its back. It would usually reach from the middle of the back to the knees, wrapping the figure completely. In addition to these few ways, it is very often worn among women from the Orient. In India, a large square scarf is folded into a triangle and broken diagonally. The ends are connected in several ways and it is typical among middle class women in all strata of the population, because it gives her the opportunity to cover herself.

The scarf is suitable for wearing in all weather conditions, whether it is summer or winter. Sometimes that extra layer is enough to keep us warm, when it's cold or protect us from the sun on hot summer days. Materials and making scarves would depend on the price that could be afforded. It could be an artistic masterpiece, a detail or a warm wrapper on cold days.

CONCLUSION

Changes in the 20th century are taking place rapidly at all levels of society, bringing democratization in clothing and erasing gender and class differences. The wealthy and the upper bourgeoisie, wearing the headscarf, used the opportunity to emphasize their financial situation once again. Small series of big fashion names are ideal for promoting personal status. Scarf is a great detail, like rare fur, handbags ... Women used to dress scarf to blend in in a corporate environment. Now they don’t feel the need to disguise or conceal their femininity anymore. Such scarves, in addition to silk or cashmere, would be woven with pearls, rare stones, hand embroidery, fringe, fine texture, weaving and everything that could make it special. Scarves like this stand the test of time, are worn for decades and are never thrown away. Today, fashion rules have changed, so we don't pay much attention to harmonizing materials, styles and colors. In the past, lace scarves were worn exclusively with long dresses, while modern women today wear them in various combinations from daytime jeans and evening gowns. Every individual participates in the creation of fashion, but fashion contributes to the development of each individual's personality.

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CAMBODIAN SILK

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ABSTRACT

Cambodia is a country in Southeast Asia with a long history of great culture and tradition. Weaving is a Khmer craft that has existed since the Funan period. Clothes made from silk include hol, phamuong, chorabab, and sarong sotr; these traditional Khmer clothes have long been used by ordinary people, low and high-ranking officials and the king. Although today there are many modern clothes imported from foreign countries or produced locally, hol, phamung, and chorabab are still popular in wedding ceremonies, traditional festivals and royal ceremonies and they are presented in this paper.

Key words: silk, hol, phamung, chorabab

Introduction

Cambodia is a country in Southeast Asia with a long history of great culture and tradition. Weaving is a Khmer craft that has existed since the Funan period. However, some researchers have said that the Khmer could produce silk product with different decorative patterns, such as Iboek prealeat , anglougn (Checkered cloth), kroma, (scarf), sarong sotr, chorabab,soeung, hol, phamoung, pidan (used in Buddhist ceremonies) in magnificent colors, which were extracted from trees and other materials. [For a long time] people have been using these types of materials for clothes and in decorations because of their glorious natural colors. This craft [weaving] is clearly apparent on the artistic skirts of the Apsara on the walls of Angkor Wat and other temples in the wonderful territory of the Kingdom of Cambodia.

Clothes made from silk include hol, phamuong, chorabab, and sarong sotr; these traditional Khmer clothes have long been used by ordinary people, low and high-ranking officials and the king. Although today there are many modern clothes imported from foreign countries or produced locally, hol, phamung, and chorabab are still popular in wedding ceremonies, traditional festivals and royal ceremonies.

What are the processes of weaving and natural dyeing? In fact, it is a very hard work to weave hol, phamuong, sarong sort, chorabab to produce one skirt or one kbin for clothing or Khmer-style decorations for places organized to attract foreign tourists. It costs craftsmen not only money to buy the silk but also mental effort and talent. However hard it is, they work on it with diligence.

We believe that result of research on natural dyeing is vital proof to show different patterns of silk weaving and natural dyeing to all Khmer people who wish to operate business in Khmer silk products made from natural dyeing but serves as a document to preserve Khmer traditions and customs for the next generation.

History of Silk in Cambodia

The silk industry started in Cambodia during the 13th century, then known as the Khmer Empire. Chinese diplomats Zhou Daguan visited the region at that time and reported the beginning of silk activities. Those developed along the Mekong and Bassac River in the south of Phnom Penh with mulberry plants to breed silk worms. The bas-reliefs of Angkor Wat and Bayon reflect these changes as Apsaras costumes display geometrical patterns similar to the Indian Ikat technique named Patola. From the 19th century until the 1970s, the weaving technique developed and the industry spread to the Tonle Sap, the largest lake in Southeast Asia, and to settlements such as Battambang and Siem Reap. As the skills had evolved, Cambodian Ikat, the dyeing technique to produce unique patterns, gained universal recognition in the 19th century. Around a quarter of families lived thanks to silk production at that time.

From the 1970’s, the silk industry was disrupted under the Khmer Rouge regime which almost destroyed the industry. They strictly limited colored clothing and imposed black pajamas for the population. The Vietnamese intervention in 1979 did not benefit the silk industry which slowly recovered only after the 1993’s transitional government.

Hol

*Keidh i*s a skein of silk which weavers tie for dyeing, in English called *ikat.* Khmer weavers have their own special technique to do that. White *keidh* was first dye with red, then with yellow and lastly with blue.

To tie the *kiedh* we use young banana sheath, but today is has been replaced by nylon. There are some organizations still preserving this technique, for example the institute for Traditional Khmer Textile located in Siem Reap. According to Khmer superstition, people believe this kind of banana trees cannot be planted near their houses.

There are many patterns of hol in Khmer tradition, which were created by weaver from generation to generation. Through the interviews with old weavers, we found that in the past, to produce one *kben* of *hol*, they had to spend at least three months to complete the work. This takes a long because they need to feed cocoons pattern were bigger than those of today, such as *phnek Ko* (cow eyes), *klim chan*, double lines…etc.
To get a high quality of *hol*, the weaver needs to have rich experience and diligence, and take great care.

Phamuong

Phamuong is a kind of Khmer weaving product that has many colors, as required by users, but generally has only one color per piece. We remember that recently Phamuong Kor Tea (the color is similar to the color of a duck’s neck) has been very well known.

Weavers use at least three thkor or more if that phamuong has a pattern or hem decoration. In Koh Dach, weavers use up to 30thkor for one called phamuong tbong pich (diamond phamuong), which has now become popular.

ផាមួងសរជើងក្បាច់អង្គរ
Hem of Phamuong, Angkor pattern

Chorabab

Nowadays, chorabab is only produces in Khsach Kandal district, Kandal province. People use chorabab in wedding and blessing ceremonies. The way to produce chorabab is similar to how to make hol and phamuong. There is a kind of cloth similar pattern s such as kantout flower, chan flower, and diamond. There is a kind of cloth similar to Chorabab called lboek. Lboek is different from chorabab because chorabab use sesoy to show up the pattern or flowers, but lboek uses silk instead. Weavers use a lot of thkor to produce chorabab; in some case they use sixty thkor.

ចរបាប់ផ្កាច័ន្ទ
Corabab Phka Chan

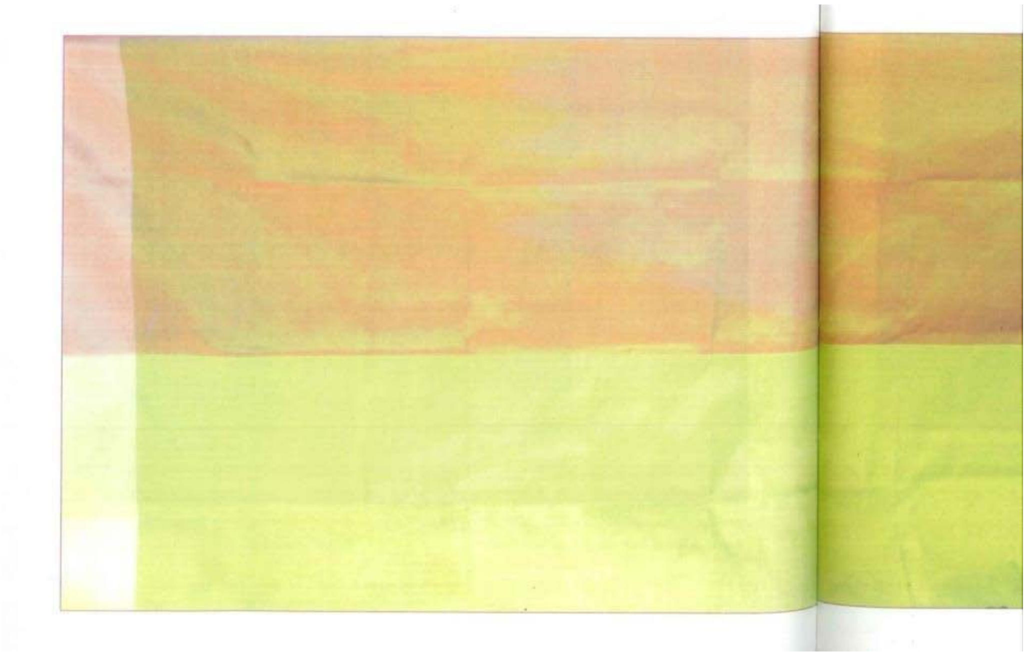
Sarong Sotr

Khmer Muslim likes to use and wear it not only at home but also in big ceremonies. The pattern of sarong is not complicated and has a few models like dom ach cvea, which is quite well-known and sarong sotr.

គោម ដុំអាចម៍ជ្វា សារុង មកពីព្រែកចង្ក្រាន
Kom Dom Ach Jvea from Prek Changkran

Scarf

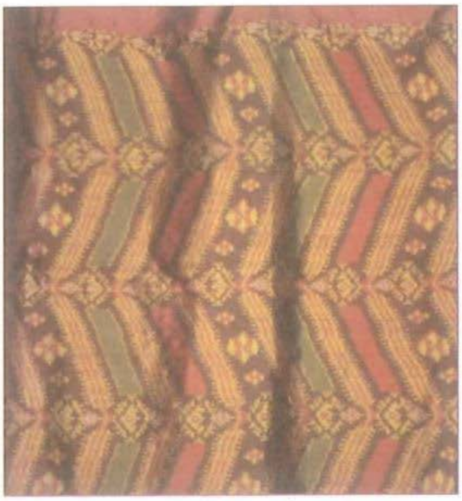
Every person has at least one scarf (*krama*). We mostly use scarves made from cotton and cotton-silk (more expensive). It is a part of Khmer tradition.



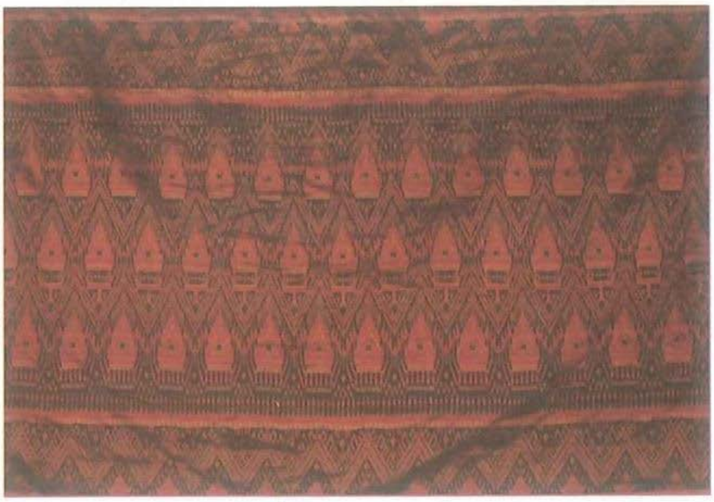
Pidan and Roneang

This is used only in Buddhist ceremonies. The pattern on pidan illustrates the life of Buddha, nature, flowers, animals an Apsara.

The way to produce pidan or roneang is almost the same as the way we make hol because the silk has to be tied and dyed. It is currently only produced in Bati district, Takeo province.



ពិដានមានរូបនាគយកពីខេត្តសៀមរាប
Picture of naga from Siem Reap



ពិដានរូបប្រាសាទនេះមានដាក់តាំងនៅអង្គការគាំពារកុមារខ្មែរខេត្តតាកែវ
Pidan at CYK, Bati district, Takeo province

ពិដាននិយាយអំពីការចេញផ្នួសរបស់ព្រះពុទ្ធនេះមានដាក់តាំងនៅអង្គការគាំពារកុមារខ្មែរ ខេត្តតាកែវ
Pidan at CYK, Bati district, Takeo province

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„ PLAGUE “ MASK AS PART OF THE COMPOSITION OF THE CLOTHING FORM

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ABSTRACT:

The plague (pestis, bubonic plague, black death, Yersinia pestis, plague) from history represents the most deadly contagion that has ever affected human civilization. Doctors were constantly looking for answers and a cure for this deadly disease in order to make vaccines and prevent further spread of the then pandemic. Only later did doctors against the plague wear special uniforms invented by Dr. Charles de Lorme in 1630, which included a cover made of wax cloth, masks with glass openings for the eyes and nose in the shape of a beak filled with herbs, straw and spices. Doctors also wore a stick to examine the patient so as not to touch them with their hands and thus come into contact. It was believed that this suit was enough to protect doctors while caring for patients.

Key words: plague, doctor, costume, mask

INTRODUCTION

History has shown that various infectious diseases occur sporadically, and cause great danger to humanity itself. Man has long been looking for a way to protect and defend himself from such enemies. Today, when the corona changes the history of mankind, the mask is imposed on man as the basic means of protection. The plague, as the forerunner of today's epidemic, has greatly contributed to the change of man and the perception of things in a new way.

Plague is a severe infectious disease caused by the bacterium Yersinia pestis, or an organism that lives in the parasite Xenopsylla cheopis, a fly parasite (flea) that is the main vector of infection, not the black rat as previously thought. Because fleas primarily attack rodents, mice and especially rats, and for that reason, these animals are also connected with the spread of this pandemic. Today we know the fact that when the climatic conditions changed, there was an increase in the population of rats, and therefore the fleas that are their parasites, while as the temperature decreased, the number of rats would also decrease, but fleas found new hosts such as common mice, marmots or squirrels. All these animals had to cross their paths with other animals at one point, which is logical, and in that way the plague got its means of transportation.

Like any deadly disease, the plague posed a danger to humanity. She pointed to great social changes, which are also seen through the aspect of fashion and clothing. In this paper analyzes the costume patented by Charles de Lorme and presents a collection inspired by a mask used during the plague, adapted to the theme and modernized with additional elements inspired by crinolines from 19th century. The collection was made as a theme of the my final work and due to the above specifics is called "Deprived of liberty".

THE SIGNIFICANCE OF THE COSTUME AND ITS ROLE DURING THE PLAGUE PANDEMIC

The plague doctor's costume was clothing worn by the plague doctor to protect against the possibility of contracting a plague disease that was thought to be airborne at the time. The costume dates from the 17th century, and consisted of a long coat a wax-coated which was paired with boots, a shirt with a hood, a hat and goatskin gloves, a hat with a wide brim. It also meant a stick with which the victims turned and the main part of the mentioned uniform - a mask in the shape of a bird's beak filled with fragrant things (often lavender), sweet substances, pumpkin seeds, various plants and they are in fact acted as a filter that they believed purified the air before doctors inhaled it.

The mask had glass openings for the eyes and a rounded beak, as in birds up to half a meter long, and it also contained small openings that represented the nostrils for the flow of air. The beak was triangular in shape and hollow on the inside, and it is no coincidence that in practice it was filled with sweet or strong-smelling substances - amber, lemon balm, mint, camphor, cloves, opium tincture and the like. The original purpose of this mask was to protect against bad air, which at that time was considered to be the cause and transmitter of the disease. Namely, the stench that spread around the sick was also considered a carrier of the plague. Doctors believed that strong perfumes could prevent infection. The plants housed in the beak of the mask acted as a kind of, believing at the time, filter that purified the air before the doctors inhaled it. De Lorme believed that the length of the beak gave enough time for the mixture to "kill" the plague before it reached the nostrils.

The protective suit was composed of a coat of heavy fabrics, most often leather, covered with wax and covered from head to toe so that the air could not reach them. The suit also consisted of gloves, boots, a hat and a cane. The hat was not really a part of the costume, it was more a symbol of the position of the doctor as a doctor. The wooden stick was worn by doctors to communicate with patients and was used to examine patients without touching them, and occasionally to drive away the desperate and aggressive ones. According to other reports, patients believed that the plague was in fact a punishment from God and often asked the plague doctor to whip them in repentance. The costume of this type was first used in Paris, but soon after throughout Europe.

Figure 1. Old Doctor Plague Ilsustrations

Based on the idea that the disease is transmitted by air or physical contact with the patient or his clothes and bedding, the smartest costume of the Middle Ages was created - the costume of the plague doctor. In order to visit sick people during the plague, doctors had to wear special clothes that were actually the result of a combination of healthy things from the population of epidemiology and prejudice.

In addition to the very recognizable mask in the shape of a bird's beak, the doctor's costume during the plague also contained the following segments:

Black coat - It was worn for a simple reason, they tried to reduce contact with the patient's infected body. Also, that shapeless black coat, which was usually made of heavy materials (such as leather), hid the fact that the doctor's whole body was smeared with wax or ointment as you created, so to speak, a layer between the virus and the doctor.

Leather pants - These pants are worn mainly by fishermen and firefighters so that water does not get inside, and the leather pants of medieval doctors protected the limbs and genitals from infection. Of course, everything there was coated with wax and grease.

Hat - In the 14th century, the doctor was easily recognizable by his wide-brimmed black hat. Allegedly, the hat also had a protective role, it was believed that a wide-brimmed hat protected doctors from bacteria but it actually represented the status of a doctor.. The rich doctors wore the aforementioned wide-brimmed hat that was supposed to ward off the spirit of illness, and the poor wore a narrow hood that pressed the mask tightly to his head. They also wore a special cloth under their hats to protect exposed areas of skin, and it had a hood-like appearance.

Wooden stick - Without this important piece of clothing, no doctor would go out on the streets of a city full of corpses. With him, the dead bodies were moved and their patients were examined without contact. They used a stick to show the Mortus where to drag the dead bodies, they used a stick to check if the person was alive or dead. If the patient showed any signs of life, they tried to treat him, but if not, they would take him to one of the hundred piles and mercilessly burn him on the street. The sky above the city was filled with the stinking smoke of burning human bodies. The incense was held in the head by a stick that was supposed to ward off evil spirits.

Leather gloves - Like the whole plague doctor's suit, the gloves were made of leather and an integral part of every doctor's uniform. They complemented the costume so that the virus would not reach the skin in the area of the hands, and they closed the coat that ended at the wrist and which mostly fit into them.

Boots - They were also made of leather and complemented the overall look of the costume.

Each part of the costume was believed to play an important role. Although doctors did not know how to do more harm than good. Namely, these clothes, or rather the coat they wore, infected more and more people, because the clothes can temporarily protect them from infection, but it also becomes a source of infection over time. Many doctors lost their lives because they became infected while taking off their uniforms.

Figure 2. Plague Doctor Costume Segments

THE IDEAL OF ONE ERA – CRINOLINE

No item of clothing, no skirt in the history of fashion has been as interesting and as unusual as a crinoline. It marks the 19th century and thanks to its appearance, women no longer had to wear multi-layered petticoats, but because of them, long linen underpants became an integral part of underwear. Someone's help was needed to put on the dress over the crinoline. A light linen dress, a corset and open underwear with a petticoat were worn under a frame of steel springs and straps. The dress was then worn over the head. The lower hoops were covered so that the women would not get caught in the open hoop and stumble.[6]

The crinoline (also known as the Victorian crinoline) had its predecessors in the form of a fartindel (one hoop at the height of the hips) from the 16th and 17th centuries and panir (extended hips) from the 18th century. It developed in several stages and the methods of making it were different. The word "crinoline" originally means a stiff linen or cotton petticoat woven with horsehair. This petticoat first appeared in fashion in the 1930s, when Victorian dresses began to grow in width, but in order to achieve the desired volume of the skirt, it was necessary to wear more than six other starched petticoats over this crinoline. All that together was very hard, bulky, and unbearably hot in the summer.[7]

The construction of the crinoline was a wire-like basket or some kind of cage that was worn under the skirt and layers of petticoats. I don't think it's necessary to say how difficult it was to move around, sit and live at all. It has not been easy for women throughout the history of clothing, and when viewed from the modern side, the crinoline really didn't just look like a cage. She was a cage. Women are closed, restricted in their movements and movements, and thus deprive her of her freedom in some way. It may have made it easier for women in some ways not to have to wear more layers of petticoats because of the current fashion at the time, but that is negligible.
The crinoline was greeted with enthusiasm in the 19th century, because it was one of the innovations that helped them solve the problem of several petticoats under which it was immensely warm. Yes, with the advent of the crinoline, one problem has been solved, but another has been made. It was just

[6] "Fashion - an illustrated guide to the glamorous world of style", 2015 Vulcan
[7] WANNABE MAGAZINE article, "The Ideal of an Epoch - Crinoline"

as impractical, mostly from the beginning, because it restricted movement and was inconvenient to dress - someone always had to help with dressing. Before they created it, it appeared in various forms and solutions. It is completely obsolete, and today the crinoline can only be seen in a wedding dress salon, theaters, stage performances or at fashion weeks where designers are inspired by the construction of the crinoline itself and its history. She also inspired me with her construction to guide her through the work and to get her place in the designed models.

As she inspired me, so did other designers. Of course, both individuals and global fashion brands such as Alexander McQueen, Christian Dior, Valentino, Dolce & Gabbana and many others. History is often as inspiring as the theory of dressing itself throughout history. The fashion of that time had an impact on today's thinking, culture and today's way of dressing. In the same way, today's fashion and the mix of events will have an impact in perhaps the distant future and will be an inspiration to many other designers of that time who will diligently study and design garments inspired by our present. We are participating in the creation of a new history, without even being aware of it. It is the same, I believe, for them when this kind of innovation came. For them, it grew into everyday life and something without which leaving the house could not be imagined. Something that the social community quickly accepted and kept for some time as an obligatory form in women's clothing in order to keep that form of bell.

There are very interesting fashion solutions on this topic as well as beautiful wedding dresses that contain a crinoline in the form of their shape to achieve that fullness that represents a kind of luxury and gives the desired model the look that every bride wants on her special day - different from our everyday life.

INSPIRATION FOR FASHION COLLECTION

Figure *3. Alexander McQueen Spring/ Summer 2013*

Inspiration is something we need to put some things into action. It is intangible, but at the same time inspiration can be an object or a person dear to us, but the energy that gives inspiration is immaterial, it is more spiritual. Depending on our interests of each man, different things inspire a woman. Inspiration encourages creativity, helps brain twists to work at full speed and thus helps us to leave a mark on this world. It helps us feel even more alive and inspired.

The inspiration for this fashion collection was found during the historical research of costumes that marked the Middle Ages, as well as in many movies and books from that time that left a certain impression on me and encouraged me to think and start the crucial - inspiration. What fascinated and attracted my attention the most was the uniform of the plague doctor from the 17th century. What left a strong impression was the doctor's mask in the shape of a bird's beak, as well as her very idea, an idea that encouraged further research and inspired me for further work. For me, the mask represents an important turning point and the captivity of the doctors of that time, and even today ourselves because of the current situation with the corona and because of its construction of a bird's beak and story, I connected it with a cage. Hence the story of the synergy of a crinoline and a mask in the shape of a bird's beak. Inspired by the story of hiding and masking, the next fashion collection was created, which contains dark colors of that time.

Figure 4. A picture of inspiration

The fashion collection "Deprived of liberty" displays extravagant breathtaking creations in a modern and wearable way. The collection is adapted to the theme and the costumes in it are carefully designed with the spirit of that time, which are painted in the style of today. The collection is intended for women's fashion shows for the autumn / winter season due to the weight and complexity of the cut that all models contain. The colors have been carefully selected and used for this collection and they additionally give a feeling of strength, weight and stability to the observer. The color that dominates the whole work the most is black because of its entire history related to the costume of the plague doctor and because of the association of black with the name "Black Death".

The fashion collection "Deprived of liberty" is a collection for women with style and wider possibilities of understanding such a topic. Inside each item of clothing from the collection, you can see the unity of color, cut and design that will hardly leave you indifferent. The collection was made using the collage technique via computer. The materials used in the collection are various types of cotton, leather and PVC materials that in combination give a complete look and significance to each model.

The materials used in making the collection are various types of cotton that form the basis of the entire collection, then leather, which is also represented in the collection and an integral part of it. PVC material appears in several models as an addition to the collection to achieve additional effectiveness. Cotton is mostly used with elastin, coated with special coatings in order to achieve the effectiveness of the cuts on the model and to make them stand out in combination with regular black cotton. In order to achieve the rigidity of the cuts, it is necessary to reinforce the material with interlining and doubling of certain parts of the cut. By combining these materials, the desired result is achieved and the models come to the fore.

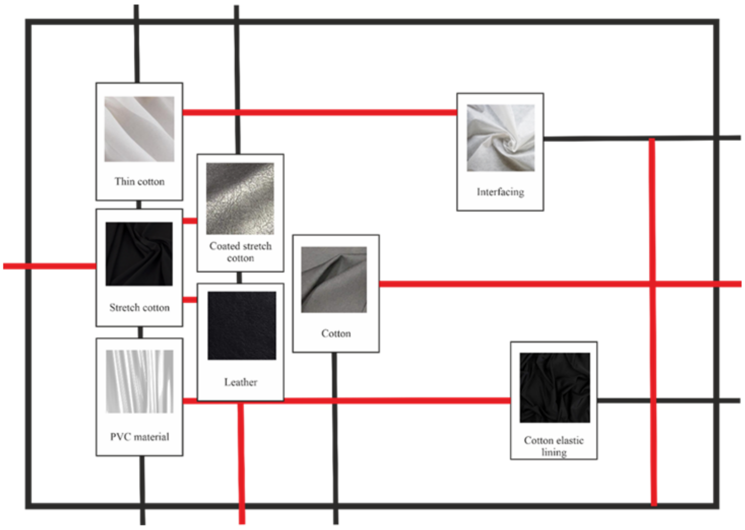

Figure 5. Map of fabrics

The collection contains 10 models that are presented through a portfolio, which one model is a realised. I will present you the realized model and its image from the portfolio to guide you a little into the whole imagined concept of my collection.

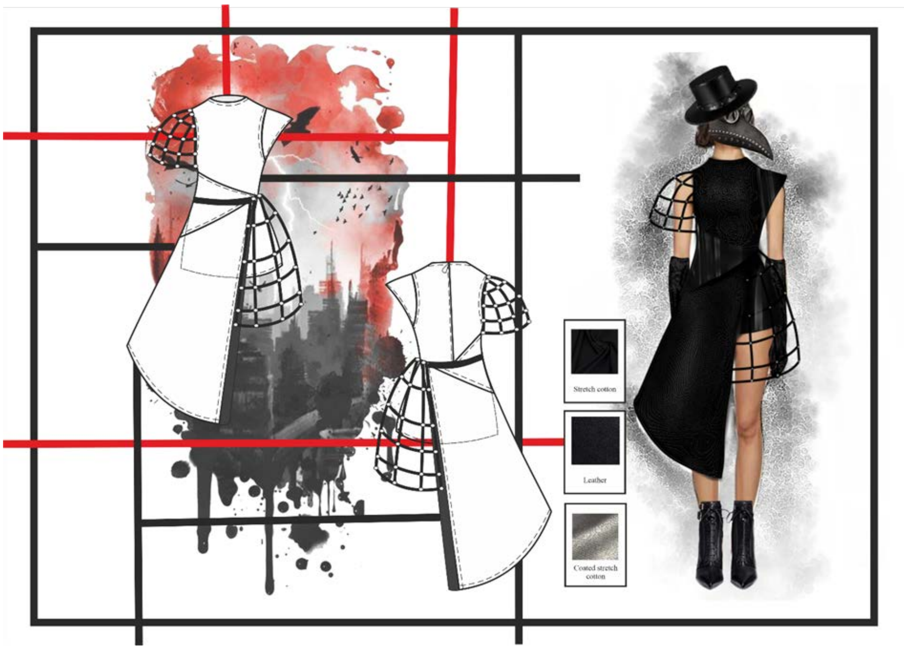

Figure 6 Realized model from collection of diploma thesis (left)

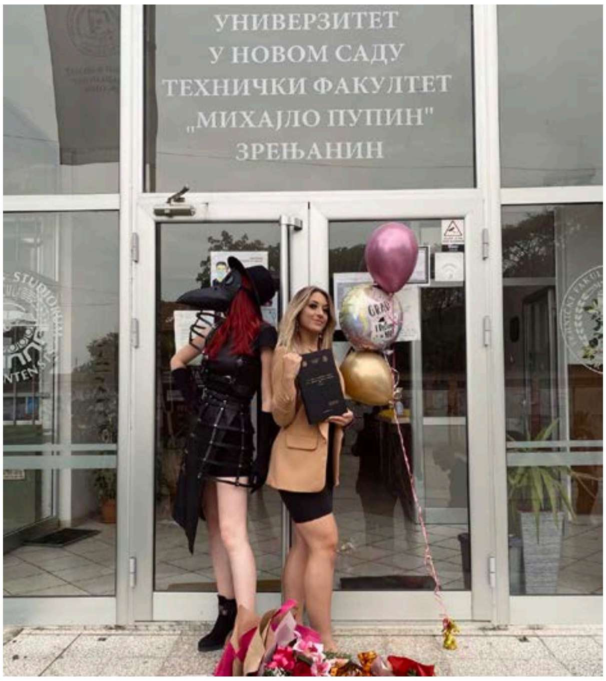

Figure 7 Sketch from the portfolio

CONCLUSION

The current situation with the corona virus and the rules in the fight against this pandemic associated me and inspired me when choosing this topic. The similarities and dress up, the history and the cause of the disease are amazing. Each pandemic has its own story and cause, but the plague pandemic has had a major impact and marks a major turning point in many fields, most notably in medicine and today’s way of life. At that time, the mask did not have the function they imagined at the time, but it helped in the development of other theories and in the further progress of medicine. Also, the plague doctor's suit itself may not have been the most effective at the time, but it developed other ideas and innovations for the work suits of today's doctors, surgeons and medical assistants.

The reason why I chose the mask for the topic, which was used by doctors from the Middle Ages during the plague pandemic that hit the whole world and took many lives from it, until the real reason for the spread of this deadly disease was revealed and symbolism represented by the crinoline is an integral element of the my creative work. For me, this topic represents a deep discussion and a broader understanding. By connecting these two motifs, the eclecticism and symbolism of the cage and the mask were obtained, ie. birds. Freedom of dress and rejection of imposed norms and restrictions that have long been part of the costume, is a social paradigm, which we have not yet freed. Clothing culture is in fact a phrase, which refers to the state of society, a mirror of community life, and many elements such as artistic attitudes, economic status, life commitment and ideological attitudes

Today, specifically the plague doctor's costume and his mask are used exclusively for entertainment or in cinema. It is styled and adapted to their ideas and needs. Many of them may have a brief insight into the events of that time, I think like all of us, because the information and theory about the disease itself and the bones is really a lot and we can't be sure what is true. What we do know is that there is a cure for the plague today, thanks to the hard work of former second-rate doctors who are now considered a symbol of sacrifice and perseverance, they showed what a doctor should look like and helped a lot in the development of the world as we know it today. While the crinoline is only available for special clothing forms as such, it has been modernized in a larger form and is an inspiration to many designers today for their fashion exhibitions and presentations in a new form.

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