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INTRODUCTION

Technical faculty “Mihajlo Pupin” University of Novi Sad has organised the 13th International Conference “ Textile Science and Economy ” with partners Faculty of Mechanical Engineering, University of Maribor and Faculty of Technology and Metallurgy, SS.Cyril and Methodius University in Skopje.

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 a number of challenges due to changing trends on the market and new ways of doing business. 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 and and business problems during at a time of great changes in the worlds market.

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, XIV International Conference – Textile Science and Economy, become better in organizational and program sense.

The Chairman of the Organizing Committee:

Asst. Prof. Marija Pesic

Zrenjanin, 21st October, 2022.

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BODY-CLOTHING-COMFORT INTERACTION

Andreja Rudolf, Tadeja Penko
University of Maribor, Faculty of Mechanical Engineering, Institute of Engineering Materials and Design, Slovenia

ABSTRACT

The modern consumer wants comfortable clothes that perfectly fit his body type and make him beautiful and comfortable. The fit of clothing must consider the different body sizes and shapes of the wearer, as well as the occasion for which the clothing is intended. When a garment does not fit well, consumers often blame their body or the poor pattern design of garments. A well-fitting garment is characterised by an appropriate amount of ease allowance. This refers to the amount of extra textile material that is allowed to exceed the body measurements to ensure comfort and body movement. The article discusses the interaction between body, clothing, and comfort through three case studies on the influence of the body shape and the garment size on the decision to purchase clothing, the comparison between the average body measurements of the population and the average body measurements in different age groups of the adult population, and the garment fit to the body shape through ease allowance and comfort for the female population in Slovenia.

Key words: body shape, clothing fit to the body, clothing comfort, ease allowance

INTRODUCTION

Today, more than ever, we find ourselves under constant pressure when thinking about what to wear, what looks good on us and how to improve our body shape and size (Fan J. et al., 2004). Clothing as near environment of human body plays a crucial role in achieving human comfort (Song G., 2011) and along with fit, is one of the important factors for consumers to purchase a particular garment (Hugo S.H, Aardt A., 2012). Much research on clothing comfort has fundamental meanings also for the survival of human beings and to improve the quality of our life (Li Y., 2010).

CLOTHING COMFORT

Many researchers define comfort in different ways, such as comfort is (Lavanya S., 2020): (a) influenced by the physiological response of the wearer, (b) temperature regulation of the body, (c) absence of unpleasantness or discomfort, and (d) a state of pleasant psychological, physiological and physical harmony between a person and the environment. All aspects of clothing comfort are equally important, as the wearer will feel uncomfortable if any of them are missing (Lavanya S., 2020). Clothing comfort results from an evaluation of the user's perspective, the environment, and the clothing factors (Sontag M.S., 1985) and can be described as absolute freedom from pain and discomfort (Hatch K.L., 1993). The thermal comfort of clothing is influenced by the physiological response of the wearer and the temperature regulation of the body. It is the absence of discomfort or unpleasantness and a state of pleasant psychological, physiological, and physical harmony between the wearer and the environment (Slater K., 1986).

The thermos-physiological comfort of clothing is achieved by a comfortable state of warmth and moisture, and the thermoregulatory capacity, thermal insulation and moisture-regulating capacity of clothing depend on the environmental and working conditions. Clothing comfort is influenced by fabric, design and fit (De Rave A. et al., 2018). Sensory comfort is the elicitation of various natural sensations when the textile material comes into contact with the skin (Malik T., Sinha T.K., 2012). Sensory comfort is strongly influenced by the fabric, fit and assembly technique of the garment (De Rave A. et al., 2018). Psychological comfort is related to self-esteem and satisfaction with the available options. This comfort is characterised by emotional attributes. It is the subjective perception of a garment that contributes to overall well-being and is related to the design, fit and overall quality of the garment. Ergonomic comfort or comfort during body movement refers to the ability to move

freely without uncomfortable restriction of movement or pressure on the skin (Uttam D., Ramratan, 2021), which is mainly influenced by the size, comfort of the garment and fit. The fit of the garment contributes to all aspects of clothing comfort and the wearer's self-confidence (Alexander M. et al., 2005).

Clothing fit and body self-image

Consumers have garment fit preferences based on aesthetic and functional expectations; these preferences have consequences in the volume and proportions people want in their garments (Ashdown S.P., Delong M., 1995). When a wearer judges the fit of a garment, the judgement is based on both: appearance and comfort. Appearance refers to the look, style, and design of the garment. Clothing fit must consider the shape of the wearer, texture, drape, and weight of the fabric and how the garment is worn (Boorady L.M., 2011). Well-fitted garments are considered vital to individual's psychological and social well-being (Smarhers D., Horridge P.E., 1987-79). When garments do not fit well, consumers blame their bodies, which results in a negative body image (Apeagyei P.R., 2008). On the other hand, unrealistic clothing sizes and the promotion of "ideal" fashionable female body shapes in the media as a "frame standard of beauty" also contribute to a negative body self-image (Alexander M. et al., 2005 Apeagyei P.R., 2008, Tebbel C., 2000).

Case study 1: The influence of clothing size on body self-image

This study explored the influence of the body shape and size number on the body self-image (Selko U., 2011). The female population of the two age groups, between 19 and 30 years, and 31 and 40 years, was investigated with the help of an online survey in Slovenia. A total of 50 women of each age group completed a questionnaire and the results were analysed and compared between age groups.
The results showed that the clothing size number had influence on women's body self-image and less on their decision to buy a garment. It was found that clothing size is for younger women an important factor when purchasing clothing compared to older women, while a higher percentage of respondents of both age groups expressed dissatisfaction when buying a bigger clothing size than they usually buy. The younger women from the age group 19 to 30 years were also more interested in their body shapes and had greater pretensions about their ideal body shape and clothing size. In spite of different body shapes of the women's respondents in both age groups it was found that the ideal clothing size for younger women was size 36 and for older size 38, while they were all considered to be their ideal body shape in the form of an hourglass. The research has shown that the media only partially influences the female population surveyed in terms of their desired body shape and clothing size, since they still prioritise comfort and fit when buying clothes. Therefore, the study points out to clothing manufacturers that there is a need on clothing for different body shapes and uniform clothing sizes or body measurements below clothing sizes of garments producers.

Clothing fit and comfort

A good garment's fit requires a proportional balance between body and garment and can only be reliably achieved with appropriate development and implementation of sizing systems, effective patternmaking, and quality manufacturing (Ashdown S.P., O’Connell E.K, 2006). Most fitting problems are due to the variety in our bodies (Brown P., Rice J., 2014). Sizing problems may derive from knowledge of the body shape and size variation within the population (Ashdown S.P., 2014). The fit preference of two consumers having the same body measurements, height, and weight can be very different and may vary greatly. Observation indicates that people differ in their preference for clothing fit, from garments that fit tightly to the body to garments that barely touch the body. The snugness or ease a person desire in clothing depends on one’s personal preferences, attitudes, or the look consumer’s desire (Alexander M. et al., 2005). Although each persons have different preferences for clothing fit the satisfaction with it will be higher if the body shape of the wearer can be considered when clothing is designed and manufactured (Birkocak D.T., Ondogan Z., 2014).

Case study 2: Research on the average body measurements of the population and the average body measurements in different age groups of the population

The aim of the study was to determine whether the average body measurements of the measured adult women population in Slovenia differ from the average body measurements of the measured women in the age groups studied: up to 20 years, 21-30 years, 31-40 years, 41-50 years and over 50 years (Pečnik, N., 2015). 179 women participated in the body measurements study. The following main body measurements were taken: body height (BH), upper bust circumference (UpBC), waist circumference (WC) and hip circumference (HC). F-test and t-test were used to determine the significance between the average value of body measurements of the measured population and the average values of body measurements in the age groups. The average age of the subjects was 34 years, their average body weight was 70.2 kg, and their average body height was 167.3 cm. The average values of the body measurements of the measured female population are compiled in Table 1. The results of average body measurements in age groups show a trend of increasing body height up to the age group of 31 to 40 years and then decreasing average body heights with age. Furthermore, we can observe an increasing trend in average chest circumference, waist circumference and hip circumference with age, which can be observed. The age group 41 to 50 deviates slightly from the trend line.
The appearance of the average female body of all measurements and the appearance of the average female body in age groups is presented using 3D virtual body models, Figure 1. We can see a visible difference between the body figures of women up to 30 years of age (age groups up to 20 years, 21 to 30 years) and those over 30 years of age (age groups 31 to 40 years, 41 to 50 years, over 50 years), Figure 1. The preliminary research shows that in order to better fit of clothes to the body, it would be necessary to design clothes for at least two age groups of the female population, based on the average body measurements for the age groups up to 30 years and over 30 years.

Digital fashion is a growing field in the world of fashion design. Simulations of virtual clothing on 3D body models to showcase the look of garments have accelerated the recent pandemic. In parallel, changes need to take place in the field of personnel training to acquire digital skills for virtual prototyping. This is also one of the objectives of the Erasmus+ project entitled *Collaborative international online learning in the field of digital fashion - Digital fashion* (DigitalFashion project, 2021). The three-year project is co-funded by the European Commission's ERASMUS+ program under the Strategic Partnerships for Higher Education. It is started in February 2022 and will end in January 2025. The coordinator of the project is the National Research-Development Institute for Textiles and Leather (INCDTP) – Romania, and the partnership includes following European institutions: National Higher School of Arts and Textile Industries – France, Hogeschool Gent – Belgium, University of Maribor – Slovenia, Textile and Clothing Technological Center (CITEVE) – Portugal, Gheorghe Asachi Technical University in Iasi – Romania. The main project results are:
PR1. New methodology for a common framework on Collaborative Online International Learning in the field of Digital Fashion.
PR2. Library of knowledge (the three databases) for virtual fashion design and technology.
PR3. Training platform of fashion design by personalized 3D virtual garment fitting.
PR4. Curricula for Collaborative Online International Learning in the field of Digital Fashion.

Table 1: Average values of the body measurements of the measured female population

Body measurements	Average body measur. (cm)	Average body measurements in age groups (cm)				
		Up to years	20 21 – 30 years	31 – 40 years	41 – 50 let	Over 50 years
BH	167.3	164.7	166.6	169.9	167.0	166.1
UpBC	90.9	85.4	87.9	93.8	92.4	96.4
WC	79.9	70.9	76.8	83.5	82.1	86.6
HC	101.4	95.0	98.9	104.2	101.5	110.0

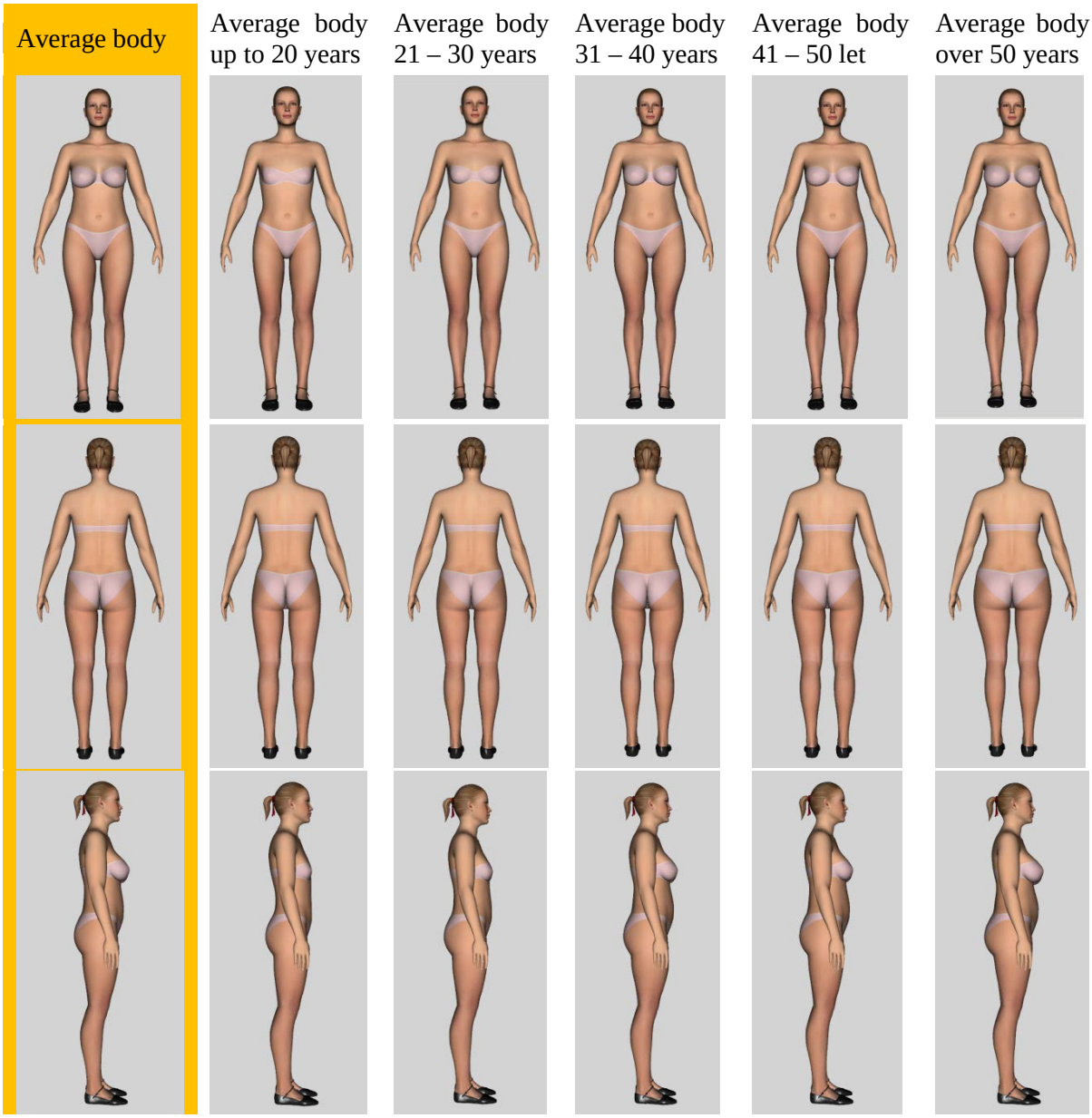

Figure 1: The appearance of the average female body and the appearance of the average female body in age groups

Ease allowance and its effect on clothing comfort

The aesthetic appearance, proper fit and drape characteristics of a garment are highly dependent on each garment manufacturing process (Datta D. B, Seal P., 2018). An ease allowance and the shape of the pattern pieces affect the fit of the garment on different parts of the body. A garment design that considers the ease allowance and the contour of the garment and knows how they affect the garment at different points contributes to an effective design. Well-fitting garments are characterised firstly by an adequate amount of ease allowance, which refers to the amount of extra fabric over the body measurements to ensure comfort and body movement, secondly by the design ease, which is developed by the designer to achieve the desired visual effect, silhouette, and style, and thirdly by fitting the body silhouette without causing unwanted wrinkles (Ashdown S.P., DeLong M., 1995). The first step in creating a pattern design for a garment is to determine the amount of ease allowance (Gill S., 2010). The ease allowance of the garment is defined as the distance between the garment and the wearer's body. In determining the measurements of a garment, the body measurements are

constant and represent the individual or standard size, while the allowance for ease is variable. In practise, there are three types of ease allowances classified according to three functions: standard ease, dynamic ease, and fabric ease (Chen et al., 2008). The standard ease allowance allows the wearer to perform basic movements such as breathing and sitting (Ng R. et. al, 2008). The dynamic ease allowance provides sufficient space for wearers with non-standard body shapes and their movements (Ng R. et. al, 2008). The fabric ease allowance considers the influence of the mechanical properties of the garment's fabric (Lage A., Ancutiene K., 2017). The appropriate level of ease allowance varies depending on the purpose of wearing and the type of garment (Sakata Y. et al, 2021).

Case study 3: Ease allowance and fitting the garment to the body shape

Garment fit to the body shape is one of the most important requirements for the appearance of the wearer in the clothing that attracts the attention of customers. From the point of view of different body shapes, the question is how we can define the ease allowance define well to ensure a well-fitting and ergonomic function of the garment, Figure 2. The main objective of this study was to investigate the fit of garments for three different female body shapes, using three different ease allowances related to the breasts, waist and hip measurements (Kocbek M. et al., 2013). The assessment of the fit of garments differs in the areas of the measurement lines in standing and sitting postures as well as in the subjective assessment of the test persons. Body shapes with larger bust, waist and hip circumferences were found to require a greater ease allowance than those with smaller circumferences. The subjects' subjective assessments of comfort when wearing garments with different ease allowances were consistent with the assessments of the fit of garments for body shapes. Based on the research results, we can conclude that it would be necessary to consider different ease allowances for different body shapes when constructing garments.

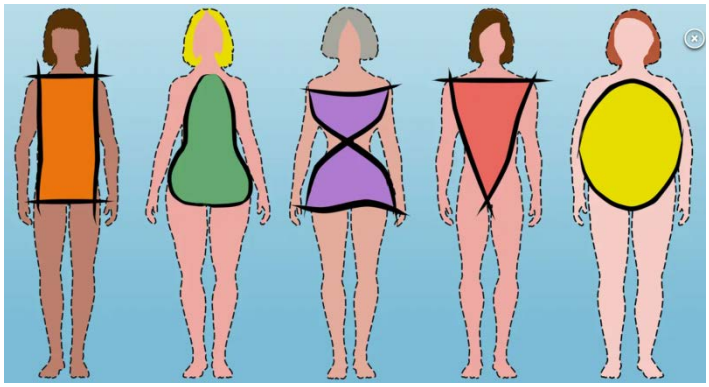

Figure 2: Women's body shapes (Cambridge E., 2022)

CONCLUSIONS

This article examines the body-clothing-comfort interaction from the perspective of body self-image, body shapes, and comfort allowance. Case studies show that there is a need for clothing for different body shapes and the use of uniform clothing sizes of garments' manufacturers or body measurements below clothing sizes. For better fitting of garments to body shapes, it would be necessary to design garments for at least two age groups of the female population (up to 30 years and over 30 years) and to consider different ease allowances for different body shapes in the construction of garments.

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ANTIMICROBIAL ACTIVITY OF COTTON YARNS TREATED WITH DIFFERENT APPLYING TECHNIQUES

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ABSTRACT

The alkaline scoured and bleached cotton yarns were treated with chitosan to achieve antimicrobial activity against gram-negative (*Escherichia coli*) and gram-positive (*Staphylococcus aureus*) bacteria using different applying techniques. Four applying techniques, exhaustion-dry-rinse (EDR), exhaustion-rinse-dry (ERD), exhaustion-pad-dry-rinse (EPDR) and exhaustion-pad-rinse-dry (EPRD) were used. The influence of the applying technique on the amount of introduced chitosan and the amount of available amino groups of chitosan treated samples were also examined. SEM was used to study the morphological properties of the cotton surface. A higher amount of introduced chitosan, amount of available amino groups, and hence better antimicrobial activity showed EDR and EPDR than ERD and EPRD techniques. The best antimicrobial activity was achieved by the exhaustion-pad-rinse-dry technique.

Key words: chitosan, cotton, antimicrobial activity, applying technique, amino groups

INTRODUCTION

Nowadays, it is a global challenge to obtain antimicrobial textiles. Different functionalization methods of cellulose material exist to achieve biologically active effects. There are the oxidation processes and synthesis of antimicrobial cellulose, the inclusion of metal nanoparticles into fibers such as silver, zinc, and copper, antimicrobial coatings such as benzophenone, and the addition of antimicrobial reagent into cellulose xanthate such as triclosan [1]. Most of these methods are controversial for humans and the environment due to inorganic salts, phenols, thiophenols, antibiotics, and formaldehyde derivatives, used during production [2]. Therefore, the increasing tendency of research is seen where the functionalization is performed using non-toxic, biodegradable, and environmentally friendly reagents [3]. Cellulose and chitosan have excellent potential for this purpose. They are the two most abundant biopolymers in the world. Chitosan is a polycationic, renewable, and biodegradable polymer known for its wide range of biological activity, including antimicrobial activity. Techniques for applying chitosan are exhaustion, padding, pad-dry-cure, pad-dry, film application, foaming, and printing.

The researchers and manufacturers paid attention to achieving antimicrobial textile matching the chitosan based cotton with good antimicrobial activity. The quick and easiest application of chitosan with cheap and easy application technique are required from scientists. This technique should give textile with good antimicrobial activity against gram-negative and gram-positive bacteria.

The aim of this study was to study the antimicrobial activity of alkaline scoured and bleached cotton yarns obtained by different applying techniques. The amount of introduced chitosan, the amount of available groups, and antimicrobial activity were studied. SEM was used to study the morphological surface of cotton.

EXPERIMENTAL PART

Materials

Plied, ring-worsted cotton yarns with 30x2 tex linear density and 330 twist/m were used. Chitosan with an MW of 50000-190000 Da (g/mol) and deacetylation degree (DD) of 75-85 % was used to

treat cotton yarns. *Escherichia coli* (ATCC 25922) and *Staphylococcus aureus* (ATCC 29219) bacteria obtained by American Type Culture Collection (ATCC) were used for antibacterial activity tests.

Chitosan applying process

Cotton yarns were pre-treated by alkaline scouring and bleaching processes before treatment with chitosan [4]. The 0.6 % (w/v) chitosan solution was prepared in 1 % (v/v) CH_3COOH for 60 min at 60 °C, followed by constant stirring, and the pH was adjusted to 4-4.5 by adding acetic acid. The prepared chitosan solution was applied to the pre-treated cotton yarns using the applying techniques shown in Table 1.

Table 1: Applying techniques for chitosan on alkaline scoured and bleached cotton yarns

Technique phases	Exhaustion-pad-dry-rinse (EPDR)	Exhaustion-pad-rinse-dry (EPRD)	Exhaustion-dry-rinse (EDR)	Exhaustion-rinse-dry (ERD)
Phase 1	Exhaustion 0.6 % chitosan solution pH 4-4.5 30:1 LR T=60 °C, t=120 min	Exhaustion 0.6 % chitosan solution pH 4-4.5 30:1 LR T=60 °C, t=120 min	Exhaustion 0.6 % chitosan solution pH 4-4.5 30:1 LR T=60 °C, t=120 min	Exhaustion 0.6 % chitosan solution pH 4-4.5 30:1 LR T=60 °C, t=120 min
Phase 2	Padded under pressure 1.6 bar	Padded under pressure 1.6 bar	-	-
Phase 3	Dried at 60 °C for 12 h	Rinsed five times at 20 °C for 10 min	Dried at 60 °C for 12 h	Rinsed five times at 20 °C for 10 min
Phase 4	Rinsed five times at 20 °C for 10 min and dried at room temperature	Dried at room temperature	Rinsed five times at 20 °C for 10 min and dried at room temperature	Dried at room temperature

Methods

Color Strength

Determination of weight add-on of alkaline scoured and bleached cotton yarns after treatment with chitosan was done by direct gravimetric method.

The color strength (K/S) of the dyed sample with C.I. Acid Orange 7 [5] was determined by measuring the corresponding reflectance value using the X-Rate Color i7 reflectance spectrophotometer and calculating the K/S value using the Kubelka-Munk equation:

$$K/S = \frac{(1 - R_{\lambda max})^2}{(2R_{\lambda max})}$$

Where: K is the absorption coefficient, S is the scattering coefficient, and R is the reflectance value of the dyed sample at the wavelength at maximum absorption.

Characterization of surface morphology by scanning electron microscopy (SEM) was done on a Philips XL 30, and 10 images were taken at different points on the sample.

The antimicrobial activity of samples against *Escherichia coli* (gram-negative bacteria) and *Staphylococcus aureus* (gram-positive bacteria) was quantitatively determined according to the standard AATCC Test method 100:2004.

RESULTS AND DISCUSSION

Using different applying techniques to treat alkaline and scoured cotton yarns, the amount of introduced chitosan is shown in Figure 1. The results indicate that the EDR and EPDR applying

techniques had introduced chitosan more than the ERD and EPRD. No significant difference was found between ERD and EPRD applying techniques. The amount of introduced chitosan on the sample treated with the EDR applying technique was 5.19 %, which is 21.63 times higher than sample treated with the ERD applying technique. Some of the introduced chitosan was removed when the rinsing phase is before the drying phase. Therefore, the ERD and EPRD applying techniques showed a lower amount of introduced chitosan than the EDR and EPDR applying techniques.

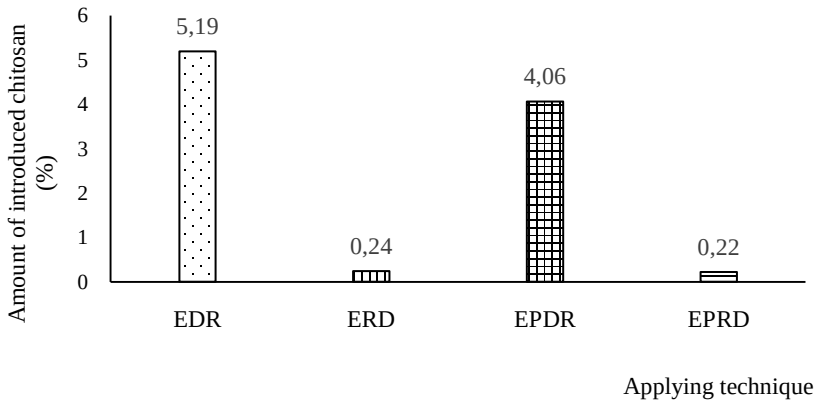

Figure 1: Amount of introduced chitosan onto alkaline scoured and bleached cotton yarns treated with different applying techniques

The amount of available amino groups onto cotton yarns treated with chitosan using different applying techniques is shown in Figure 2. Dyeing with Acid Orange 7 of the yarns treated with chitosan is possible due to the electrostatic interaction between the positive groups from the chitosan (acquired at the level of the N atom from the amino groups of chitosan) with negative groups from the acid dye. Intensity type of electrostatic interactions, the attraction is reflected in the value of color strength (K/S), which can justify the effects that generate by grafting with chitosan and its amino groups. The lower K/S value indicates that chitosan treated samples have a lower amount of available amino groups which interact with anion dye [6]. The amount of amino groups introduced by ERD and EPRD applying techniques was neglected. The results indicate that the EDR and EPDR applying techniques had more amount of available amino groups.

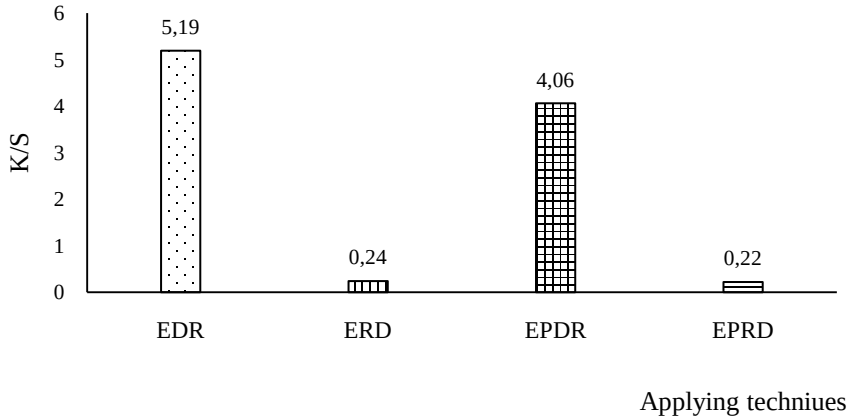

Figure 2: Amount of amino groups onto alkaline scoured and bleached cotton yarns after treatment with chitosan using different applying techniques

The presence of chitosan introduced onto alkaline scoured and bleached cotton yarns using different applying techniques was observed with scanning electron microscopy (SEM). The SEM images are shown in Figure 3. The SEM image of the surface of alkaline scoured and bleached samples revealed characteristic parallel ridges and groves. This indicates that the alkaline scouring and bleaching

processes peel the non-cellulosic component or completely remove the cuticle. Comparing SEM images related to untreated and chitosan treated, reported in Figure 3, the presence of the intruded chitosan was clear. The surface features of the chitosan treated samples differed from those of the untreated ones. The surface texture decreased, and the presence of a thin layer on the single fiber can be noticed without gluing them. After applying chitosan, the surface became smooth regardless of the applying technique.

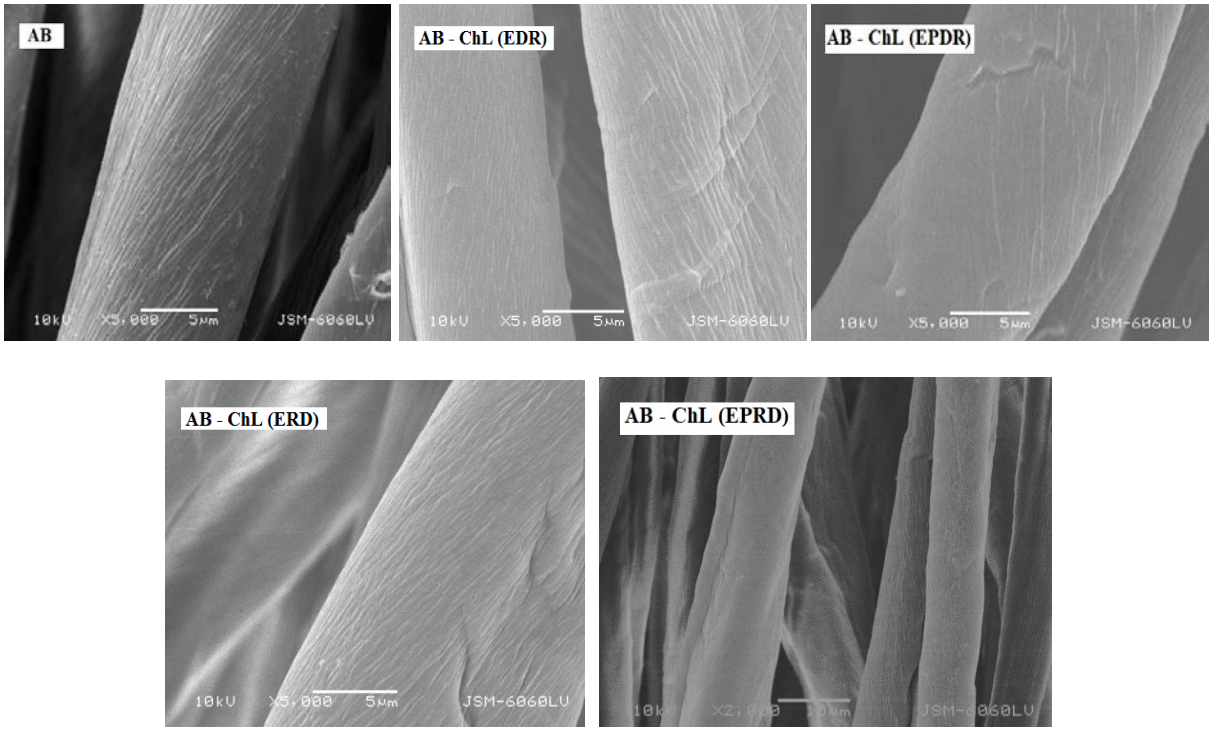

Figure 3: SEM images of alkaline scoured and bleached surface (AB) and treated with chitosan (AB-ChL) using different applying techniques EDR, ERD, EPDR and EPRD

The treated alkaline scoured and bleached cotton yarns using different applying techniques were evaluated for antimicrobial activity against *Staphylococcus aureus* (gram-positive bacteria) and *Escherichia coli* (gram-negative bacteria). The results are shown in Figure 4. Effective antimicrobial activity had textile materials that reduce gram-negative and gram-positive bacteria by more than 75 % [5]. All methods were noticeable effective in *Escherichia coli* bacteria reduction. This antibacterial activity was more than 90 %. The bacteria reduction percentage for ERD and EPRD applying techniques showed a maximum 59 % reduction for *Staphylococcus aureus*. For EDR, the antimicrobial activity was around 66 % against *Staphylococcus aureus*. Samples treated with chitosan using EPDR applying technique showed the greatest bacteria reduction percentage against *Staphylococcus aureus*. Free amino groups form chitosan react with hydrogen ions and give NH_3^+ cations, which react with the negative charge from the bacterial cell surface, leading to the emission of intracellular components and the cessation of vital cell functions [7]. It was observed that regardless of the applying techniques, the treated samples showed over 95 % reduction against *Escherichia coli* bacteria indicating excellent antimicrobial activity (Figure 4). According to some studies, chitosan treated cotton has greater antimicrobial activity against gram-positive bacteria (*Staphylococcus aureus*), compared to gram-negative one (*Escherichia coli*) [8]. According to other research, this trend is reversed [1].

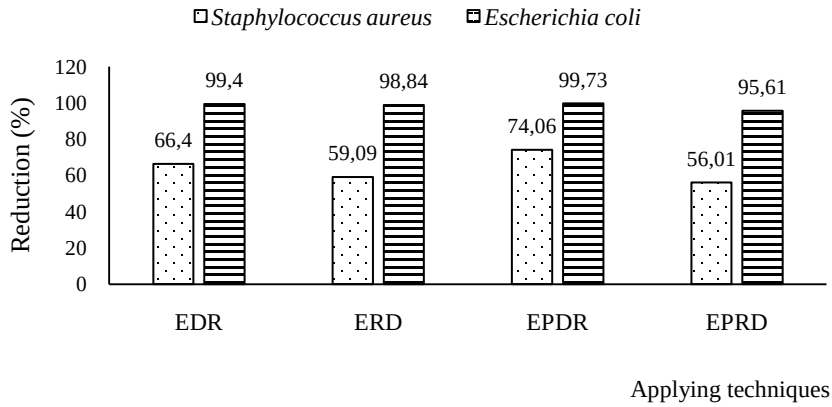

Figure 4: Reduction percentage against Staphylococcus aureus and Escherichia coli of alkaline scoured and bleached cotton yarns treated with chitosan using different applying techniques

CONCLUSION

To find the influence of applying techniques for chitosan on antimicrobial activity of alkaline scoured and bleached cotton yarns, different applying techniques were used and the suitable applying technique was selected. It was found that for ERD and EPRD applying techniques, no substantial differences were noticed in the amount of introduced chitosan, amount of available groups, and antimicrobial activity against *Escherichia coli* (gram-negative bacteria) and *Staphylococcus aureus* (gram-positive bacteria) bacteria when rinsing phase was before drying phase. The results for EDR and EPDR showed a higher amount of introduced chitosan, the amount of available amino groups, and better antimicrobial activity than ERD and EPRD techniques. Applying techniques showed a reduction against *Escherichia coli* by more than 75 %, indicating excellent antimicrobial activity, and a reduction against *Staphylococcus aureus* lower than 75 %. EPDR applying technique showed the best antimicrobial activity against both bacteria.

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EFFECT OF YARN FOLDING ON COMPRESSION PROPERTIES OF RIB KNITTED FABRICS

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ABSTRACT

Generally, the operation of folding or plying modifies and improves existing single yarns to an appreciable degree by combining them together. The properties of folded yarns have been the subject of many investigations; however, there is a lack of studies devoted to the influence of yarn folding on the compression properties of textile fabrics. Therefore, this study focused on the effect of yarn folding on the compression behavior of the rib knitted fabrics. The rib knitted fabrics were produced by combining one of the two cotton two-folded yarns, differing in folding twist, with one of the two complex hemp yarns (two assembled and folded). The compressibility, resilience, as well as deformation components of compression were determined. The compression-release curves of the rib knitted fabrics were analyzed. The obtained results indicated that the packing density of the fibers in the yarn is a key determinant of the investigated compression parameters of the rib knitted fabrics.

Key words: compression, recovery, yarn folding, hemp, cotton

INTRODUCTION

The lateral compression behavior is one of the most important properties of textile materials used for garments since the compression properties are closely related to the softness and smoothness of the material (Stankovic S., 2012). These two parameters significantly determine wearing comfort. In addition, the cyclic compression behavior of clothing textiles is even more important for comfort performance. In clothing textile materials, fibers are organized into yarns in a structured array depending on the yarn type (staple or filament) and spinning technique. The yarns are further processed into woven or knitted structures. During the weaving process, warp and weft yarns are tightly interlaced. A knitted structure consists of three-dimensional loops of yarn interlocked together. Therefore, the compression behavior of woven and knitted fabrics is governed by fiber properties, yarn compression properties, and fabric structure. Compression behavior of textile materials is controlled by fiber bending, slippage with friction at contact points and irreversible fiber arrangement (Stankovic S., 2014). Therefore, the fiber geometry and deformation properties have an influence on the compression ability of the fabric (Stankovic S., 2008a; Majumdar A. and Pol A.B., 2014). The compression properties of yarn are determined by component fibers and their arrangement within the yarn. These reflect in the packing density of yarn which directly influences the compressibility behavior of the fabric. For example, difference in the elastic properties of hemp and acrylic fibers were projected into different compressibility of the knitted fabrics made therefrom (Stankovic S., 2006). In the investigation conducted by Majumdar and Pol (Majumdar A. and Pol A.B., 2014), the compressibility of woven fabrics ranged from the most compressible 100% cotton fabric to those of the lower compressibility as the proportion of bamboo fibers increased. These results were attributed to the higher hairiness and lower packing density of the cotton yarn. The effect of weft yarn twist level on compression properties on woven cotton fabrics was confirmed in the investigation conducted by Atalie et al. (Atalie D. et al., 2019), in which the fabrics composed of yarns with lower twist had higher compressibility and compressional resilience. Kim and Kim (Kim H.A., Kim S.J., 2018) investigated the influence of the yarn spinning method (ring, compact, and air-vortex spinning) on the compression behavior of single jersey knitted fabrics. They ranked them from the ring yarn knitted fabric being the most compressible to the air-vortex yarn knitted fabric as the least compressible. The minimal compressibility of the air-vortex yarn knitted fabric was explained by parallel bundles in the yarn core, which made this yarn slightly rigid under lateral compression. The lower compressibility of the compact yarn knitted fabric as compared to the ring yarn knitted fabric

was attributed to the less hairiness and higher compactness of the compact yarn structure. In the investigation conducted by Stankovic (Stankovic S., 2008b), the hybrid staple/filament yarns were designed, and the compression behavior of the rib knitted fabrics made therefrom was analyzed experimentally and theoretically.

The process of folding or plying yarns modifies and improves properties such as the evenness (diameter), strength, liveliness (balances the residual torque) and surface characteristics. Although the characteristics of folded yarns have drawn the attention of many investigations, to the best of the authors' knowledge, the effect of yarn folding on the compression characteristics of textile fabrics was investigated in only one research so far. Stankovic and Bizjak (Stankovic S. and Bizjak M., 2014) indicated in their investigation that two-folded yarn contributed to the higher compressibility of the single jersey knitted fabric. Therefore, in this research an attempt was made to get more insights into the effects of yarn folding on the compression behavior of rib knitted fabrics.

EXPERIMENTAL

Two single yarns – 100% hemp and 100% cotton, both having the same nominal linear density (50 tex) and twist (400 m^{-1}) were used to produce two-folded yarns. The properties of the single yarns are given in Table 1. The cotton yarn was produced by rotor (open-end, OE) spinning technique, and OE yarn is known to be composed of concentric layers – the highly twisted core and outer sheaths with fibres having variable twist level (Lord P.R., 1971), due to which the actual twist in OE yarns is difficult to measure. It is generally accepted that the real twist of OE yarn is lower than the measured value, and it will consider in this investigation that the cotton and hemp yarns have similar twist.

Three two-folded yarns were produced – one composed of two single hemp yarns (FCs) with nominal twist (secondary twist) of 300 m^{-1}, and two variants of two-folded cotton yarns differing in folding twist (secondary twist) intensity (FCo1 and FCo2 with 300 m^{-1} and 600 m^{-1}, respectively). The folding yarns were subjected to steaming 20 minutes at 80° C in an autoclave, and storage for at least 72 hours in a conditioned room (65% R.H. ± 2% and 20 ° C± 2 ° C) in order to release tensions. The properties of two-folded yarns are presented in Table 1.

Table 1: Characteristics of the single and two-folded yarns

Yarn Parameter (unit)	Single yarns		Two-folded yarns		
	Hemp (Cs)	Cotton (Co)	Hemp/hemp (FCs)	Cotton/cotton (FCo1)	Cotton/cotton (FCo2)
Linear density (tex)	47.8	48.9	95.6	103.2	101.2
Twist (m^{-1})	370	474	297	305	548
Diameter (mm)	0.22	0.34	0.41	0.38	0.34
Bulk density (g $cm^{-3)}$	1.258	0.539	0.721	0.910	1.115
Packing factor	0.84	0.36	0.48	0.61	0.74
Hairiness (m^{-1})	3.4	17.6	6.7	14.8	7.2

In addition to these three two-folded yarns, two assembled hemp yarn, 2Cs, (doubled two hemp yarns without twist) was also used to produce four variants of 1x1 rib knitted fabrics. By combining one of the two cotton plied yarns (FCo1 and FCo2) with one of the two complex hemp yarns (FCs and 2Cs), four variants of rib knitted fabrics were obtained:

- FCo1+ 2Cs: two-folded cotton yarn with lower folding twist level + two assembled hemp yarn;
- FCo1+ FCs: two-folded cotton yarn with lower folding twist level + two-folded hemp yarn;
- FCo2+ 2Cs: two-folded cotton yarn with higher folding twist level + two assembled hemp yarn;
- FCo2+ FCs: two-folded cotton yarn with higher folding twist level + two-folded hemp yarn.

Samples were knitted under the same processing conditions in order to obtain, as much as possible, identical structure. Construction characteristics of the rib knitted fabrics are presented in Table 2. The

rib knitted fabrics were relaxed lying on a flat surface without tension in a conditioned ambient (65% R.H. ± 2%, 20°C ± 2°C).

Table 2: Construction characteristic of the rib knitted fabrics

Parameter (unit)		FCo1+ 2Cs	FCo2+ 2Cs	FCo1+ FCs	FCo2+ FCs
Loop density	Course(cm^{-1})	9	9	8	8
	Wale (cm^{-1})	8	8	8	8
	Surface (cm^{-2})	72	72	64	64
Loop length (mm)		6.83	7.07	7.46	7.53
Thickness (mm)		2.36	2.39	2.38	2.48
Mass per unit area (g m^{-2})		977.6	1001.8	949.2	948.4

In order to evaluate the compressional behavior of the rib knitted fabrics, they were subjected to compression-release cycles using the hand operating thickness tester (TexTesT-360). The samples were compressed and relaxed for five cycles starting with a minimal load (0.29 N), through a progressively increased load from 1.67 N (4.12 N, 6.57 N, 11.48 N) to approximately tenfold load (16.38 N). When the maximum compression force was reached, the test reversed in the same way until the releasing of sample was completed. The thickness of the sample was registered under each compression and recovery stage. The sample thickness measured at the initial force was recorded as the original sample thickness (thickness without added load). The difference in the initial sample thickness (T_0) and their thickness under maximum load (T_{max}) determined the knit compressibility (C) for each compression cycle (Stankovic S., 2006):

$$C = \frac{(T_0 - T_{\max})}{T_0} 100 \quad (1)$$

For each rib knitted fabric, five separate tests were conducted on different portions of the knit, so each numerical value of the thickness was the mean value of five measurements. Based on the compression-release curve for each compression cycle, the energy properties of the rib knitted fabrics were calculated. The amount of energy absorbed is obtained by calculating the area under the compression curve. The area under the relaxation curve defines the released energy. The area covered by the hysteresis loop represents the dissipated energy. The ratio of released and absorbed energy characterizes the ability of elastic recovery, i.e. the resilience of the knitted fabric (RC) (%).

RESULTS AND DISCUSSION

The rib knitted fabrics were produced under controlled settings of the knitting machine. However, some differences in their structural characteristics were noticed (Table 2) as a consequence of internal structure of the yarns. The rib knitted fabrics having as a component the folded hemp yarn were characterized by lower stitch density which in turn was influenced by their lower course density. This can be attributed to the greater mobility of hemp fibers in the two-folded yarn which resulted from almost twice reduced fiber packing density as compared to the single hemp yarn (Table 1). Due to reduced fiber packing density, the flexibility of the folded hemp yarn was higher as compared to the single hemp yarn, and therefore the loop length of the FCo1+FCs and FCo2+FCs knits (Table 2) was higher, and the mass per unit area was lower as compared to the knits having two assembled hemp yarn as a component. As can be noted, the folded cotton yarns were characterized by different bulk density and packing factor (Table 1) due to their different folding twist intensity. As a consequence, their different flexibility could be expected, which resulted in slightly higher mass per unit area of the FCo2+2Cs knit compared to the FCo1+2Cs counterpart, as well as somewhat higher thickness of the FCo2+FCs than that of the FCo1+FCs counterpart.

The compressibility of the rib knitted fabrics, determined as a difference in the initial fabric thickness and its thickness under the maximum compression force is presented in Table 3. The results showed

that the rib knitted fabrics with the less twisted cotton yarn (FCo1) yarn as a component were characterized by higher compressibility as compared to the rib knits composed of the more twisted cotton yarn (FCo2). This can be explained by higher mobility of cotton fibers in the FCo1 yarn (lower packing density, Table 1), as compared to the FCo2 yarn. The comparison between the rib knitted fabrics composed of FCo1 yarn as a component indicated that the FCo1+FCs knit was characterized by higher compressibility, which can be attributed to the increased fiber mobility in the folded hemp yarn (lower packing factor) as compared to the fiber mobility in the single hemp yarn. However, between the rib knitted fabrics composed of the more twisted cotton yarn (FCo2) as a component, that having the folded hemp yarn as another component (FCo2+FCs) was characterized by the higher compressibility as compared to the FCo2+2Cs. It seems that in this case, the effect of higher surface loop density predominated. A higher number of loops on the unit area means a higher number of interlacing points in which the fibers are additionally compressed; hence their reduced mobility. With an increase in the number of interlacing points, the mobility of yarn segments in the knit is also reduced, which all together leads to a decrease in the compressibility of the FCo2+2Cs knitted fabric. In addition to the higher mobility of the fibers in FCo1 yarn, its twice as high hairiness compared to the FCo2 yarn (Table 1) must have contributed to the compensation of the effect that increase in the surface loop density has on the compressibility of the knitted fabric.

Table 3: Compressibility of the rib knitted fabrics

Composition	C (%)				
	1. cycle	2. cycle	3. cycle	4. cycle	5. cycle
FCo1 + 2Cs	23.0	13.7	12.3	11.6	10.6
FCo1 + FCs	25.9	14.5	13.2	12.6	12.2
FCo2 + 2Cs	19.7	10.4	9.60	8.84	8.29
FCo2 + FCs	22.2	12.5	11.3	10.7	10.4

The results given in Table 3 indicate the same described relations for all compression cycles, but the compressibility decreases for each subsequent cycle which indicates the permanent deformation in the rib knitted fabrics under cyclic compression. This is also confirmed by the compression-release curves for five successively cycles presented in Figure 1. Significant changes in the thickness of the knits were exhibited between the first and the second compression cycle. Changes in thickness became smaller in further compression cycles until the fifth cycle after which the thickness change was stopped. However, even when the total deformation of the rib knitted fabrics was decreased with repeating cycles, the compression hysteresis remained due to interfiber friction and the viscoelastic nature of the fibers. As a consequence of irrecoverable fiber rearrangement at the previous compression cycles, the rib knits became less compressible, but the non-elastic deformation also decreased. Therefore, the compression-release curves for the fifth cycle were shifted to the left from the original ones, and the hysteresis loop surface area was reduced with repeated cycling.

Resilience is a general descriptive characteristic of textile materials expressing their elastic reversibility. Compression resilience gives an indication of the ability of the fabric to retain its softness in compression cycles. The values of the compression resilience of the rib knitted fabrics were given in Table 4. As can be noted, the FCo1+FCs knit being the most compressible was characterized by the lowest resilience. Increased fiber mobility in the two-folded hemp yarn caused an increase in the compressibility of the FCo1+FCs, but also a decrease in the permanent deformation of the knit. The highest compression resilience was exhibited by FCo2+2Cs knitted fabric which was characterized by the lowest compressibility. Between the rib knitted fabrics composed of the less twisted cotton yarn, that having the two assembled hemp yarn as a component was characterized by higher resilience. The same trend was observed in the knitted fabrics composed of the more twisted cotton yarn as a component. This effect can be attributed to the higher surface loop density of the knits containing two assembled hemp yarn as a component (Table 2). A greater number of yarn interlacing points in these knits reduced the mobility of the yarn in the knit and the fibers in the yarn, which to a certain extent prevented permanent fiber slippage and rearrangement. As there was a decrease in the permanent changes in the knits with repeated cycles (overlapping of the compression

curves), the compression resilience gradually increased and approached the constant value (Table 4). Therefore, it is expected that with further use, the rib knitted fabrics would exhibit constant values of compressibility and resilience. In other words, the knitted fabrics are mechanically conditioned.

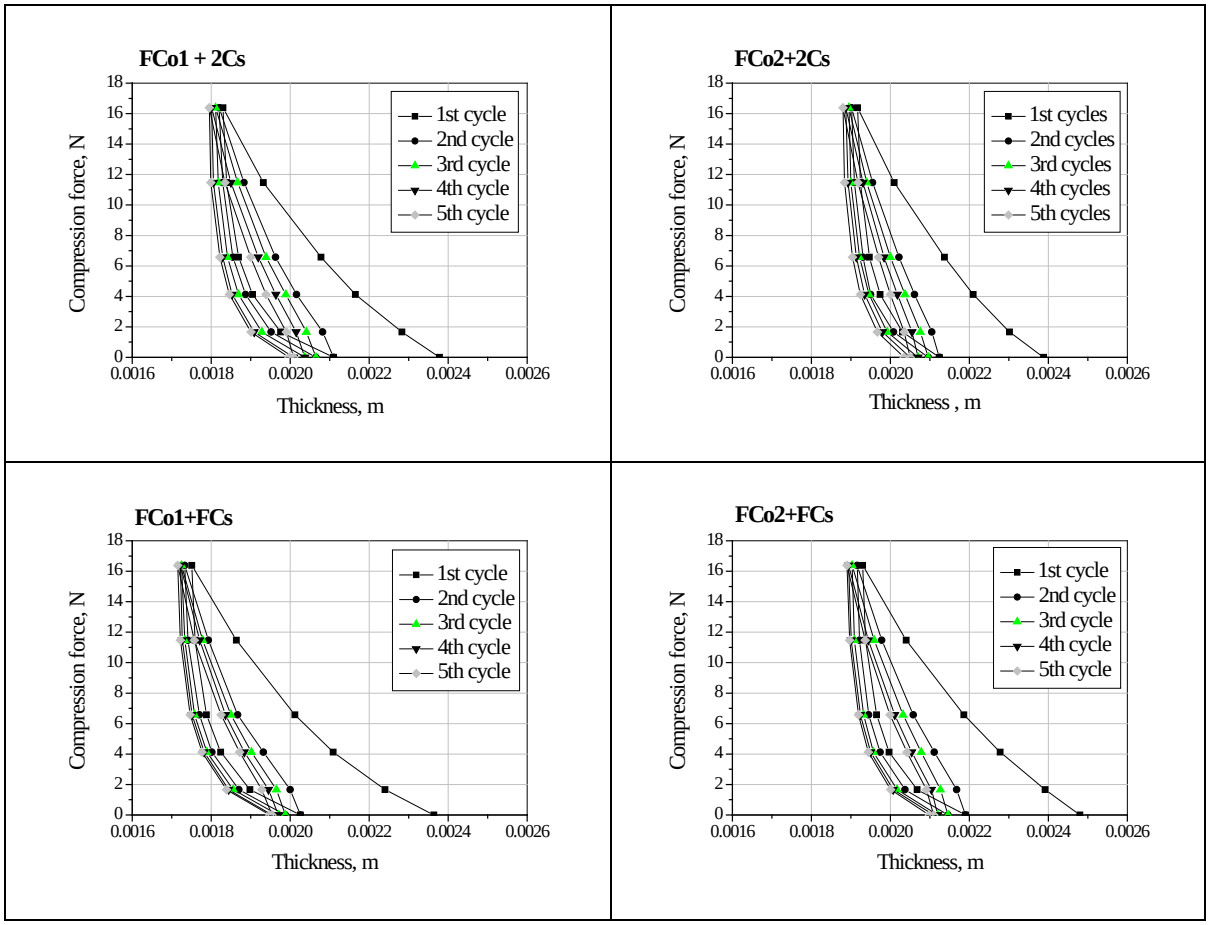

Figure 1: Compression-release curves for five successively cycles

Table 4: Compression resilience of the rib knitted fabrics

Composition	RC (%)				
	1. cycle	2. cycle	3. cycle	4. cycle	5. cycle
FCo1 + 2Cs	92.0	95.9	96.5	96.8	97.1
FCo1 + FCs	90.8	95.7	96.7	96.7	97.0
FCo2 + 2Cs	92.8	96.6	97.2	97.5	97.5
FCo2 + FCs	91.5	96.1	96.7	96.9	96.9

The compression curves define the energy-absorbing properties of the repeatedly stressed materials, and therefore the deformation components were determined by calculating these properties as well as specific parameters – the irreversible compression work of all-cycle compression and the compression work of viscoelastic deformation of all-cycle compression according to the procedure described elsewhere (Stankovic S., 2008b; Stankovic S., 2014). The values of the percentage of plastic (D_p) and viscoelastic (D_{ve}) deformation components are given in Table 5. The obtained results indicate that the knitted fabrics composed of the folded hemp yarn as a component (FCs) were characterized by lower permanent deformation as compared to their counterparts. In addition, the rib knitted fabrics composed of the less twisted cotton yarn (FCo1) were characterized by lower permanent deformation. This can be attributed to increased fibers mobility in the FCs and FCo1 yarns as compared to the 2Cs and FCo2 yarns, respectively.

Table 5: Compressional behavior of the rib knitted fabrics

Composition	$WC^{a)}$, $x10^{-3}$ J (1+2+3+4+5)	$WC_p^{b)}$, $x10^{-3}$ J (1-5)	$WC_{ve}^{c)}$, $x10^{-3}$ J	$D_p^{d)}$ (%)	$D_{ve}^{e)}$ (%)
FCo1 + 2Cs	7.2	3.7	3.5	51.4	48.6
FCo1 + FCs	7.2	3.6	3.6	50.0	50.0
FCo2 + 2Cs	6.1	3.2	2.9	52.5	47.5
FCo2 + FCs	7.3	3.7	3.6	50.7	49.3

[a)] The total non-elastic compression work of repeated cycles, [b)] the irreversible compression work of five-cycle compression, [c)] the reversible compression work of five-cycle compression, [d)] plastic deformation, [e)] viscoelastic deformation

CONCLUSION

The experimental material investigated made it possible to analyze the effect of yarn folding, as well as the folding twist intensity, on the compression properties of the rib knitted fabrics. The obtained results indicated that the effect of yarn folding is reflected through the influence on fiber mobility in the yarn due to which the compression and resilience were modified. The results also indicated that the packing density of yarn can be effectively controlled by the intensity of the folding twist. By increasing the folding twist intensity of the cotton yarns, the fiber packing density increased which caused a reduction in the compressibility but an increase in the resilience of the knits. By increasing fiber mobility in the yarn, plastic or permanent deformation was decreased. Bearing in mind that the geometry of yarns was determined by their composition (hemp and cotton), it can be concluded that the type of fibers influences the packing density of yarns and consequently, the compression properties of the knitted fabrics.

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ADVANCED STUDENT PROJECTS IN THE SPIRIT OF INTERNATIONALISATION

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ABSTRACT

This text examines Project Work as an essential tool for implementing the overall rationales of internationalisation called idealism, instrumentalism and educationalism. The article presents the methodology of the course 'Project Work' and its results comprehended by international students and the methods and outcome of inter-institutional and individual projects carried out by the Author in recent years, from the perspective of internationalisation, as a vital concept and strategic priority in today's high education. The article examines the opportunities for professional fulfilment and development inherent in participation in international education and educational projects. It introduces examples of student projects and the internationalisation potential of instructors.

Key words: internationalisation, project work, teaching practice, high education, self-development

INTRODUCTION

The internationalisation of higher education as a concept and strategic program has evolved and has become an important strategic priority for many high education institutions. More than ever, national, regional, and global university rankings are driving the agendas of institutional leaders to reach excellence in research, teaching, and learning. HEIs are investing significant resources in it, which has evolved from a marginal activity to a critical aspect of the reform agenda during the past half-century. [1] Internationalisation is seen as how HEIs respond to the impact of globalisation. As a necessary means of self-transformation, it allows students and academic staff to see the world from perspectives that transcend their backgrounds, enabling them to learn about new cultures and countries.

This text examines Project Work as an essential tool for implementing the three rationales of internationalisation: idealism, instrumentalism and educationalism. Furthermore, participation in inter-institutional and individual international projects with students is an opportunity for professional fulfilment and development of the instructors' professional, educational, language and intercultural skills.

SELECTED STUDENT PROJECT WORKS – REJTŐ FACULTY, ÓBUDA UNIVERSITY

Project Works provide an excellent way for personal development on many levels; they stimulate problem-solving, self-esteem, and confidence in the student. According to the general education goal, the project must enable the student independently to carry out project work comprehending experimental, empirical, and theoretical investigation of one or more ways of presenting problems within central subjects of the student's education. [2] The 8-credit course 'Project Work' at the Óbuda University can be set up in different fields: textile-, garments, paper- or printing design and technology, marketing, quality and environmental management, and environmental engineering. Projects can be different:

1. Making leaflets, posters, booklets, or websites with information on different topics
2. Designing fabrics-, garments-, leather goods- collections, and fashion designing
3. Creating blueprints
4. Methods, analyses, and technology research in diverse fields of technical sciences, the area of art, and design.

Topics of the practice work with terms and descriptions of the tasks are detailed in a '4-point schedule' in line with the general product design and product development methodology. (Table 1)

Table 1: General topics of the practice work with terms and description

Week	Subjects with a brief description
1-3	Confirming the topic of the project work with the supervisor; task scheduling
4-7	Applied research, the establishment of the requirements
8-12	Methodology, idea generation and design process
13-14	Presentation of the project work and introduction of the readymade prototype and poster

In the following, the methodology will be introduced by three selected students' project works: a project realised in the framework of a summer internship, a project with complex returns realised in teamwork, and a project of a technological nature, realised in the framework of theoretical work.

A four-week internship project with Brazilian students – Academic Year 2014/15, II. Semester

Participants of this project were Brazilian students spending their four-week internship as the final stage of their one-year academic study program in Budapest at the Institute of Product Design of Rejtő Sándor Faculty, Óbuda University. The assignment within the summer practice focused on the development of denim accessories for the brand IKONIKA. The students completed the product development steps following the general methodology during the practical work. They then worked together with their professor in the well-equipped workshop in Budapest, from the phase of gathering inspiration to the design process through the creation of experiments, samples, and templates (stencils) used for printing. [3] (Fig. 1)

Figure 1. Work with the Brazilian students in the workshop of Dr Edit Csanák

Designing of 2018 Spring-Summer Collection in Teamwork – Academic Year 2017/18, II. Semester

Participants of this project work were students on Erasmus+ student exchange from the Technical Faculty "Mihajlo Pupin" Department of Clothing Engineering from Zrenjanin (Serbia). [4] Special features addressed to the students were getting inspiration from the rich and unique treasure of motifs, colours, shapes, and techniques of the cultural heritage and folk art of the Serbs settled in the territory of Hungary. Setting contact with the Serbian Cultural Centre and research work in the library. The unique features were: to contact the legendary Tekelandijanum institution in Budapest and visit Szentendre and the surrounding villages; to present the final results at the Student Scientific Contest and the Global Sustainable Fashion Week.

The further specific task was to organise the work in a team similar to a present-day fashion company; the tasks were broken down among the participants of the project work depending on their best manual, organisational and communicative skills and operational capabilities.

The '4-point schedule' specified the tasks according to the general policy of the course and the universal methodology of product design. It was shared with the student group by the following:

1. Applied research on the latest Spring-Summer 2018 fashion and market trends.

2. The organization of the teamwork and specification of the roles. Time scheduling. Launching a platform using advanced tools to maintain communication. Establishment of the requirements and specification of the project goals. Creation of online mood boards.
3. Framing the design concept of the collection. Preparation of worksheets for 1-3 designs and sewing the prototypes.
4. Elaboration of the experiences in a collective essay.

The joint work of the students resulted in a non-standard fashion collection. The team members agreed to work on one complex fashion collection consisting of 4 capsules in line with each other. The concept was to use four words that begin with the letter S as an association with the coat of arms of the Serbian national flag, known as 4S.[1] They participated in the National Conference of Scientific Students' Associations (OTDK, April 2018). Furthermore, they introduced their work at the internationally recognised professional event Global Sustainable Fashion Week (GSFW, April 2018), representing their country, Serbia. (Fig. 2)

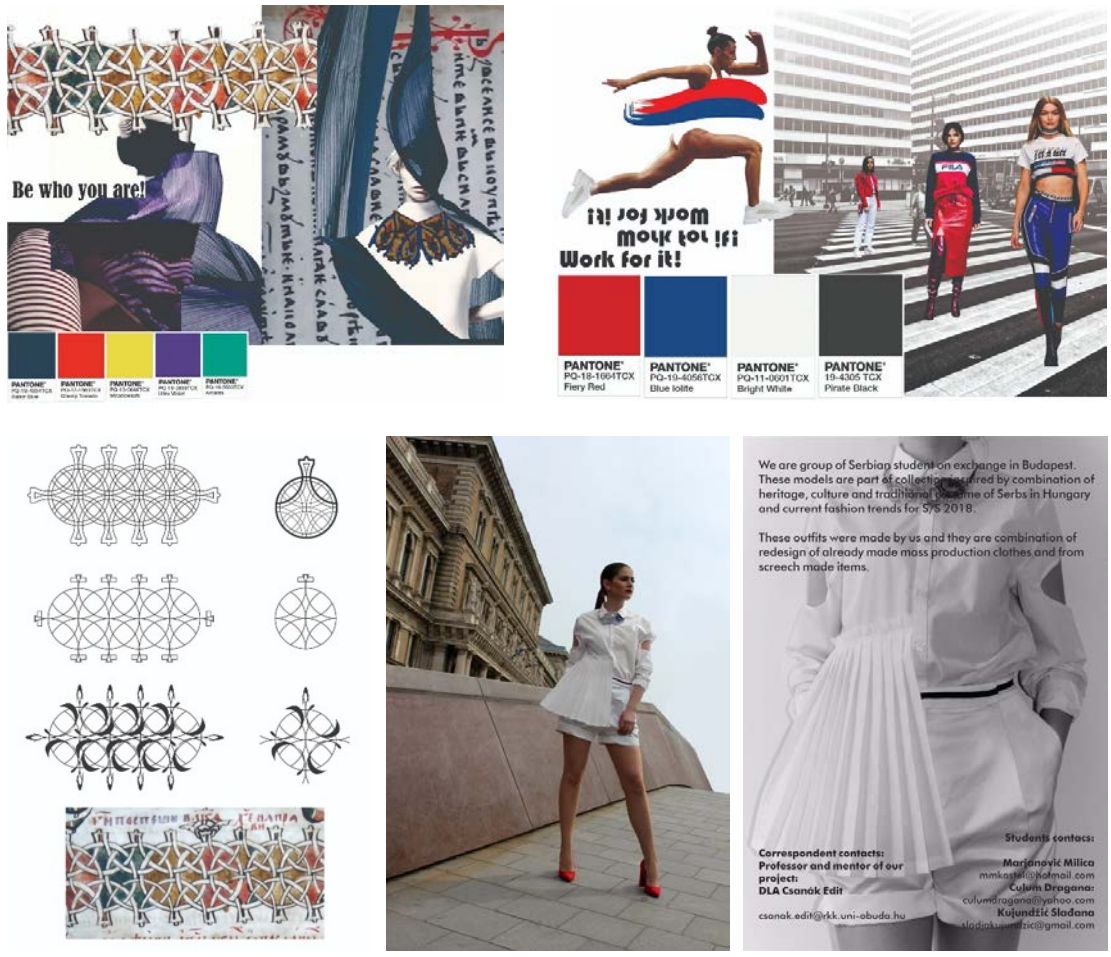


Figure 2: Mood boards, graphic designs, campaign image and flayer of the collection “4S”

Advanced Technologies and Features of the Budapest Metro Line 4

The course 'Project Work' has been chosen by an incoming student from a Technical Faculty in France. The assignment addressed to the student examined forward-looking technologies on the Budapest metro line 4, carried out on observatory analysis and research on the technical features and advanced technology used on the Budapest metro line 4. Since a small number of writings are

[1] *“Samo sloga Srbina spašava!”* – which means: „Only the Unity Saves the Serbs!” – is a national slogan of Serbs. The words picked for the names of the capsules were **S**erbia, **S**trong, **S**tatement and **S**mart.

available in English about the metro lines of Budapest, the research has been carried out based on individual observation and technical interpretation of what was seen. The attention in this research was on the understanding of what is seen. The focus was on five stations of Metro Line 4 (M4), with a particular focus on their innovative technological solutions. To carry out this project, the student visited each station of the M4. Because of their particularities, we decided to focus on five of them. Because of their distinctive design, this project focused on theoretically investigating their technological aspects concerning design and advanced technology. As a result of the student project, a stunning and meaningful report was created, which was published in the form of a joint publication in the English-language periodical published by the Faculty, which, in addition to allowing the student to visit and better understand the metro stations, deepen the knowledge learned at the alma mater and the host institution represented the added value of the project. (Fig. 3)

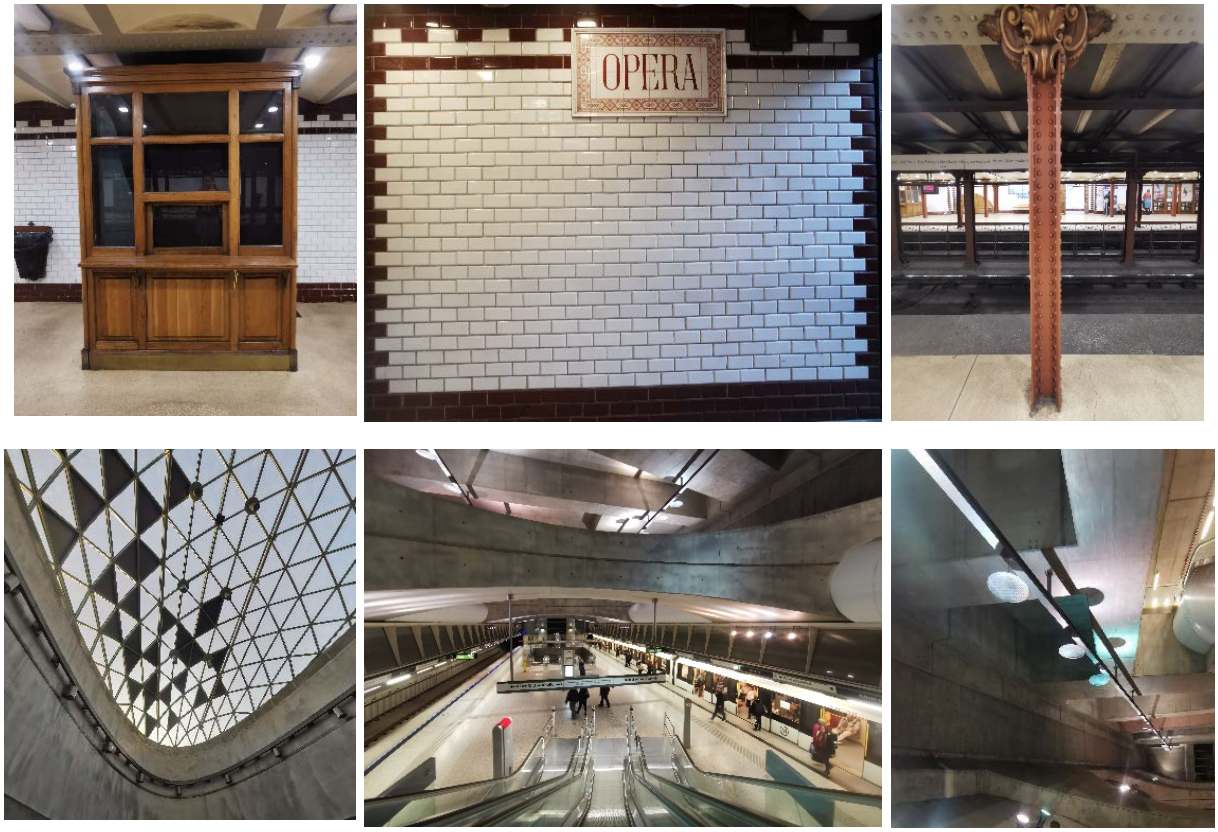


Figure 3. Pictures of the materials used for the construction of Budapest's metro stations

Summary of the Student Project Work outcomes

The above-introduced projects had variable and valuable returns for the students and the instructor. The most significant benefit from the project realised in the framework of a summer internship was the performance of collaboration, deepening one of the vital motivations of HE internationalisation: cultural acceptance and networking. The project, realised in teamwork with a Serbian student team whose members came from different backgrounds and levels of education, was a new experience for the Serbian-speaking instructor from the point of view of deepening the culture of her native country and practising the native Serbian language. Application of the standard methodology gave complex results for the students:

1. They learned the general methodology of product design and collection development and can apply it in their future professional life in the fashion industry.
2. Presentation of the project work at the scientific contest helped integration into University life.

3. Presentation at an international fashion event gave special recognition to this project.
4. The students’ complex- and soft skills advanced during the collective work.

The technological project helped the student to know the city better during her stay, which allowed easier integration. The student could use and deepen the specialised knowledge gained at her alma mater institution within the customised framework. At the same time, in an essay written according to the method of the host institution's methodological expectations, she could raise her knowledge of design methodology acquired during the exchange semester.

THE SIGNIFICANCE OF INTERNATIONALIZATION IN TEACHING PRACTICE

Internationalisation is frequently reduced to "study abroad" initiatives or student exchanges, but it is much more. The goal of "becoming international", in addition to maximising opportunities of acquiring international and intercultural competencies for the student (including "students at home"), can also be a strategic objective for the institutions and personal motivation for the instructors. Putting study program competencies with an international/intercultural approach into one’s teaching practice contributes to internationalisation by providing long or short-term teaching services. It is also an effective form of self-development which’s most significant benefits are:

- enhanced critical thought;
- improved problem-solving and creative skills;
- individual development;
- enhanced language skills;
- a more considerable sensitivity the society.

Experiences will be summarised by the introduction of 2 selected education internationalisation projects: working as Visiting professor (International teacher) at the Jianghan University in China (Wuhan, Hubei province) in the School of Design during the academic year 2018/19, winter semester, and establishment of the new course ‘Creative Thinking’ at the Rejtő Faculty in 2021, to host special lectures of visiting instructors from abroad.

131 Days in China – Design and Methods

This part of the article focuses on the methodology of working with International students in China. The author has been working at Jianghan University in Wuhan (Hubei province) in the School of Design as an International teacher – (Visiting professor) for one semester before the COVID-19 Pandemic in the academic year 2018/19_I. [5]

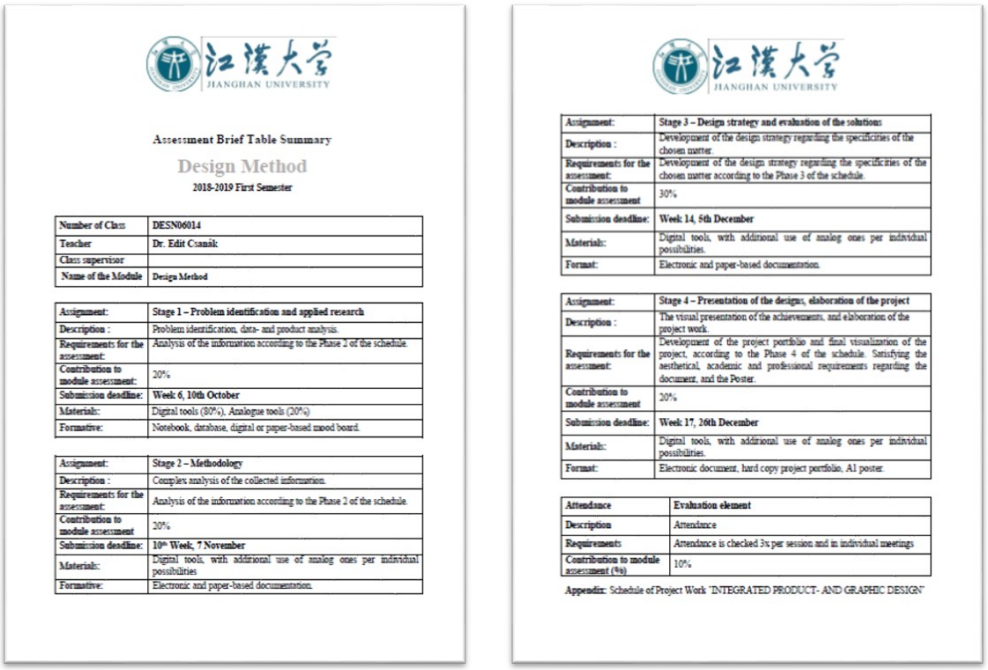
The School of Design is one of the 19 schools formed by Jianghan University, one of the largest universities in Wuhan. The school, established in 2008, invites prestigious experts and scholars to open up extracurricular classrooms for the students' talent development. The Author has developed the methodology of three subjects for the Study Program of Graphic Design; Design Method, Graphic Design and Visual Word, and Image Creation and Animation.

The curriculum of the subject Design Method: The module deals with the impact of social and cultural changes on typographic design. Students examine the relationship between the meaning of a word and its typographic expression. The module aims to present the views and work of leading graphic designers, which design methods are expected to be applied independently. The module encourages students to engage with less traditional approaches to creating solutions. To this end, they are expected to be continuously involved in independent lead research activities and to make graphical comments based on everyday observations and experiences. The development of presentation and presentation skills was also part of the curriculum.

Design Method Assessment Brief Table Summary: The document details how the students are expected to solve phases of product development in their projects while developing their visual design

skills. The method refers to the process of problem definition, applied research, concept generation, and evaluation. Steps are:

- **Stage 1 – Problem identification and applied research:** Problem identification, data- and product analysis.
- **Stage 2 – Methodology:** A detailed analysis of the collected information.
- **Stage 3 – Design strategy and evaluation of the solutions:** Development of the design strategy regarding the chosen matter's specificities.
- **Stage 4 – Presentation of the designs, elaboration of the project:** The visual presentation of the project's achievements and elaboration. (Fig. 4)



JIANGHAN UNIVERSITY

Assessment Brief Table Summary

Design Method

2018-2019 First Semester

Number of Class	DESN06014
Teacher	Dr. Edit Csanák
Class supervisor	
Name of the Module	Design Method

Assignment:	Stage 1 – Problem identification and applied research
Description :	Problem identification, data- and product analysis.
Requirements for the assessment:	Analysis of the information according to the Phase 2 of the schedule.
Contribution to module assessment:	20%
Submission deadline:	Week 6, 10th October
Materials:	Digital tools (80%), Analogue tools (20%)
Formative:	Notebook, database, digital or paper-based mood board.

Assignment:	Stage 2 – Methodology
Description :	Complex analysis of the collected information.
Requirements for the assessment:	Analysis of the information according to the Phase 2 of the schedule.
Contribution to module assessment	20%
Submission deadline:	10th Week, 7 November
Materials:	Digital tools, with additional use of analog ones per individual possibilities
Formative:	Electronic and paper-based documentation.

JIANGHAN UNIVERSITY

Assignment:	Stage 3 – Design strategy and evaluation of the solutions
Description :	Development of the design strategy regarding the specificities of the chosen matter.
Requirements for the assessment:	Development of the design strategy regarding the specificities of the chosen matter according to the Phase 3 of the schedule.
Contribution to module assessment	30%
Submission deadline:	Week 14, 5th December
Materials:	Digital tools, with additional use of analog ones per individual possibilities.
Format:	Electronic and paper-based documentation.

Assignment:	Stage 4 – Presentation of the designs, elaboration of the project
Description :	The visual presentation of the achievements, and elaboration of the project work.
Requirements for the assessment:	Development of the project portfolio and final visualization of the project, according to the Phase 4 of the schedule. Satisfying the aesthetical, academic and professional requirements regarding the document, and the Poster.
Contribution to module assessment	20%
Submission deadline:	Week 17, 26th December
Materials:	Digital tools, with additional use of analog ones per individual possibilities.
Format:	Electronic document, hard copy project portfolio, A1 poster.

Attendance	Evaluation element
Description	Attendance
Requirements	Attendance is checked 3x per session and in individual meetings
Contribution to module assessment (%)	10%

Appendix: Schedule of Project Work 'INTEGRATED PRODUCT- AND GRAPHIC DESIGN'

Figure 4. Design Method Assessment Brief Table Summary

The Table in-depth details the evaluation criteria for a given task. Each step has been evaluated separately for each project work. Training outcome requirements include a detailed description of the project task and deadlines, making it clear to students what to do.

Design Method – The project task description: The overall objective:

- To develop a new product from an existing one, focusing on features;
- To make the product better, applying innovative solutions;
- Focus on quality;
- Focus on graphic design.

Design Method – Presentation of theoretical and practical work: The presentation session aimed to develop the students' presentation skills. Students were allowed to give a lecture in Chinese, as only a few of them could provide a speech in English. (Fig. 5) **Essays** submitted for evaluation and the **posters** prepared were presented at the end-of-the-semester exhibition. (Fig. 6, and Fig. 11)

Figure 5. Students were allowed to give a lecture in Chinese, as only a few students were able to give a lecture in English

Figure 6. Design Method – Selected Posters of the Project Work

Graphic Design & The Visual Word curriculum: The module encourages students to formulate their design views and working methods. Students were expected to focus on exploiting their particular strengths; be illustrative, typographic, stylised, and accurate.

- Development of visual observation and manual capabilities;
- Analysis of the visible world;
- Understanding of the visual cognition process;
- Clarifying the concepts of realistic representation and stylisation and understanding the difference between them;
- Exploiting particular strengths by using analogue tools in combination with digital ones;
- Exploration of ideas in a series of designs made in a holistic approach by confident application of elements and principles of art and design;
- Application of typography as a core subject within the graphic design; micro and macro aspects of typography; versatility and diversity of typography's artistic and practical application;
- Exploration of the relationship between the spoken word and written text and between the visual expression and the graphics image were core elements of the subject's content.

Graphic Design & The Visual Word – Assessment Brief Table Summary: The complex and challenging assignments were broken down into stages:

- **Stage 1 – Exercise 1: Figural composition:** Series of graphic design composition with stylised figural objects. (Fig. 7)
- **Stage 2 – Exercise 2: Identity design:** Designing a label system for a fashion brand; identity design for an imaginary brand choosing the purpose of the label, with integrated application and evaluation of typography. (Fig.8)
- **Stage 3 – Final Exam: Graphic design of consumer goods:** Graphic design of fashion goods for an imaginary fashion brand. (Fig. 9)

Figure 7. Graphic Design, Exercise 1: Figural Composition

Figure 8. Graphic Design, Exercise 2: Identity design for a Fashion Brand

Figure 9. Graphic Design, Final exam: Graphic Design of Consumer Goods

The curriculum of Image Creation & Animation (Experimental Animation): The module focuses on exploring the principles of imaging and animation as a time-based medium.
Image Creation & Animation Assignment – Creation of Motion Graphics Sequence: The challenging assignment was broken down into stages:

- **Assignment stage 1:** Examination of human proportions and movement. Freehand drawing and sketching of the figure (pen sketch). Creation of the character with a focus on solid drawing and exaggeration.
- **Assignment stage 2:** Concept and storyboard - Working out of a storyboard to an animation sequence. Creation of a character.
- **Assignment stage 3:** Methodology - Analysis, focusing. Ideation of the sequence, digitalisation of the character, and creating a flip book. (Fig. 10)
- **Assignment stage 4:** Final Animation - Creating a few-second animation sequence using animation software (time-based media) and digital tools.
- **Assignment stage 5:** Presentation of achievements.

Figure 10. Exp. Animation: Assignment stage Flip-Book

Figure 11. End of semester exhibition: 2 teachers, 96 students, over 200 works

Outcomes of personal development and development of individual teaching portfolio: Altogether, 33 lectures have been created in Prezi software and held from 3 subjects.

- Design Method: 10 lectures
- Graphic Design: 14 lectures
- Animation: 9 lectures

Students had to work on different projects, creating a conceptual solution on a specific topic related to graphic design, preparing both textual and artistic content, developing their manual and intellectual skills, and working freehand and with computers.
Part of the lectures has been uploaded to the website www.editio.hu.[2] The lecture's transcript is also available for most content in PDF or flip-book format. QR-Code allows easy access to the contents, even to be browsed on a smartphone.

Establishment of a course on Creative Thinking

International visiting professors contribute to the intercultural dimension of the institution, adding value to the specific course(s). To adequately contextualise their contributions to students' study and ensure that they do not fit seamlessly into the logical structure of a particular unit (which problem frequently occurs), the Rejtő Faculty decided in 2021 to create an elective course, "Creative Thinking

[2] Access link: https://editio.hu/jianghan-university/

I.”. The course aims to deal with the connections that arise during problem-solving, approaching them from different areas of the profession. Students become familiar with the unique areas of contemporary design theory and address the special needs that arise during design, approaching them from specific disciplines. By addressing the particular issues and criteria of putting theory into practice, the goal is to sophisticate the relationship to object creation and deepen creative thinking.
From its beginning, the Product Design Institute of the Rejtő Faculty hosted lectures of 5 internationally recognised researchers in the framework of ERASMUS+ Teaching Mobility and cooperation of the Doctoral Schools. The course timetable is custom, depending on the planned period of the psychical training activity of the guest lecturer.

LABi3 – INTERNATIONAL PROJECT COOPERATION

According to an MoU dated 2019, signed by the Rejtő Sándor Faculty of Light Industry and Environmental Engineering of Óbuda University with the Hochschule Hannover University of Applied Sciences and Arts, the Rejtő Faculty participates in an international project the LABi3, which aims to develop innovative teaching methods and educational materials on the topic of Sustainable Circular Economy (SCE). Instructors from the Institute of Environmental Engineering and, from 2020, the Institute of Product Design participate in the Project, cooperating with international partner institutions from 5 countries, involving different academic disciplines.

The collaborative student group of the two institutes applied to the LABi3 1.0 Photobook Project with the topic of textile waste recycling. The work has been organised as prescheduled online meetings in which the participating universities worked out the framework of the expected final achievements. The final goal was to develop new teaching materials and methods using advanced tools and technology.

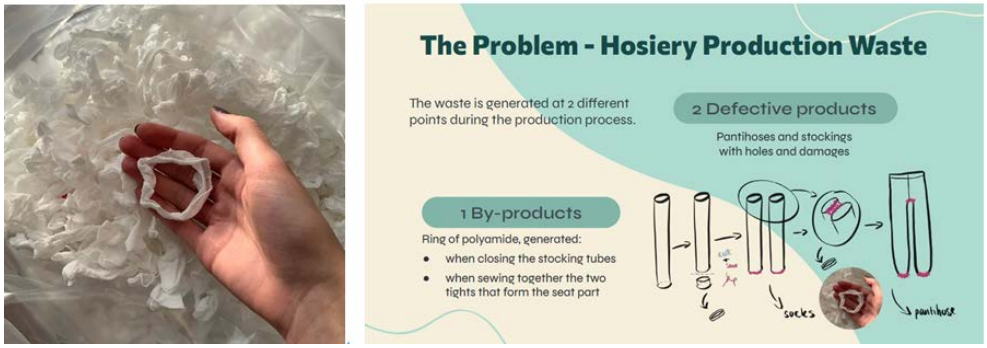


Figure 12. Illustration from the LABi3 1.0 Photobook Project publication

The Óbuda University Student group article, *"Circular Economy in The Textile Industry – A Case Study"*, has been published as part (chapter) of the student research publication book. In 2021, LABi3 1.0 was completed, resulting in 1 student publication and two faculty/university affiliation publications. [6] [7] The new LABi3 2.0 Photobook Project project cycle began in September 2022. The instructors and students were invited to personally participate in a one-week workshop, which will take place in November 2022 in Hannover.

CONCLUSIONS

The internationalisation of higher education as a concept and strategic program has evolved and has become an important strategic priority for many high education institutions. More than ever, national, regional, and global university rankings are driving the agendas of institutional leaders to reach excellence in research, teaching, and learning. Participation in *inter-institutional and individual international projects with students is an opportunity for professional fulfilment and development of the instructors' professional, educational, language and intercultural skills.* This text examined

Project Work as an essential tool for implementing the three rationales of internationalisation: idealism, instrumentalism and educationalism. The article presented the methodology of the course 'Project Work' and its results comprehended by international students. The text introduced the methods and outcome of inter-institutional and individual projects carried out by the Author in recent years, from the perspective of internationalisation, as a vital concept and strategic priority in today's high education. The article examined the opportunities for professional fulfilment and development essential in participation in international education and educational projects on examples of student projects and also from the potential of self-development and growth of the education portfolio of the instructor.

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PAPERS

APPLICATION OF LASER ENGRAVING ON ACETATE FABRIC FOR CLOTHING DESIGN

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ABSTRACT

Laser engraving technology is an environmental protection technology that is water-free, eco-friendly, and low-energy consumption during treatment. The application of laser engraving technology can improve production efficiency and save labor costs. This paper summarizes the application of laser engraving technology for acetate fabric embellishment in clothing design with different patterns. The experimental results show that the surface fibers of the fabric can be melted and evaporated after laser engraving with color changes effect, and the processing effect of matte printing is formed. This technique applied design application provides an efficient surface treatment method for acetic fabric which is accurate and environmentally friendly. It provides new design possibilities for the embellishment of textile and garment design with acetic fabric.

Key words: laser engraving, pattern, acetate fabric, clothing design, sustainability

INTRODUCTION

The problem of pollution and waste of resources in the textile and garment industry has always received widespread attention. Textiles in the finishing processing, will produce a large number of printing and dyeing wastewater and air pollution, printing dyes, finishing agents, surfactants and other chemical agents produced by heavy metals, formaldehyde, carcinogens and other harmful substances will not only cause pollution to the environment, but also have certain health hazards to the contact (Kant, 2012). Sustainable development is undoubtedly the direction of the development of the textile and garment industry today. As an environmental protection technology, laser is in line with the sustainable development trend of the industry and is also widely used in the industry. The environmental protection of laser engraving technology is mainly reflected in the following two aspects. First, the laser engraving process does not require the participation of chemical reagents such as water and dyes, which will not cause pollution to the environment and save water resources. Second, thanks to the precision of laser technology, the use of laser technology can reduce fabric loss during processing. The use of laser engraving technology can be used to surface treatment and redesign of textiles, enrich the appearance of products, and improve the added value of products and designs.

Many domestic and foreign scholars have studied the application of laser engraving on clothing and textiles from the perspectives of fabric performance effect, appearance effect, design application, etc., among which the experimental research objects are mostly denim fabrics and polyester fabrics. Scholars Nayak R and Paddye R classify laser technology according to the medium, summarize the various applications of laser technology in clothing production, and discuss the potential hazards and health problems of laser technology (Nayak & Padhye, 2016). Scholars Juciene M (Juciene et al., 2014), Kan (Kan, 2014) and others analyzed the influence of laser technical parameters on the color of denim. Scholar Kan and Chi-wai used CO_2 laser to fade two types of denim fabrics and perform subsequent analysis (Kan, 2014). Scholar Yuan G. X. et al. used laser engraving technology to polyester textiles and studied the effect of laser treatment on fabric properties and the application of laser engraving treatment in clothing design (Yuan, 2012). In addition, scholar Seo M. and Koo Y. S. used laser technology to sculpt polar fleece fabrics and perform functional testing and visual evaluation (Seo & Koo, 2017). In this paper, through the laser engraving experiment of a single-sided acetate fabric, it is concluded that the laser engraving on the acetic acid fabric can achieve the matte

printing effect, and the comparative analysis obtains the experience of applying laser engraving technology on the acetic acid fabric for fabric reprocessing for design reference application.

METHODOLOGY

The laser has the characteristics of strong controllability, stable and concentrated energy, good directionality, and fine beam (Nayak & Padhye, 2016). The use of laser technology to engrave the fabric is to use a laser with a certain energy value to quickly heat the area to be treated, so that the fibers and dyes in the heated area produce high-temperature melting, vaporization and etching reactions (Ghorannevissa, 2007). The influencing factors of the laser treatment effect include the laser energy intensity, the thickness of the processed fabric, composition, structure and dyeing and finishing process. According to the difference in surface treatment effect, the application of laser engraving to fabrics can be divided into laser hollow carving, laser embroidery, laser etching, and laser fading.

Laser engraving and embroidery

Laser engraving is the use of laser beams to cut the fabric according to the set pattern to form a hollowing effect, commonly used in leather materials, synthetic fiber fabrics. The boiling point of the leather material is very low, and the tear strength is large, and the material irradiated by the laser beam will evaporate immediately, without burn marks or deformation, and it is not easy to break after hollowing out (Vasanth & Muthuramalingam, 2019). The edges of the synthetic fibers are melted and gelatinized after laser cutting, and the edges are flat and without burr (Nayak & Padhye, 2016). Laser hollow carving is not suitable for selecting fine line patterns and large-area hollow patterns, and it is necessary to ensure that the lines after hollowing out are not easy to break when designing patterns. Dense patterns can be achieved in combination with laser hollow carving and laser etching, reducing the hollow area and increasing the layering of the pattern. The cutouts of long lines can be fixed with the help of other lines or blocks (Hu et al, 2016). In addition, laser cutting can also be combined with computer embroidery, computer embroidery can cover the raw edge after cutting. Laser embroidery can efficiently complete multi-layer composite cutout pattern embroidery fabrics, mostly used in lace patterns and lace production (Ni & Zhang, 2018).

Laser engraving and laser colour-fading

Laser engraving is the laser on the surface of the fabric of the fiber melting, gasification to produce an etching effect, laser will be the surface dye gasification after the formation of the fading is called laser fading, the specific discoloration effect and the fabric of the natural color and dyeing situation is related. Laser fading is most used in the treatment of various denim fabrics, and it is often possible to sculpt a gradient pattern that is lighter than the color of the fabric by changing the size of the laser energy, and some fabrics have a yellowish color that has been laser faded (Kan, 2014). In addition, after the fabric of different materials is laser etched, the thickness and surface texture of the fabric will change accordingly. Fabrics with large thickness and multi-layer structures are suitable for laser etching, and the pattern and fabric surface produce a thickness difference after engraving, forming an emboss-like effect. Laser etching of multi-layer structural fabrics also produces contrasts between different layers of structures (Hu et al., 2016).

Effect of laser engraving treatment on fabric

Laser engraving can directly produce changes in the appearance of the fabric after treatment, while also affecting the structure, touch and partial performance of the fabric. After laser engraving, the molten fibers destroy the original tissue structure, hardening the surface and making it less breathable. As a result, the tear strength and tensile strength of the fabric are reduced, and the etching effect of the warp and weft directions is average (Yuan et al., 2012). When designing laser engraving applications for fabrics, it is necessary to fully consider the material, structure and application scenarios and

performance requirements of the products to ensure that the treated fabric can meet the standards of consumption.

EXPERIMRENTAL

Treatment parameter

The experiment used a CO_2 laser (SEI Laser, Italy) to engrave the fabric surface. The specific parameters are as follows:
(1) Resolution (dpi): raster axis: 80, vertical axis: 100
(2) Speed (mm/s): 12000
(3) Jump speed (mm/s): 12000
(4) Jump delay (μs): 1000
(5) Light delay (μs): 800

Materials

Acetate fiber is a kind of man-made fiber spun from acetylated cellulose pulp. It similar to the appearance of mulberry silk fabric which could present soft drape, delicate luster and good function (Ni R. and Zhang Y., 2018). In this experiment, the acetate fabric with a grammage of 320g/m^2 is applied.

Process

The experimental process for laser engraving are divided into four main steps: (1) Use Adobe Illustrator and Adobe Photoshop software to design patterns and ensure that the patterns are in gray mode. The engraving effect of the gradient can be achieved by adjusting the gray value of different areas of the pattern; (2) Set parameters and complete equipment debugging to ensure that the engraved pattern is clear; (3) Use the gradient strip pattern to engrave the fabric, compare the engraving effects of different intensities, and determine the required laser intensity; (4) Place the fabric on the laser engraving table, adjust the pattern size and confirm the treatment position, and carry out laser engraving processing.

Results

In this paper, two patterns were designed for laser surface engraving (Figure 1 and Figure 2). The pattern treatment experiment selected 40%, 60% and 80% as the energy intensity, respectively. The experiment shows the effect of three lasers of different energy intensities on the fabric (Figure 3). The pink acetate fabric is carved with 40% energy and the pattern is powder white, with a clear silhouette and a matte effect. The pattern part is slightly stiffened to the touch. After the pink acetate fabric is carved with 60% energy, the pattern is pink and white, the square in the pattern is dark pink, and the pattern is incomplete and incoherent. After the pink acetate fabric is carved with 80% energy, the pattern is pink and white, and the square in the pattern is a yellowish dark pink, and the pattern is roughly complete. Through laser engraving experiments, it is determined that 40% of the intensity of energy is better on the engraving effect on the experimental fabric. Among the three patterns of points, lines and surfaces, the engraving effect of the dough pattern is the best.

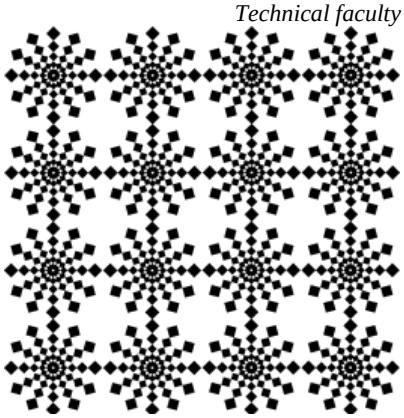

Figure 1: Fig. Pattern design style I

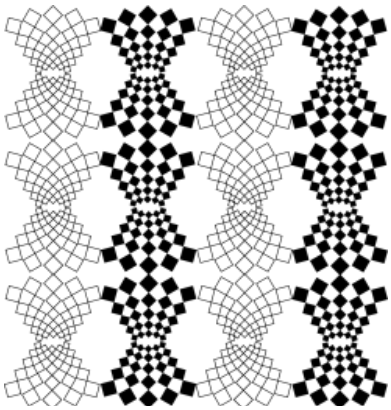

Figure 2: Fig. Pattern design style II

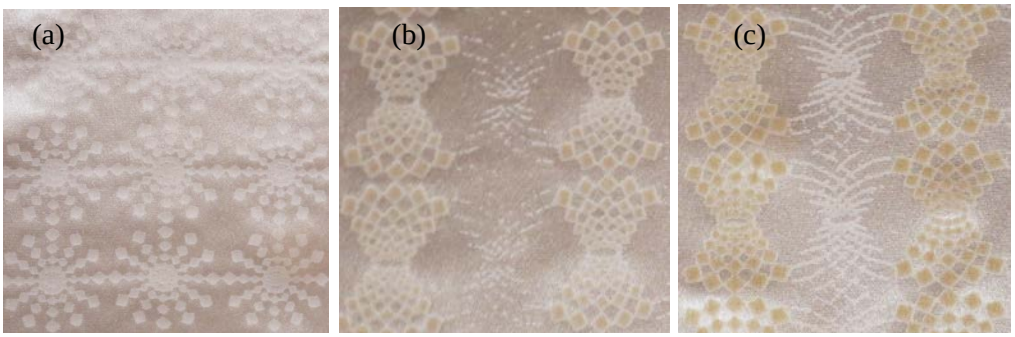

Figure 3: Acetate fabric after laser engraving
(a. Laser beam treatment at 40% intensity; b. Laser beam treatment at 60% intensity; c. Laser beam treatment at 80% intensity)

DESIGN APPLICATION

The most common acetate fabric is woven satin fabric, which is widely used in dresses, scarves, ties, suits, shirts, skirts, and clothing linings. This design is inspired by bionic floral origami (Figure 4), and the skirt is mainly made of satin acetate. After the bionic origami experiments, different folding effects were compared and the origami with phalaenopsis style was selected and applied at the chest of the dress to emphasiz as the visual effect of the overall garment. At the same time, starting from the whole, the A-shaped skirt of the triangular insert was designed. Extracting the phalaenopsis element, a laser-engraved pattern of petal textures was designed on a triangular insert. The slender lines at the beginning and end are divergent from top to bottom, changing with the shape of the skirt inserts. According to the effect of the laser engraving experiment above, 40% of the laser intensity is selected for engraving.

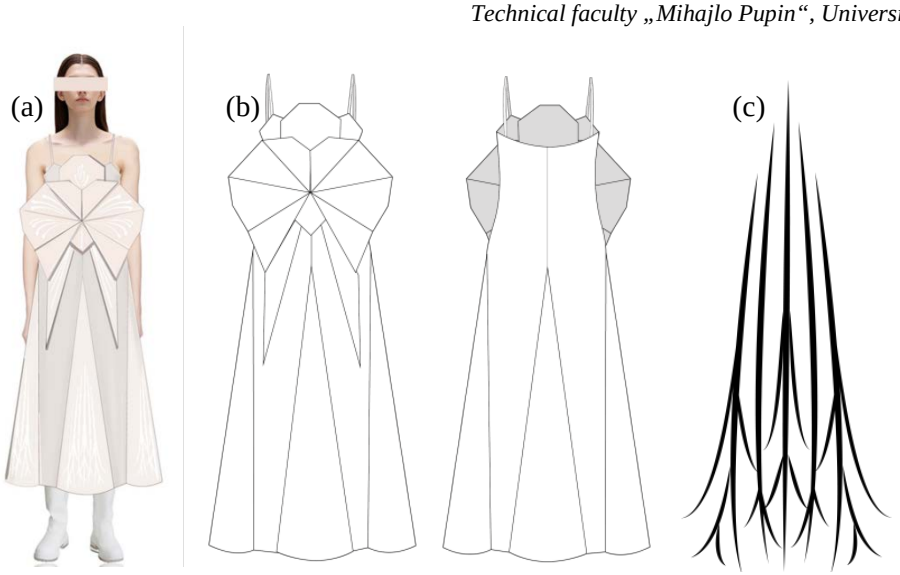

Figure 4: Garment design by using laser engraving
(a. Illustration; b. Technical drawing; c. pattern design for laser engraving)

On the basis of the origami shape on the chest, the ready-to-wear adds a pleated organza decoration with laser hollow polka dots (Figure 5), adding a sense of agility. The production process is to establish the folding shape and draw the crease diagram (Figure 5-a), engrave on the organza with laser equipment, and manually crimp the fabric according to the fold line to obtain the effect as shown in Figure (Figure 5-b). Design the arc cutting pattern (Figure 5-c), and cut the hollow pattern to obtain (Figure 5-d). The laser-engraved white crease line becomes hard, which is convenient for the smooth organza to be folded. The arc and dots obtained by cutting are symmetrical to each other, forming an elegant corrugated shape with a sense of melody.

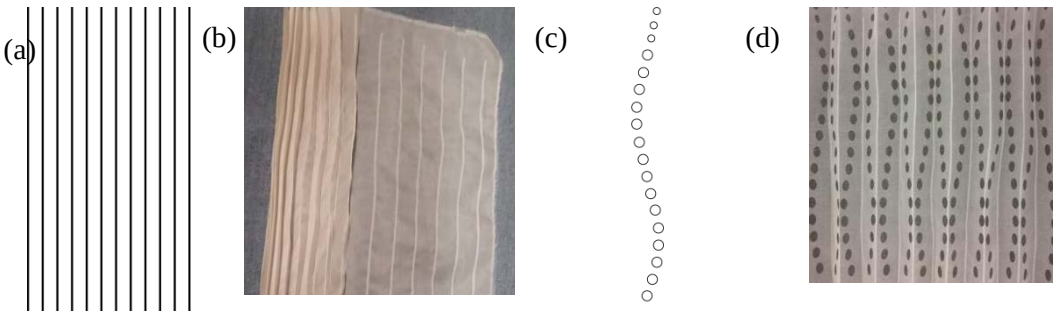

Figure 5: Process of embellishment for fabric by using pleating and laser engraving
(a. Pleating line pattern; b. Pleated fabric; c. laser pattern; d. laser engraved fabric)

The effect of the petal texture pattern on the skirt is looming, and the divergent petal lines and pleated decorations echo each other (Figure 6). The matte engraving effect and the delicate luster of the acetate fabric form a texture contrast, which enhances the layering of the overall clothing.

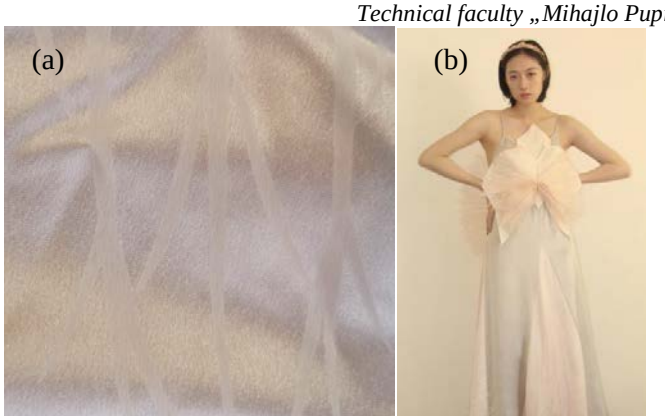

Figure 6: Clothing design by using laser engraving
(a. detail of laser engraved fabric; b. Clothing design)

CONCLUSION

Laser engraving is an environmental protection technology, which is widely used in clothing industry. This design approach by using laser engraving provides a perspective for sustainable clothing design and research, as well as to provide ideas for creative design. From the perspective of enterprises, the application of laser engraving can increase the added value of garment products, improve production efficiency, save labor costs, and thus improve market competitiveness and economic benefits. In addition, it can also comply with industry trends and help enterprises establish an environmental protection value. The application of laser engraving technology in clothing and textile design can be achieved by laser hollow carving, laser embroidery, laser etching, laser fading, laser welding, etc. This versatile technology can be applied to diverse fabrics to form a variety of embellishment effect. The experiment results show that the application of laser engraving technology on glossy acetate fabric can form a printing effect of matte dark pattern, and the surface fibers of the engraved pattern are melted, forming a texture contrast with the glossiness of acetate fabric. Among the three patterns of dot, line and plane, the engraving effect of plane pattern is the best. The use of laser engraving technology can efficiently position and embellish acetate fabrics or related garments, which can enrich the design and appearance of fabrics. In this process, water and other dyeing and finishing are not required, which can enhance the added value of fabric products and designs.

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MONITORING OF STABILITY OF PRODUCTION PROCESS OF LADIES TIGHTS APPLYING STATISTICAL METHODS

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ABSTRACT

The primary goal of every manufacturer is to produce the highest quality products in the shortest time. Thus, in today's conditions of modern production and modern market, it is necessary to apply modern control using statistical methods. The market, where there is a lot of competition, sets stricter requirements in terms of quality, price and delivery of the product and services. Therefore, it is necessary the companies to work properly, by applying appropriate tools and methods that will help to increase its competitiveness, functionality and productivity. At the same time, the companies' needs to fully meet the strict requirements and expectations of its customers by striving to continuously quality improvement, reducing the variability of all processes and improving their capability. Therefore, the application of statistical methods get more important role as an assistance in quality management. Usage of statistical tools, especially control charts, can also significantly contribute to meeting the standards requirements. Also helps to determine if particular process is stable regarding variability and to evaluate the influence of external and internal factors. The paper investigates the occurrence of defects in the production of lady's tights. The Control charts are the applied tools for determination whether a production process is in a controlled statistical state. This control chart is a graph, which is used to study the process changes over the time.

Key words: Quality control, statistical process control, p- and np- control charts, variability

INTRODUCTION

No matter how far technology goes ahead, in practice products do not indicate a 100% compliance with required standards (Başar A. *et al*., 1999). Continuous improvement is essential to ensure superior quality (Ertugrul I. *et al*., 2014). In order to achieve a successful quality control process, it is necessary to apply appropriate statistical techniques that would perform timely control and recognition of disputed situations that could disrupt the dynamics of the production process (Blagojevic N.P. *et al*., 2016).

Deming W.E. describes Statistical Quality Control like: "Statistical Quality Control covers all application stages in production of statistical principles and methods in order to ensure the production of a product the most economically and the highest usefully and also in the way of having a market" (Baskan Ş., 1997). Statistical process control is a tool used for minimizing the production of defective products and a tool which aims at adherence to the standards, also enables production to comply with expected quality specifications (Şahin O., 2013).

Reasons of variability for quality are divided into two groups as general and specific reasons. General reasons are random impairments existing in process functions and the ones which consist of natural reasons. These mentioned impairments cause predictable variabilities in process characteristics of products and they can't be destroyed unless there isn't variability in the business. General reasons occur based on some factors like working conditions, technological levels of machines, the nature of quality program, the determination of raw materials features. Specific reasons cause unexpected impairments in the process and in the product variability. Specific reasons aren't related to the characteristics of process; they are impairments resulting from a certain reason like workers position, raw material noncompliance, distortions of machine settings. The presence of specific factors is immediately understandable in a well-designed process control. The presence of change because of specific reasons can only be determined by statistical process control (Dülgeroğlu K.Ö., 2010). The most important aim of statistical process control is to keep process under control by terminating specific reasons of process change (Işığıçok E., 2005). The production process is under statistical

control if only natural variations are present, while if the presence of some unusual variations is observed, it is considered that is out of control. Timely identification of the sources of such variations is very important for quality maintenance (Abbasi S.A. *et al*., 2012).
Control cards can be used to evaluate the parameters of the production process, and also can provide information that can be useful for improving the process. It is considered that the most important role of control cards is in enhancement and improving the processes, Figure 1 (Montgomery, D.C. *et al*., 2011).

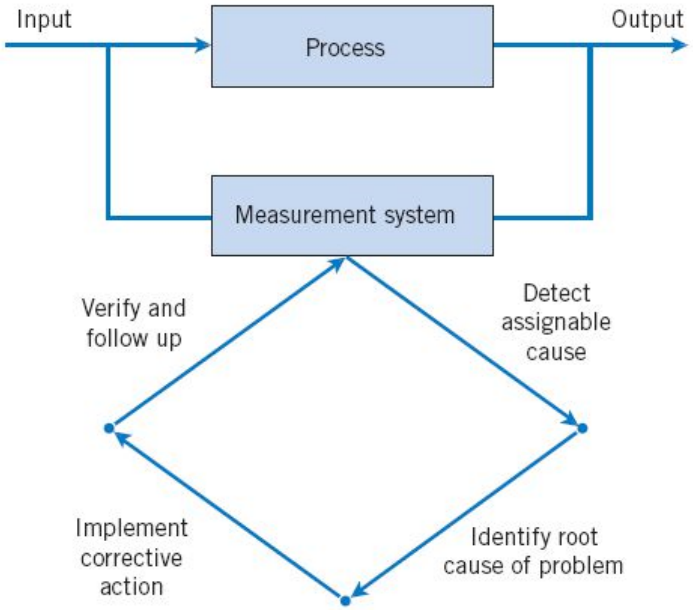

Figure 1: Process improving by application of control cards

The use of control charts is a step to be taken previously to destroy determinable reasons to minimize the process variability and to stabilize the process performance (Montgomery D.C., 1991). The control chart is a graphical display of the process by which can be obtained information that are needed to be understand its current quality performance. They represent a "picture" of the process. They shows how the measurable data (for process, product, machine, worker, tool, etc.) are moving in a certain period of time and what needs to be done to be improved (Mudronja V., 2013). Changes from non-natural causes affect the process adversely, thus these causes should be identified, researched and kept under control. A control card is a significant tool to distinguish whether changes in the process consist of natural or non-natural causes (Baskan Ş., 1997).
Control charts will only identify causes of variation. Then, the Management must authorize action for eliminating the occurred causes (Anderson R.D. *et al*., 1993).

The aim of this paper is to investigate the stability of the production process of both machines, by introducing the control charts in the production of women’s tight, after collecting needed information’s and applying the Pareto analysis in the first our study (Stevkovska-Stojanovska R. *et. al*., 2021).

EXPERIMENTAL PART

In the first study, by collected production information’s and presented Pareto charts, for both machines it is determined that the highest percentage of defects occurs from breaking thread 2 (Stevkovska-Stojanovska R. *et. al*., 2021). 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 diagram 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 diagram

helps to analyze and identify the main field where energy and knowledge for better condition can be directed (Stevkovska-Stojanovska R. *et. al*., 2021).

To go one step forward, with aim to determine if the process is stable or not, control charts are applied. If the process (measured data) is between the upper and lower control limit, the process is stable and in this case we do not need any interventions.

More specifically, in this paper we applied the control charts for monitoring the quality by produced defective pieces:

- **p- control chart**- the control chart used for proportion of defective items (Anderson R.D. *et al*., 1993). This control chart as quantities method is used to research whether products obtained in certain and equal time period are defective or not; and
- **np- control chart**- the control chart for number of defected pieces (control chart for the defected products, for assessment of compliance to the quality norm, as it gives needed information based on which can be taken appropriate action for elimination of the factor/causes that have negative influence on the quality).

RESULTS AND DISCUSSION

The checklists give a realistic picture of the condition of both knitting machines, the achieved production, the type, number and percentage of defects that exist, per day and shift. Based on these data, a Pareto diagram was designed, which indicate that the largest percentage of defects are of the type D- thread breaking 2 (thread insertion), followed by: thread breaking 1, missing thread, machine downtime and broken needle (Stevkovska-Stojanovska R. *et. al*., 2021). They are presented on the following table.

Table 1: Percentage of defective pieces, per type of defect, on Machine 1 and Machine 2

	% of defective pieces, per type of defect				
	A	**B**	**C**	**D**	**E**
Machine 1	27.8	15.9	7.5	48.1	0.6
Machine 2	26.8	22.3	9.5	39.6	1.8

The next table present the summarized data for both machines, per shifts.

Table 2: Production on Machine 1 and Machine 2

	Machine 1				**Machine 2**			
	I shift	**II shift**	**III shift**	**All shifts**	**I shift**	**II shift**	**III shift**	**All shifts**
Produced pieces (n)	2840	3110	2550	**8500**	3080	3570	3000	**9650**
Defective pieces (d)	235	213	188	**636**	205	198	173	**576**
% of defective pieces	8,3 %	6,8 %	7,4 %	**7,5 %**	6,7 %	5,5 %	5,8 %	**6,0 %**

With aim to improve the monitoring of quality process, with determining whether the variability is controlled or not, control charts are applied.
The control limits for p-control chart are calculated by following formulas:

$$k_{g,d} = \bar{p} \pm 3 \cdot \sqrt{\frac{\bar{p}(1-\bar{p})}{\bar{n}}} \quad (1)$$

Where:

$$\bar{p} = \frac{\sum d}{\sum n} \quad (2)$$

and

$$\bar{n} = \frac{\sum n}{\sum day} \quad (3)$$

The control limits for np-control chart are calculated by the formulas:

$$k_{g,d} = \bar{n} \cdot \bar{p} \pm 3 \cdot \sqrt{\bar{n} \cdot \bar{p}(1-\bar{p})} \quad (4)$$

So, based on the above-mentioned formulas, in the table below are presented the needed values, based on which control charts will be designed for machine 1.

Table 3: Calculation needed for p- and np- control charts, machine 1, period (06.03.-15.04.)

			p- control chart	**np- control chart**
	$\bar{p}$ (%)	$\bar{n}$	K_g	K_g
Machine 1, I shift	8,3	129,09	15,5	20,07
Machine 1, II shift	6,8	141,36	13,2	18,69
Machine 1, III shift	7,4	134,21	14,1	18,97
Machine 1, all shifts	**7,5**	**134,9**	**14,3**	**19,3**

The lower control limit - K_d is not calculated since ideally is to be 0. But, anyhow in this case it is very close to that value.
The p- and np- control charts are presented in the Figure 2 and Figure 3.

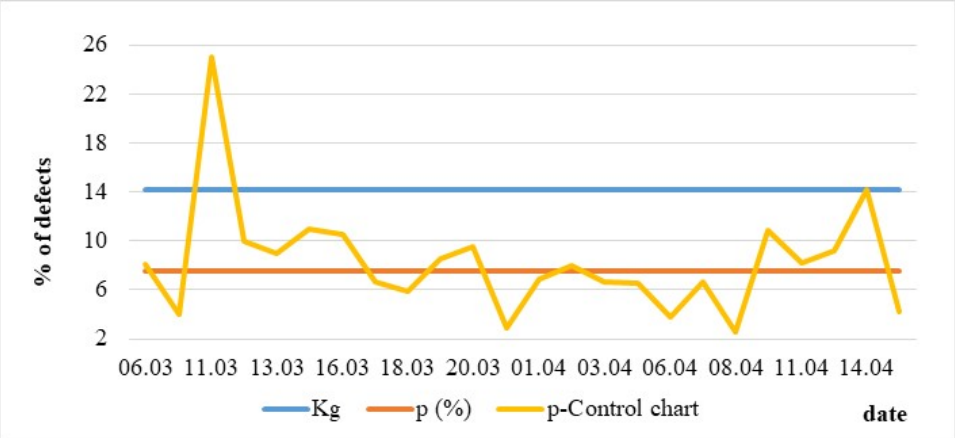

Figure 2: p- control chart, machine 1, all shifts

The control charts gives indication that the process is not stable, i.e. the number of defects is above the upper control limit (K_g), on 11.03.
The following is presentation of the working of the machine 2, in the same period of analysis, with the same workers.

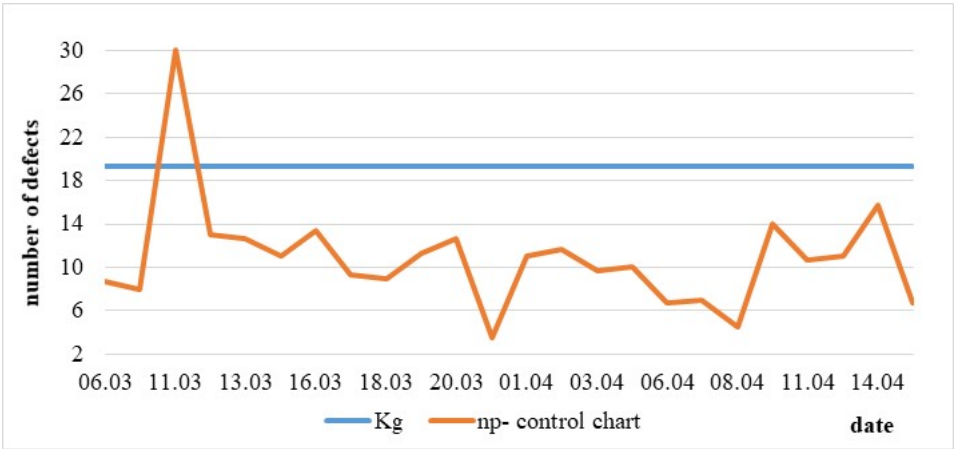

Figure 3: np- control chart, machine 1, all shifts

Table 4: Calculation needed for p- and np- control charts, machine 2, period (06.03.-15.04.)

			p- control chart	**np- control chart**
	$\bar{p}$ (%)	$\bar{n}$	K_g	K_g
Machine 2, I shift	6,7	146,7	12,8	18,8
Machine 2, II shift	5,5	155,2	11,1	17,2
Machine 2, III shift	5,8	150,0	11,5	17,2
Machine 2, all shifts	**6,0**	**150,8**	**11,8**	**17,7**

The p- and np- control charts for Machine 2 are presented on the Figure 4 and Figure 5.

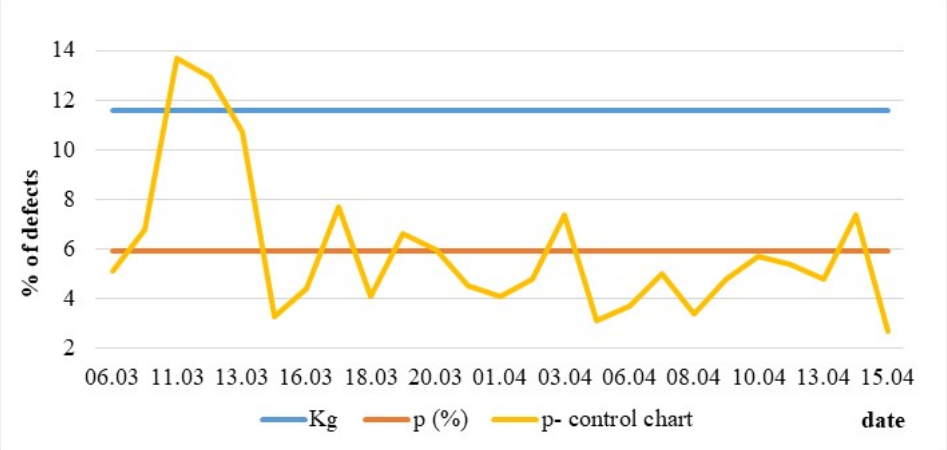

Figure 4: p- control chart, machine 2, all shifts

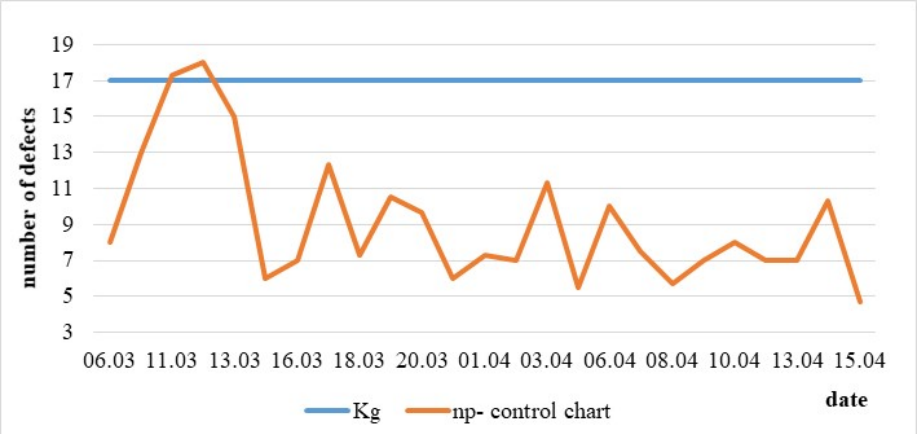

Figure 5: np- control chart, machine 2, all shifts

The conclusion from control cards, for machine 2, is that the process is unstable, as consequence of increased number of defected pieces and reduced production on March 11 and 12.

CONCLUSION

In this study the stability of the production process of both machines for tights was analyzed, by introducing the control charts.
For this aim several activities were done:

- collecting of all needed information's connected with production and defects
- calculations needed for design p- and np- control charts
- drawing p- and np- control charts

The results give indication that the processes are not stable on both machines. Specifically, the number of defects is above the upper control limit (Kg), on 11.03 for first machine and on March 11 and 12 for the second machine, as and consequence of increased number of defected pieces and reduced production.
The main task of control chart is to help in determination of process variability during certain period of time. This way the control charts are very useful for effective working with higher productivity and lower expenses. Step forward should be discovering the causes that led to the unstable production process. This can be accomplished by applying another statistical method, such as the Ishikawa diagram (causes and consequences) etc.

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EXPLORING 3D MODELLING SOFTWARE AND PROTOTYPING WITH PPE AND TEXTILE DESIGNERS

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ABSTRACT

The use of 3D CAD software is expanding in various fields, but the thing they have in common is a virtual 3D model. In this paper we will discuss 3D modelling using three different techniques applied in two research projects. First, we focus on parametric 3D modelling used widely for industrial products, second, we briefly discuss modelling using freeform surfaces, and third, 3D models defined with a spatial triangulated mesh.
The aim of the first research project, ‘Redesigning PPE Gowns’, funded by the Arts and Humanities Research Council (AHRC) in the UK, was to enhance the design of reusable, personal protective equipment (PPE) as worn by healthcare workers to treat patients with coronavirus. All existing gown details were modified, including the cuffs, where a solution was identified to reduce cross-contamination with a doffing hook, to make it easier to remove the gown safely. The doffing prototype was developed using CAD software Rhinoceros 3D and SolidWorks and its design based on the shape of a flower, each petal providing a potential hook. In the second project ‘OptimTex - Software Tools for Textile Creatives’, research was performed to improve textile software knowledge and skills for students in higher education. The investigation enabled the students to experiment with virtual 3D prototyping and 3D mesh processing.

Key words: 3D software, prototyping, doffing hook, virtual modelling, PPE, 3D textile design

INTRODUCTION

3D CAD (Computer Aided Design) software operates with virtual 3D models and is used in various fields. According to licence providers there are two main types, proprietary and FOSS (Free and Open-Source Software) (Snyk Limited, 2022). Some uses of FOSS in the field of 3D CAD will be highlighted in this paper. Free software often has limited software features and other user-oriented functionality but can be a good replacement for expensive packages. 3D CAD software helps students to understand how manipulating concepts using CAD and virtual reality can inform analogue material practice and experimentation (Nimkulrat N., 2020).

In the project ‘OptimTex - Software Tools for Textile Creatives’ photogrammetric 3D human scanning was deployed to support virtual pattern developments. OptimTex is a project to collect and build knowledge base from different fields to support young creative textiles. With our partners, several knowledge fields were covered, our was to 3D scan human body and to repair and re-model 3D mesh for further garment patterns creation in CAD/PDS (Pattern Design Software) (Cupar A., et al., 2019).

In the project ‘Redesigning PPE Gowns’ we applied 3D CAD within the field of 3D industrial design to extend product use and safety.
So, both projects share a fusion of textile, engineering, industrial design, photogrammetry, and digital visualisation towards creating ergonomic designs to support users.

Research for the project "Redesigning PPE: enhancing the comfort and safety of healthcare workers wearing isolation gowns to treat patients with COVID -19" (AHRC/ UKRI, 2021) was developed to answer the engineering question, "What new materials, design, and manufacturing approaches should we start to consider in preparation for pandemics, e.g. reusable PPE to replace single use?" (UKRI, 2020). In reviewing the literature on PPE for healthcare workers and the results of a survey of nurses from the NHS (National Health Service) (Šterman S., et al., 2022), we obtained a great deal of

detailed information about the problems they faced, particularly when wearing one-size disposable garments. Based on this information, we designed reusable protective gown prototypes (Townsend K., et al, 2022). In addition to the problem of gown size, we addressed other issues associated with one-size-fits-all, such as sleeve/gown-length, cuff, neck and waist fastenings and difficulties in putting on (donning) and taking off (doffing) the gown without spreading coronavirus. In this article, we present some of the potential solutions for redesigning the sleeve cuff, and how this initiated the development of a doffing hook, created using 3D modelling which can assist with the safe removal of the protective clothing.

Fashion and textile designers have been experimenting with emerging technology since the 1990s, to integrate 2D surfaces and 3D concepts with the human body (Townsend K., Goulding R, 2010; Townsend K., et al. 2020). Consequently, hybrid approaches to hand and digital craft are part of most designers' methodologies. However, proprietary 3D software remains costly and often encompasses standardized tool sets embedded within it that can undermine the creative autonomy of the designer leading to uniformity (Taylor J., Townsend, K., 2014). By using a mix of proprietary and FOSS in both the Redesigning PPE (Doffing Hook) and OptimTex projects the designers were able to explore 3D CAD from an open perspective.

METHODS

This practice-oriented study responds to the identified need for research into the design of reusable PPE (isolation gowns) and the area of 3D modelling. The first step was a literature review of both fields to expose areas that could be interconnected. We identified a solution for a problem of doffing PPE gowns with a hook. The prototype was made using the FDM 3D printing method. Another practice-oriented study involves 3D scanning of a human body with 3D photogrammetry and to repair and re-model 3D mesh using 3D modelling tools. Presented are two projects where multiple research fields were involved, mostly exposed 3D modelling, to serve as complementary approach.

RESEARCH AND DESIGN OF PPE GOWNS

Gowns are primary garments intended as uniforms for workers in various occupations, providing protection at work. This requirement could be met effectively if the sizes and materials were always adapted to the needs of the users and working conditions (Townsend K., et al., 2022).
Unfortunately, problems with the wearing of gowns have been identified on several levels. First, the literature review (Wong H., 2022) evidenced many examples where PPE, especially gowns, interfere with day-to-day working practices. This fact was also confirmed by interviews with clinical and nursing leads and wearers in various hospitals in the United Kingdom, where the survey was conducted in the first stage of the research in "Redesign of PPE Gowns" (Šterman S., et al., 2022). The review of 30 disposable and reusable gowns also confirmed the problems with sizes, patterns and materials used.

Findings from empirical research into gown design and use enabled us to identify critical elements that could improve users' experiences with PPE. Since reusable gowns are a more sustainable solution than disposable gowns, we have developed a reusable gown system incorporating multiple sizes to accommodate different body types and postures involved in nursing patients with Covid. Medical gowns play an important role in protecting the health care system from the transmission of microorganisms and body fluids (Vozzola E. et al., 2018). The protection of the body is crucial for nurses' safety both during work and after work, when doffing.

Issues relating to donning and doffing gowns were reiterated in our survey alongside other issues relating to the design of the PPE gown (Nottingham Trent University, 2021). In this article we focus on cuffs, sleeves, and doffing. The most requested design option for a cuff was for a thumb loop. Most of respondents thought the sleeves are too long. Regarding the question: is your gown easy to put on and take off? Respondents' experiences varied widely depending on the type of gown they

wore, how experienced they are, and how much time they have, to put it on and take it off. For these reasons we considered an extended cuff with several details. First, a cuff with a loop only (see also Figure 1-left), second, a cuff with a strap in different positions (see also Figure 1-middle) that can be hung on the innovative doffing hook and variation of the cuff (see also Figure 1-right).

Figure 1: An extended cuff with a loop (left), prolonged cuff with different positions of a strap (middle) and an extended cuff with two positions of the band, that would be used at the doffing hook (right)

Designing different 3D objects requires the application of different 3D modelling techniques. For our projects four types are applicable: 3D point cloud, 3D mesh, 3D surface model, and 3D volume model. In project ‘OptimTex’ for the capture of 3D objects and their representation, 3D point cloud and 3D mesh were used. Both virtual object types consist of a huge amount of data that describes real objects, involving 3D mesh editing and modelling. Scanned 3D meshes usually have holes and other errors which must be repaired to enable further use of a mesh. On the other hand, in designing the doffing hook for ‘Redesigning PPE Gowns’, both surface and volume models were used along with the corresponding modelling techniques of: Parametric solid 3D modelling, NURBS modelling (Farin G. E., Hansford D., 2000), and SubD modelling.

Parametric solid 3D modelling

Parametric solid 3D modelling is widely used in the product design industry. Speculative models with sketches and other features are compounded to build the final 3D model. Changes are possible with parameter adjustments. For parametric solid modelling of Flower hook and Pipe hook we chose SolidWorks although it is not a FOSS (Solidworks help, 2022; Vukašinović N., Duhovnik J., 2019).

Subdivision 3D surface modelling

Subdivision (or also SubD) is type of more “soft” modelling. Subdivision surfaces can be reshaped by modifying control objects which can be also added to create more detailed part of model. Modifying control objects means moving, rotating, or scaling three types of objects: points, edges, or faces. The final 3D model is usually a freeform object, often with a shape rarely or even impossible to achieve with parametric solid modelling. Continuity between neighbouring surfaces is assured, therefore beautiful shape transitions can be achieved (Kanaya Y., et al., 2007). 3D modelling of the Beast hook was performed in Rhinoceros 3D version 7 (Rhinoceros, 2004; Subdivision Surface Modeling, 2004).

Mesh modelling

Mesh modelling can be also performed with subdivision, but the larger number of spatial points involved, the harder it becomes to control. The modelling technique is like SubD modelling, but the final result is a mesh where continuity between neighbouring faces is difficult to control. For our project ‘OptimTex’ only mesh editing and processing approaches for closing holes, smoothing, and refining transformation were performed (Wikipedia, Affine, 2022). For mesh modelling and repairing Blender and MeshLab were used.

3D OBJECT DIGITALISATION

For a bespoke approach to garment production, 3D body scanning, 3D modelling and the reconstruction of the scanned body as a kinematic avatar, present very useful and advanced tools. As partners, the project, ‘OptimTex - Software tools for textile creatives’ (E-learning, 2022) several software solutions for textile creatives were utilised by students, supported with practical examples.

Most of software employed is freely available to download and our focus in this paper will be on 3D oriented solutions.

In this paper the software Meshroom (Meshroom, 2022) MeshLab (MeshLab, 2022), and Blender (Blender, 2022) are discussed, as they were used to perform several steps to generate 3D objects as starting point for further work. Detailed use of 3D software is shown on projects Moodle page, where students can attend courses from project (E-learning, 2022).

Step 1: taking series of pictures from different angles of an object
Any modern digital camera can be used, especially convenient is mobile phone camera. There are several rules and suggestion to take in account to get acceptable final result, collected in (Meshroom, 2022). Also, video can be used to obtain pictures from video. But still images assure better results.

Step 2: using pictures to obtain digitized virtual 3D object using 3D photogrammetry
In 'OptimTex', the free software for 3D reconstruction Meshroom was introduced to students. The software is a complex composition of many partial solutions for photogrammetry. The program functions like a pipeline, where each successfully completed step leads to another one. With inappropriate input images the whole procedure cannot be completed. Therefore, is very important to follow rules in Step 1. The first two steps involve: importing images into program, saving the project, and starting computing processing. The process takes some time, depending on the number of input images, their size and mostly on computing capacity. A successful finished project builds a MeshroomCache maps structure, stored on disk. In each map a result of partial steps can be found. The finished result, the 3D model with .OBJ extension is stored last, called Texturing. There are plenty of other software for obtaining 3D meshes from pictures, some FOSS, some proprietary, but based on user experience (Author 1) and simplicity, the Meshroom is a good solution.

Step 3: scale adjustment of an object
The virtually crafted 3D object needs scale adjustment for any further manipulation. It is a main step whereby a user is responsible for producing an accurate result. Physical dimensions must be measured on both a real object and virtual 3D object to obtain the correct scale. This step must be repeated several times to get an accurate measurement while virtual and physical sizes can be at odds in the early modelling stages. In project OptimTex, MeshLab was used for scale adjustment and 3D environment mesh removal to get clean and proper scaled object, in our case the human body. With 3D scanning, scaling is already part of calibration process.

DOFFING HOOK

Evolution and shape exploration was performed in Rhinoceros 3D v7. Finally, three types of hooks were chosen according to appearance, production possibility, and usability: Beast, Pipe and Flower. All three models were modelled in SolidWorks 2021.
The hooks are meant to be mounted on a wall with wall inserts and screws like for example any ordinary kitchen cabinet. It is important to be mounted stiff enough to hold an adults' weight. All variants have multiple protrusions slightly inversed to facilitate contact with the cuff loop of the protective garment. Variants Beast and Pipe can also serve as key, or other object holders.

Model 1 - Beast
First model has the most complex shape. Therefore, it was modelled completely in Rhinoceros 3D. Shape was designed using SubD tools, then basic cylinders were subtracted using the Boolean difference tool. The Beast Hook will be made of moulded aluminium or another metal that can be sterilised. Its appearance has aesthetic associations with a creature's head with horns, muzzle, and eyes. The two eyes represent two screws, holding the hook on the wall as shown in Figure 2 (see also Figure 2-left).

Model 2 – Pipe

Second model in Figure 2 (see also Figure 2-middle) was meant for simple production, cut from single piece of pipe with an added plate at the back. The shape was redrawn from a sketch in SolidWorks 3D. The Pipe Hook can also be made of moulded metal or a suitable alternative material. Its appearance can be associated with a hand, grabbing upwards. Four screws hold the hook on the wall.

Model 3 - Flower

Third model, in Figure 2 (see also Figure 2-right), was again redrawn in SolidWorks 3D. Basically the section sketch is revolved and removed space between petals in the following extrude tool. The Flower Hook can be moulded or can be produced with a turning and additional milling for petals. This hook is mounted with three screws on the wall.

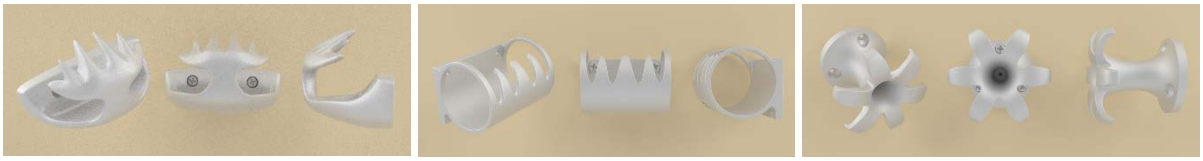

Figure 2: Beast hook (left), Pipe hook (middle) and Flower hook (right)

3D PRINTING

The manufacturing of virtual 3D objects can be performed using different techniques. From conventional material removal and welding to additive manufacturing (AM). For shape research and functionality testing an FDM (Fused Deposition Modelling) 3D printer was deployed due to accessibility, fast process, low price, and suitable material properties (Flynt, 2022). For 3D printing materials PLA (Polylactic Acid) and PETG (Polyethylene Terephthalate Glycol) were used (see also Figure 3-photos). Basically, the 3D shape is important to analyse at this stage, therefore envisaged material properties are not as important as the details and potentially functionality of a product. On the sketches (see also Figure 3-sketches) are shown new possibilities of using cuffs for easier doffing with a band on the outer side.

Figure 3: 3D printed Flower Hook (Photo 1 and 2) and Pipe Hook (Photo 3) and an extended cuff with different positions of the band, that could be used with the Flower Hook (sketches on the right)

TESTING

All three doffing hooks were mounted on a wall and tested for PPE removal. It was considered not to fully load the hook as FDM printers use plastic materials with lower stress than metal products. Testing the first generation of doffing hooks highlighted inappropriate design elements, such as the petals of the Flower Hook needing to curve more acutely, and the Beast Hook proving to be difficult to install due to limited access to the screw holes. Within Rhinoceros and SolidWorks, the models were modified, and 3D printed again. The modified shapes of the hooks were all appropriate for removing the PPE by the cuff loops. The next step is to manufacture hook prototypes from aluminium and include them in Gown Wearer Trials to test them in the healthcare working environment.

CONCLUSION

Each profession operates within the parameters of its field, using materials and technologies in physical, and increasingly virtual realms. This paper explores how interdisciplinary research can

highlight and seek to solve human and environment centred problems using 3D modelling and prototyping. The two described projects are good examples of collaboration and cooperation across different fields. In the Redesigning PPE project, the hook design is used to add value to the gown, by protecting the wearer against contamination from viruses, but this product could also be used by other professions that work with toxic substances, such as pesticides. The idea has wide applicability and requires further research into areas of use in laboratories, workshops, and other industrial workplaces. This emerging technology acts as a catalyst for the established disciplines of fashion, textiles product design and many others, to collide, interact, and innovate.

ACKNOWLEDGEMENTS
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VOLUME ELECTRICAL RESISTIVITY OF FLAX SINGLE JERSEY WEFT-KNITTED FABRICS

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ABSTRACT

The aim of this work was to investigate the volume electrical resistivity of three plain single jersey weft-knitted fabrics produced from the same flax yarn but with different structural characteristics. The influence of structural characteristics of knitted fabrics (number of courses, mass per unit area, and thickness), atmospheric conditions (relative air humidity and temperature), as well as pilling caused by abrading knitted fabrics with the same knitted fabric, on the volume electrical resistivity of knitted fabrics, were examined in the scope of this investigation. The study showed that the increase in structural characteristics leads to a decrease in the volume resistivity of knitted fabrics. A decrease in air humidity causes an increase in the volume resistivity of investigated knitted fabrics. An increase in temperature causes a decrease in volume resistivity in all examined knitted fabrics. Furthermore, a decrease in the volume resistivity for all knitted fabrics after pilling was registered.

Key words: flax weft-knitted fabric, volume electrical resistivity, structure, atmospheric conditions, pilling

INTRODUCTION

Textile materials can be in contact with machine parts in the production process, in mutual contact, and with the user's body during exploitation. As textile materials are typical dielectrics (insulators), with very high electrical resistance, contacts and/or friction of textile materials with non-fibrous and fibrous materials cause the appearance of static electricity (Gonzalez J.A., 2005). Generated static electricity on the surface of textile materials can cause serious problems during their manufacturing (fire in the process of production of textile materials, disruption of fiber orientation in spinning products, increase in interruptions during weaving, etc.), and in their commercial use (increased dirt, cleaning problems, sticking textile materials for the consumer bodies or other textile materials, increased pilling, as well as the appearance of fatigue, headaches, and other physiological disturbances) (Morton W.E., and Hearle J.W.S. 2008, Asanovic K.A. et al., 2007, Kramar A. et al., 2014). The generation and difficult dissipation of static electricity from textile materials is connected to the high electrical resistance of materials. The electrical resistance is often determined as an indicator of static electricity dissipation from the textile surface, because the intensity and speed of dissipation of the generated static electricity from the textile material are inversely proportional to its electrical resistance (Asanović K. et al., 2010, Kramar A. et al., 2014).

The electrical resistance of textile materials depends on several factors: raw material composition (Morton W.E., and Hearle J.W.S. 2008, Chen Q. et al., 2021, Asanovic K.A. et al., 2021), moisture content in fibers (Morton W.E., and Hearle J.W.S. 2008, Asanovic K.A. et al., 2021), electrolyte content (Morton W.E., and Hearle J.WS. 2008), air humidity (Morton W.E., and Hearle J.W.S. 2008, Asanovic K.A. et al., 2021, Ivanovska A. et al., 2020, Ivanovska A. et al., 2022), temperature (Morton W.E., and Hearle J.W.S. 2008), and polarization effect (Morton W.E., and Hearle J.W.S. 2008). Furthermore, alkali modification and oxidation of fabrics (Ivanovska A. et al., 2020), washing/drying cycles (Tunàkovà V. et al., 2017), softening (Ivanovska A. et al., 2022), coatings with different substances (Gan Lu. et al., 2015, Ivanovska A. et al., 2022), thermal fixation of woven interlining on the woven fabrics (Asanović K. et al., 2020), as well as abrasion of textile materials change their electrical resistance (Asanovic K.A. et al., 2021, Varnaitė S., and Katunskis J. 2009).

As already mentioned, the electrical resistance of textile materials depends on several factors, but also on changes in some characteristics of textile materials created as a consequence of washing, cleaning, wearing, or coating. Furthermore, in the available literature, no attention has been paid to the influence of pilling on the electrical resistance of knitted fabrics.

Pilling is a phenomenon that occurs when loose fibers are pull out of the fabric construction and roll into small spherical bundles (pills) on the surface, which usually happens during abrasion and wear (Binjie X., and Hu J., 2008). Pilling, as a fabric surface defect, causes an unattractive appearance and an uncomfortable fabric handle (Binjie X., and Hu J., 2008), as well as changes in some properties of knitted fabrics such as compression, comfort, and strength (Asanovic K.A. et al., 2022a). Therefore, the aim of this study was to evaluate the influence of structural characteristics of knitted fabrics (number of courses, mass per unit area, and thickness), atmospheric conditions (relative air humidity and temperature), and pilling on the volume electrical resistivity of knitted fabrics.

MATERIALS AND METHODS

Materials

In this work, the three plain single jersey weft-knitted fabrics, produced from the same flax spun yarn with a linear density of 27x2 tex, were used as experimental material. Some structural characteristics of the investigated knitted fabrics are given in Table 1.

Table 1: Structural characteristics of the investigated knitted fabrics

STRUCTURAL CHARACTERISTICS	SAMPLE 1	SAMPLE 2	SAMPLE 3
Number of wales, cm^{-1}	7.0	7.9	8.0
Number of courses, cm^{-1}	7.2	8.4	10.1
Stitch density, cm^{-2}	50.4	66.4	80.8
Mass per unit area, $g \cdot m^{-2}$	189	211	226
Thickness, mm	0.726	0.769	0.779

Methods

The number of fabric wales, the number of courses, and stitch density were determined according to standard EN 14971:2006 using Method A. Fabric mass per unit area was not determined by the standard method. The deviation from the standard refers to the dimension of the samples. Namely, the samples were in dimensions of 2x5 cm, which is needed to determine the volume electrical resistance. In this way, it is possible to determine the mass of the samples before and after pilling under the same conditions, and the obtained results are comparable. The thickness of knitted fabrics was measured at a pressure of 9.96 kPa using a thickness tester (AMES, type 414-10, USA). The average of ten measurements for the number of fabric wales, fabric courses, and thickness, as well as five measurements of mass of each sample, before and after pilling, was considered. All measurements were realized at 31±1°C and 40% relative air humidity.

Investigated knitted fabrics were subjected to pilling using SDL ATLAS M235 Martindale Abrasion and Pilling Tester. Pilling was performed at 7000 rubs using the same knitted fabric as abrasive materials.

The volume electrical resistance of the investigated knitted fabrics was determined in the course direction using the voltage method (Asanovic K.A. et al., 2010). The measurement was performed under the decrease of the relative air humidity (in further text humidity) in the chamber (from 60% down to 40%) at room temperature (31±1°C) for samples before and after pilling, as well as at 40%

humidity and 23±1°C for samples before pilling. All examined samples consisted of two fabric specimens connected to electrodes during each measurement. Based on the determined knitted fabric volume electrical resistance, the volume electrical resistivity of samples (in further text volume resistivity (ρ)) was calculated before and after their pilling (Asanovic K.A. et al., 2010).

RESULTS AND DISCUSSION

Influence of structural characteristics on the knitted fabrics' volume resistivity

The obtained results of volume resistivity of investigated knitted fabrics are presented in Figure 1. The volume resistivity was determined in the course direction at room temperature of 31±1°C and 50% humidity in the chamber.

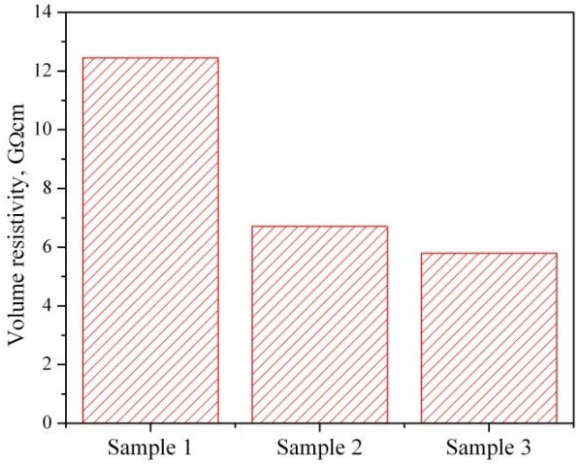

Figure 1: Volume resistivity of the knitted fabrics

The histogram presented in Figure 1 shows that with the increase in values of structural characteristics (number of courses, mass per unit area, and thickness, Table 1), the volume resistivity of knitted fabrics decreases. The highest differences in resistivity were between Samples 1 and 3 ($\rho_{(Sample\ 1)}/\rho_{(Sample\ 3)}$=2.15), and the lowest differences were between Samples 2 and 3 ($\rho_{(Sample\ 2)}/\rho_{(Sample\ 3)}$=1.16). Sample 3 has higher values of all structural characteristics than Sample 1 (number of courses for 28.7%, mass per unit area for 16.4%, and thickness for 6.8%). The higher values of structural characteristics, primarily the higher number of courses, ensure the easier flow of directional movement of charge in Sample 3 than in Sample 1 and, thereby, lower volume resistivity value.

Influence of atmospheric conditions on the knitted fabrics' volume resistivity

Atmospheric conditions (humidity and temperature) are also important factors that influence on the electrical resistance of textile materials (Morton W.E., and Hearle J.W.S. 2008). The values of volume resistivity of investigated knitted fabrics in the course direction, determined by decreasing the humidity from 60% down to 40% at 31±1 °C, are shown in Figure 2.

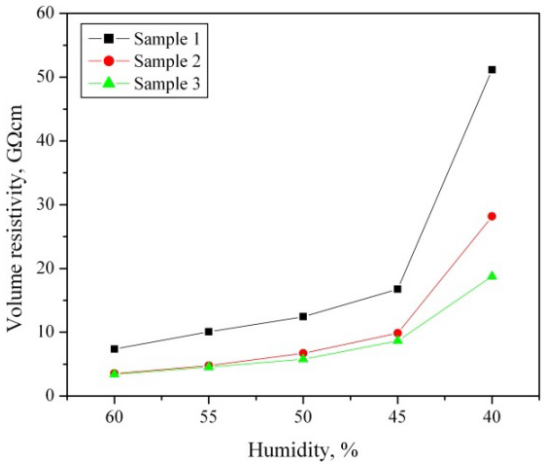

Figure 2: Volume resistivity of the samples throughout the humidity decrease

Volume resistivity at 40% humidity was higher about 7.0 times for Sample 1, 8.0 times for Sample 2, and 5.5 times for sample 3 than at 60% humidity (Figure 2). Much lower values of volume resistivity at 60% than at 40% humidity can be explained by the influence of humidity on partly ionization of water molecules, which were around the knitted fabrics, and neutralization of electric charges on knitted surface by these molecules (Ivanovska A. et al., 2020). The presented results confirm the significant influence of humidity on the volume resistivity of knitted fabrics.

The influence of temperature on the knitted fabric volume resistivity at 40% humidity is presented in Figure 3.

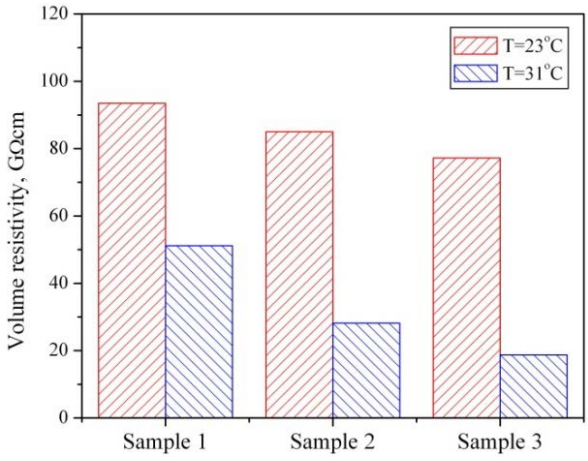

Figure 3: Volume resistivity of the samples at different temperatures

An increase in the temperature from 23°C up to 31°C is followed by the decrease in the samples' volume resistivity values for all knitted fabrics, probably due to increasing the mobility of water molecules with an increase in temperature. The obtained results are in accordance with the results presented in the literature (Morton W.E., and Hearle J.W.S. 2008). Presented results show that with the increase in fabrics' structural characteristic values (from Sample 1 to Sample 3, Table 1), the differences between the resistivity of the same sample determined at two temperatures also increase (Figure 3). The highest difference is in Sample 3, but the lowest is in Sample 1. This phenomenon appears probably due to a simultaneous increase of values of structural characteristics from Sample 1 to Sample 3, followed by an increase in moisture content of samples (Asanovic K.A. et al., 2022b), and an increase in mobility of water molecules at a higher temperature. All three mentioned factors together ensure the easier flow of directional movement of charge through the sample.

Influence of pilling on the knitted fabrics' volume resistivity

The volume resistivity was determined in the course direction at room temperature of 31±1 °C and 40% humidity. Resistivity's were determined before and after pilling (Figure 4). The effect of pilling on the knitted fabric volume resistivity after 7000 rubs was considered.

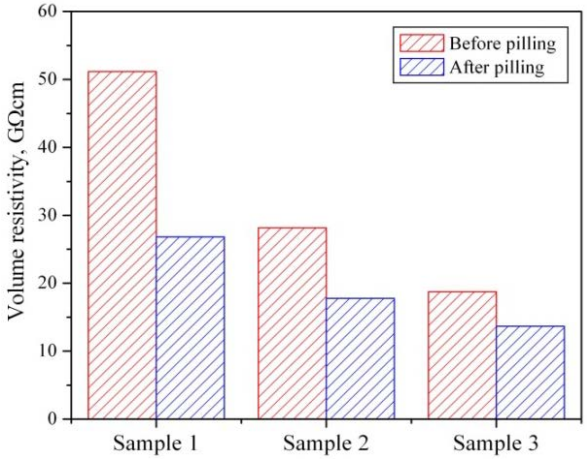

Figure 4: Influence of pilling on the knitted fabrics' volume resistivity

The histogram presented in Figure 4 shows that pilling leads to a change in the volume resistivity of all investigated samples. A decrease in the volume resistivity due to pilling was registered in all samples ($\rho_{(\text{before pilling})}/\rho_{(\text{after pilling})}$ for Sample 1, Sample 2, and Sample 3 are: 1.9, 1.6, and 1.4, respectively). The decrease in volume resistivity is not expected, bearing in mind that pilling causes a reduction of values of all structural characteristics of knitted fabrics (number of courses from 2.4% up to 4.0%, mass per unit area from 6.9% up to 18.1% and thickness from 13.1% up to 14.4%), thus decreasing the lot of knitted fabrics which participates in the transport of directional movement of charge through the sample. The reason for the decrease in the volume resistivity after pilling can be found in the changes on the fabric surface during the abrasion process that causes a pilling of knitted fabrics. Surface fuzzing and formed pills are evident on the surface of knitted fabrics after pilling. Furthermore, fuzz is not present only on the surface of the fabric. Fuzz also fills the space between the loops, thus contributing to the easier flow of directional movement of charge and decreasing the volume resistivity in all samples.

CONCLUSION

The presented results showed that the lowest value of volume resistivity has the knitted fabric with the highest number of courses, mass per unit area, and thickness. The highest values of structural characteristics ensure the easiest flow of directional movement of charge through the sample which leads to the decreased volume resistivity. Volume resistivity of knitted fabrics was higher at 40% humidity than at 60% humidity for about 5.5 times up to 8 times. An increase in the temperature from 23°C up to 31°C is accompanied by the decrease in the knitted fabrics' volume resistivity due to an increase in mobility of water molecules with an increase in temperature. The highest decrease in volume resistivity, with an increase in the temperature, is noticed for knitted fabric with the highest values of all structural characteristics (Sample 3). Furthermore, it was noticed a decrease in the volume resistivity after pilling for all knitted fabrics from 1.9 times down to 1.4 times, probably due to surface fuzzing during pilling. Formed fuzz, which fills the space between the loops, allows the easier flow of directional movement of charge thus decreasing the volume resistivity of all knitted fabrics.

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GLCM PRINT MOTTLE ASSESSMENT OF SUBLIMATION PRINTED FABRIC

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ABSTRACT

The fabric was printed with different printing temperature and pressing time parameters using the sublimation printing process in solid-tone black color with a 100 % total ink limiting level. Non-uniformity of the print was examined through print mottle determined by grey level co-occurrence matrix (GLCM) image processing method. Color strength of print was also determined by reflectance spectrophotometry. The print with the lower print mottle was obtained at a printing temperature of 190 °C with a longer pressing time of 120 s or at an increased printing temperature to 210 °C with a reduction of the pressing time to 60 s. The print with a lower value of print mottle had the lowest entropy, contrast and correlation and the highest energy and homogeneity. The print with a higher color strength was accompanied by decreased print mottle. Choosing a suitable printing temperature and pressing time for the sublimation printing process helps achieve low print mottle and high color strength print and balances cost, price, and quality.

Key words: sublimation printing, print mottle, GLCM, color strength, solid-tone surface uniformity

INTRODUCTION

Sublimation printing is increasingly considered necessary in the textile industry. Sublimation is suitable for printing on textile, especially where it is not easy to achieve a high fidelity image on the textile by printing techniques, such as ink jet printing, rotary screen printing, and roller printing. In a typical case, the print textile may be a textile with a shape or texture challenging to feed to a printer or a textile that does not readily receive high fidelity images by some printing techniques. In sublimation printing, the desired image is reverse printed on sublimation transfer paper by ink jet printing. The reverse printed transfer paper and textile to receive the desired image are combined with a heat press under temperature and pressure, where sublimation dyes transfer from the paper to the textile material [1,2]. This printing also demands the technologist to develop an appropriate process to ensure that the final quality of the print matches the low print mottle and high color strength. Non-uniformity of printing density called print mottle is a common print defect [3,4]. Print mottle occurs through systematically structured patterns, which the human notices quickly. The print mottle is caused by variation in the amount of ink transferred onto the textile, variation in surface porosity, textile deformation, and printing parameters.

The customer's desire to achieve print quality matching the minimal print mottle and a maximum color strength of print. When printing, it is crucial to choose the most suitable printing temperature and pressing time, as this will significantly differ in the print unevenness and color strength. So it is essential to know the printing temperature and pressing time to achieve print with maximum color strength and minimal print mottle. The printing temperature and pressing time affect the company’s economic performance and costumer's requirements.

This study aimed to investigate the change in print mottle and color strength by different printing temperature and pressing time settings when sublimation printing on fabric in solid-tone black color with the 100 % ink limiting level.

EXPERIMENTAL PART

Material

White fabric, 97 % polyester and 3 % elastane, with 160 g/m^2 weight, 0.36 mm thickness, and 43 cm^{-1} and 22 cm^{-1} warp and weft densities, respectively, with twill structure, was used.

Printing Procedure

The test image for printing was created in Adobe Illustrator software in the CMYK color system and consisted of the rectangle (3.5cmx3.5cm dimensions) in solid-tone black color with 100 % total ink limiting level (C=0 %,M=0 %,Y=0 %,K=100 %). The test image was printed on commercially available sublimation transfer paper with 105 g/m^2 weight by an A4 format EPSON ink jet printer with four CMYK ink jet channels. The printer was installed with sublimation ink SUBLYFUN by Print Equipment Gmbh&Co. Pre-pressing, and sublimation printing processes were performed by the press model BESTSUB SB3A (38cmx38cm) and medium pressure (2.3-3.5 bar). The pre-pressing of the fabric was conducted at printing temperature for 6 s, and then sublimation printing was performed at 170 °C, 180 °C, 190 °C, 200 °C, and 210 °C temperature and pressing time of 30 s, 60 s, 60 s, 80 s, and 120 s. Afterward, the printed fabric was cooled to room temperature, and the baking paper was removed. The sublimation printed fabric was conditioned and tested in a standard atmosphere (temperature 20 °C and 65 % relative humidity) for 24 hour.

Methods

Color Strength

The color strength (K/S) of printed fabric was determined by measuring the corresponding reflectance value using the X-Rate Color i7 reflectance spectrophotometer and calculating the K/S value using the Kubelka-Munk equation:

$$K/S = \frac{(1-R_{\lambda max})^2}{(2R_{\lambda max})}$$

Where: K is the absorption coefficient, S is the scattering coefficient, and R is the reflectance value of the print at the wavelength at maximum absorption.

GLCM (Grey level co-occurrence matrix) image processing method

Print mottle was assessed by the image analysis method using grey level co-occurrence matrix (GLCM). After sublimation printing, printed fabrics were digitalized by flatbed scanner EPSON L3151 at 600 dpi scanning resolution without auto-correction. Scanned images in the TIFF files were scaled at 500x500 pixels for easier processing in MATLAB. Then, samples were subjected to GLCM analysis to obtain quantitative print uniformity results. GLCM analysis was done in MATLAB software with code according to Uppuluri [5] using the following parameters: the number of grey levels was set to 256 (L^* channel), the distance between two pixels (d) was set to 1, and four angles of orientation were used (horizontal 0°, right-diagonal 45°, vertical 90°, and left-diagonal 135°). Print mottle using MATLAB code was assessed through contrast, homogeneity, energy, entropy, and correlation parameters.

RESULTS AND DISCUSSION

The effect of the temperature and pressing time printing parameters on the color strength of print is shown in Figure 1. Increasing the pressing time to 60 s and increasing the printing temperature to 210 °C, the K/S value of the print increased. Increasing the pressing time to 120 s, the K/S value of the

print increased with increasing the temperature to 190 °C; above this temperature, the color strength of the print decreased. The greatest K/S value of print was reached in 120 s up to the temperature of 190 °C, while with a further increase in temperature to 200 °C and 210 °C, the greatest K/S value of print was reached in 80 s and 60 s respectively. A higher K/S value indicated intensive color strength. The higher degree of sublimated dye on the fabric leads to higher values of color strength [6].

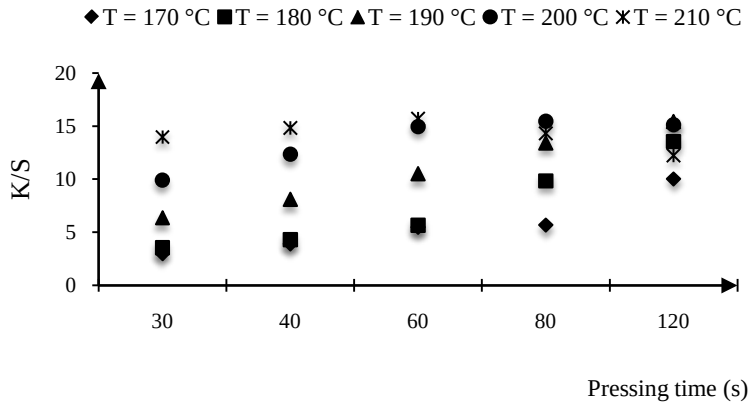

Figure 1: Color strength of sublimation prints obtained at different temperatures and pressing times

The overall print mottle changes of the sublimation printed fabric are assessed by the GLCM image processing method [7]. In Figure 2 are shown the results of the contrast GLCM parameter. Print obtained at a higher temperature for a shorter pressing time had the lowest contrast between pixels in the image; therefore, it can be regarded as the sample with the smallest contrast. The reason why contrast was lower when printing at a higher temperature and shorter pressing time was connected with sublimation dye on the fabric, and hence with grey levels in an image. Print obtained at a higher printing temperature for a shorter pressing time had a lower contrast value. So the amount of sublimated dye was higher and was evenly distributed over the fabric than print obtained at a lower printing temperature and shorter pressing time, which resulted in a higher variation of grey levels in an image. Unequal transfer of sublimation dye on the surface of fabric led to a higher contrast value. The print is considered uniform when the contrast is zero [8].

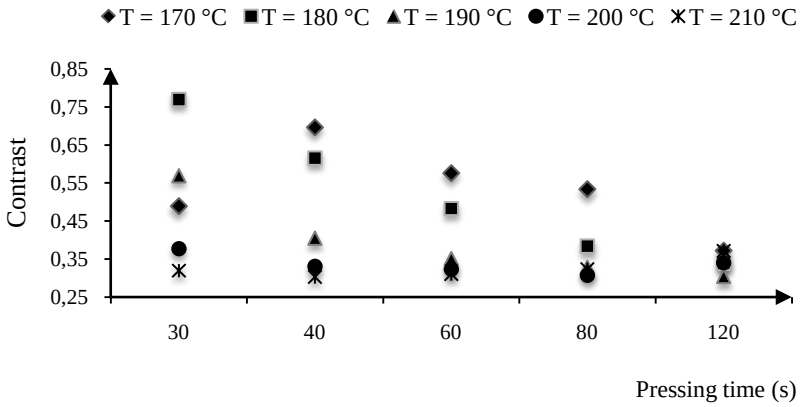

Figure 2: Contrast GLCM parameter of sublimation prints obtained at different temperatures and pressing times

Homogeneity measures how close the distribution of the pixel is in a GLCM. This value is inversely proportional to contrast. As homogeneity increases, the contrast decreases [8]. The values of homogeneity GLCM parameter of prints obtained at different printing temperatures and pressing times are shown in Figure 3. The value for the homogeneity of the print increased by increasing the pressing time to 60 s and increasing the printing temperature to 210 °C. The maximal value for the

homogeneity, up to the temperature of 190 °C, was achieved in 120 s, while with a further increase in temperature to 210 °C, the maximal homogeneity value was reached in 60 s. The homogeneity value of 1 corresponds to the homogeny print surface with no variations [8].

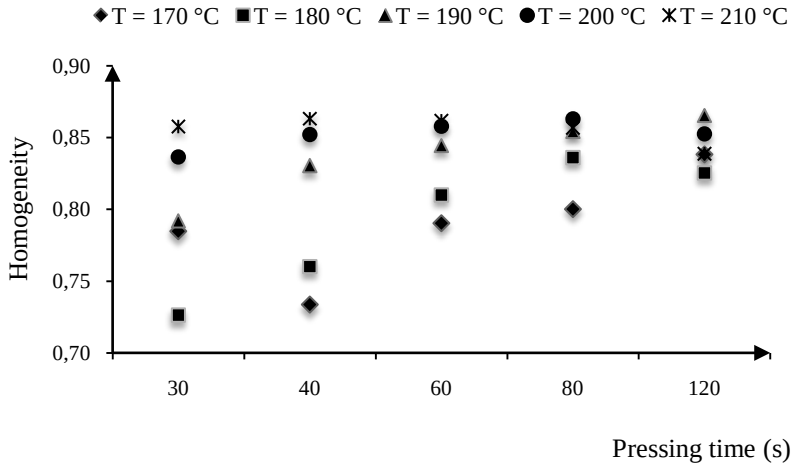

Figure 3: Homogeneity GLCM parameter of sublimation prints obtained at different temperatures and pressing times

Energy value measures the uniformity of pixels in GLCM. The energy values are also large as the pixels get more similar [9]. The results of the energy GLCM parameter of print obtained at different temperatures and pressing times are shown in Figure 4. The energy value increased by increasing the pressing time to 60 s and increasing the printing temperature to 210 °C. Increasing the pressing time to 120 s, the energy value increased to 190 °C; above this printing temperature, the energy decreased. The energy parameter showed the same trend as in the case of the homogeneity parameter.

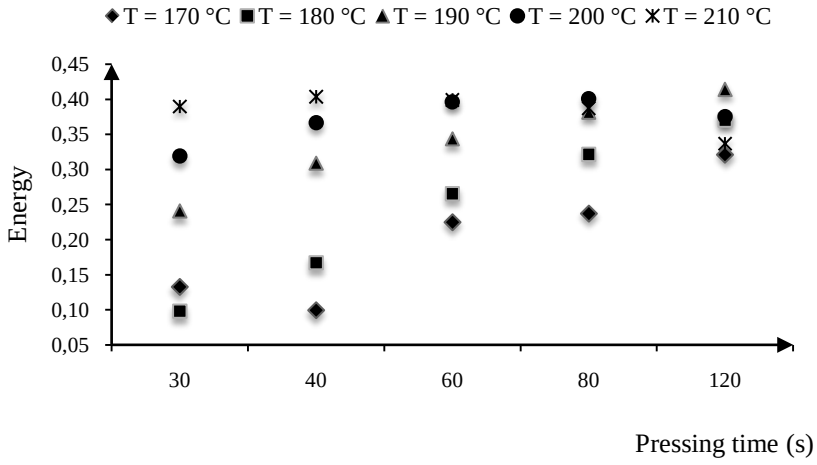

Figure 4: Energy GLCM parameter of sublimation prints obtained at different temperatures and pressing times

The opposite trend of energy represents entropy. System disorder measures entropy. Extraction of entropy parameter value from images depends on the printing temperature and pressing time selection. The results of the entropy GLCM parameter of prints obtained at different temperatures and pressing times are shown in Figure 5. The minimal value for the entropy was achieved in 120 s at the temperature of 190 °C, while with a further increase in temperature to 210 °C, the minimal entropy value was reached in 60 s. The entropy parameter correlates best with human texture perception, and if the entropy value is high, a particular texture becomes more visible and noticeable [9]. Therefore, it

can be concluded that higher entropy values indicated stronger texture patterns perceived more easily. However, the trend for contrast was followed by the entropy parameter.

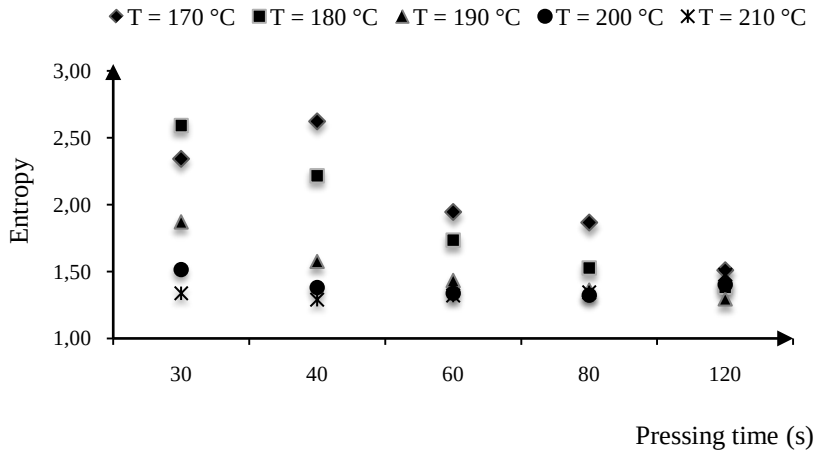

Figure 5: Entropy GLCM parameter of sublimation prints obtained at different temperatures and pressing times

The results of the correlation GLCM parameter of prints obtained at different temperatures and pressing times are shown in Figure 6. The correlation decreased by increasing the pressing time to 60 s and increasing the printing temperature to 210 °C. The correlation parameter showed a similar trend as in the case of the contrast and entropy parameters. The correlation determined a linear dependency of grey levels with those of neighboring pixels. Correlation gives information about how correlate a pixel to its neighboring pixels. Its values ranged from -1 to 1 [8], where -1 is perfect negatively correlated, 0 is uncorrelated, and 1 is perfect positively correlated. Low values of correlation correlated to the uniform print surface.

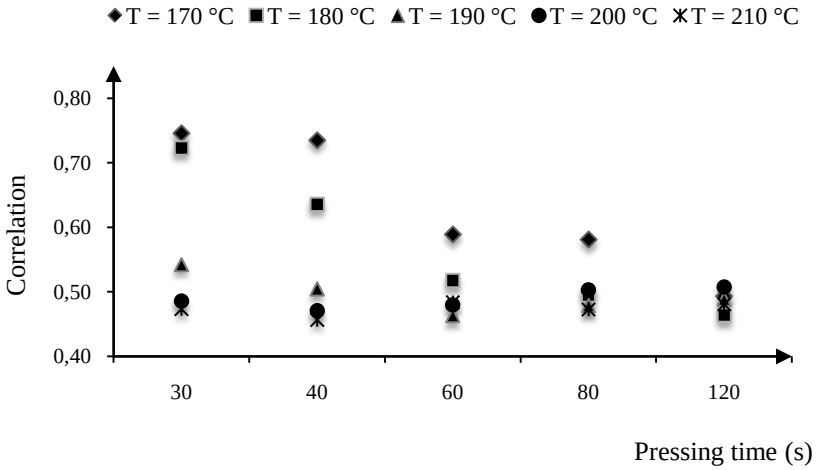

Figure 6: Correlation GLCM parameter of sublimation prints obtained at different temperatures and pressing times

CONCLUSION

The effect of change in print mottle was analyzed to determine print quality obtained by sublimation printing at different printing temperatures and pressing times on fabric in solid-tone black color with 100 % total ink limiting level. The contrast, homogeneity, energy, entropy, and correlation GLCM parameters from GLCM were used for this purpose. Color strength of print was also determined. GLCM parameters' results depend on selecting the correct printing temperature and pressing time.

Increasing the printing temperature to 190 °C allowed the minimal print mottle and a maximum color strength of print to be reached in a long time of 120 s. With a further increase in printing temperature to 210 °C, the minimal print mottle and a maximum color strength of print were achieved in a shorter pressing time. Considering the importance of printing temperature and pressing time for the sublimation printing process in terms of print mottle and color strength, working with a printing temperature of 190 °C for 120 s pressing time or 200 °C for 80 s or 210 °C for 60 s will achieve a high print quality and match the rigorous costumer's requirements. Choosing a suitable temperature and pressing time for sublimation printing helps achieve different print quality, reach the required print quality, and balance cost, price, and quality.

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INFLUENCE OF HYDROGEN PEROXIDE ON DISINFECTION DURING HOUSEHOLD WASHING

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ABSTRACT

To reduce energy consumption in households, numerous guidelines and laws recommend washing at low temperatures. However, low temperatures do not kill microorganisms, so the hygiene of washed textiles is questionable. Nevertheless, disinfection in household laundry is partly provided by perborates or percarbonates (bleach activators), which contain hydrogen peroxide (HP) but are added only in washing powders. Despite their popularity with consumers, liquid laundry detergents do not contain bleach activators and do not disinfect at low wash temperatures. The aim of this study was to investigate whether the addition of HP to liquid laundry detergents disinfects laundry at low temperatures during household washing and what the optimal washing conditions are. The disinfection effect was tested according to the standard EN 16616:2015. HP was added at different concentrations (0.5%, 1% and 3%) to the liquid detergent during the main wash using a household washing machine. Combinations of HP and peracetic acid (PAA) were also tested. Using the same washing condition, a colored fabric was also washed to determine the effect of bleach on the color of the washed fabric. The addition of 3% HP in the main wash resulted in excellent reduction (~7 log CFU cm^{-2}) without discoloration of the fabrics. Lower concentrations of HP resulted in less reduction in bacterial growth.

Key words: textile care, low-temperature washing, disinfection, hydrogen peroxide, color difference

INTRODUCTION

Due to the large amounts of laundry in everyday life, the decision to wash with lower temperatures (30–40 °C) and lower water consumption can be one of the measures to reduce energy consumption and thus reduce greenhouse gas emissions from households (Pakula C. and Stamminger R., 2010). Life cycle assessment studies of clothing, detergents, and washing machines show that the use phase is generally the most energy-consuming phase in the life cycle of clothing, ahead of the production and transport phases (Laitala K. and Jensen H.M., 2010; Kruschwitz A. et al., 2014). In the last 20 years, the preferred washing temperatures worldwide have been between 30 °C and 60 °C (Kruschwitz A. et al., 2014; Lambert E. et al., 2015; Pakula C. and Stamminger R., 2010; Rogers D., 2015). However, washing at low temperatures cannot ensure sufficient cleanliness of the laundry and especially sufficient disinfection of the laundry (Brands B. et al., 2016; Honisch M. et al., 2016). Hygienic textiles can only be achieved at a washing temperature above 60 °C or with the addition of antimicrobial agents. It is realistic to assume that pathogenic microorganisms are not killed when contaminated laundry is washed at temperatures of 30–40 °C, especially since these temperatures are ideal for the development and multiplication of potentially pathogenic microorganisms (Bockmühl, D.P. et al., 2019; Kruschwitz A. et al., 2014; Laitala K. and Jensen H.M., 2010). A recent breakthrough study showed that more and more bacterial strains are becoming resistant to classical antimicrobials and that *E. coli*, *P. aeruginosa*, and *S. aureus* are the three leading resistant pathogens associated with mortality from antimicrobial resistance (Murray C.J. et al., 2022). The problem of textile washing hygiene is partially solved by oxidants added to detergents in the form of perborates or percarbonates (bleaching activators) (Betz M. and Cerny G., 2001; Bockmühl D.P. et al., 2019; Pušić T. et al., 2007). Under suitable conditions, active oxygen is released into the wash bath where it oxidizes colour stains while acting against a variety of microorganisms (bacteria, bacterial spores, fungi, yeasts, and viruses) (Brands B. et al., 2016; Hickman W.S., 2002; Yun C. et al., 2017). Bleach activators are only present in solid detergent powders, but their share has been decreasing since 2010 due to EU environmental regulations. Liquid detergents, which are popular among consumers (Ferri A. et al., 2016), do not contain bleach activators at all because they are unstable in liquid formulations

(Beck R.H.F. et al., 2007). Thus, the result of using liquid detergents with a low-temperature laundry care program manifests itself in hygienically unsafe textiles and internal parts of the washing machine, which represents the possibility of spreading potentially pathogenic microorganisms through textile products (Honisch M. et al., 2016). Achieving adequate hygiene of laundry and internal parts of the washing machine during low-temperature washing is a particular problem with regard to current and future epidemics.

In order to achieve a balance between energy saving, adequate hygiene and effective soil removal, it is crucial to optimise the process of household washing by introducing cold disinfection. Accordingly, the use of ecologically acceptable agents that do not pollute wastewater, are safe for humans and do not pose a risk for the development of long-term resistance of microorganisms due to increased use is urgently needed.

Among antimicrobial agents, hydrogen peroxide (HP) and peroxyacetic acid (PAA) are among the most environmentally friendly disinfectants (Köse H. and Yapar N., 2017; Upson S. and Clarke C., 2018). They are characterised by high efficiency, broad spectrum antimicrobial activity, low toxicity, and ease of use. Both HP and PAA are already used in professional textile care (Fijan S. and Šostar-Turk S., 2010), but their introduction into the household washing process remains an important, complex and largely unexplored research task.

The aim of our study was to determine whether the addition of HP to liquid detergents during household washing at low temperatures provides sufficient disinfection of laundry and what the optimal washing conditions are. The disinfection effect was tested according to the standard EN 16616:2015. HP was added at different concentrations (0.5%, 1% and 3%) to the liquid detergent during the main wash in a household washing machine. Combinations of HP and PAA were also tested. At the same time, a coloured fabric was washed to determine the influence of oxidants on the colour of the washed fabric.

EXPERIMENTAL

Disinfection efficacy

Disinfection efficacy was tested against standard bacterial strains *E. coli* ATCC 35218, *P. aeruginosa* ATCC 278 and *S. aureus* ATCC 25923 according to the standard EN 16616:2015. Briefly, cotton carriers of 1 cm^2 were inoculated with a bacterial inoculum with a cell concentration of 1.5 $x10^9$ CFU mL^{-1} (OD 620 nm). After drying at room temperature in a safety cabinet, the carriers were transferred to sterile cotton bags and placed in a washing machine (Asko model, Gorenje, Slovenia) together with the ballast of 100% cotton fabric (170-190 g/m^2) with a total weight of 2.45 kg. Household washing was performed at 40 °C using the program "Universal with prewash". The conditions of the wash cycles are listed in Table 1.

Table 1: Washing cycles conditions

Washing cycle	Time (min)	Washing bath volume (l)	Temperature (°C)
Prewash	16	3	28
Main Wash	30	10	40
Rinse	10	3	26

Immediately after the start of the main wash, 12.5 ml of defibrinated sheep blood per kg ballast fabric and 5 g/L of liquid detergent Ox (Yuco hemija d.o.o., Serbia) and the corresponding amount of disinfectants Belox (35% hydrogen peroxide HP) and Persan S15 (15% peroxyacetic acid, PAA) (Belinka Perkemija, Slovenia) were added. At the end of the main wash, the bags containing the carriers were removed. Each sample carrier (Ns) was transferred to a separate tube containing 5 ml of neutralizer (0.25 mol/L phosphate buffer) and glass beads. Bacterial cells were detached from the

carriers by vortex shaking for 10 minutes. A serial dilution of the sample liquid was prepared, and 1 ml was transferred to a Petri dish and poured with agar. Endo agar (Merck) was used to obtain *E. coli*, cetrimide agar (Sigma Aldrich) for *P. aeruginosa*, and mannitol salt agar (Biolife) for *S. aureus*. Agar plates were incubated at 37 °C for 24 h, and colonies were counted. The results were expressed as log CFU cm^{-2}. All experiments were performed in five parallel runs and three replicates. Cotton carriers with bacteria not exposed to the washing and disinfection process were considered as control (Nc). Bacterial cell reduction was expressed as relative reduction (R) in percent and absolute reduction was calculated as log reduction RL= (Ns/Nc) (log CFU cm^{-2}).

Color change

The effect of the presence of HP and PAA in the main wash cycle on color change was determined by color measurements of blue-dyed 100% cotton fabric after washing with or without the addition of HP and PAA. Washing was performed under the same conditions as previously described. Color characteristics were determined using a Datacolour Spectraflesh 600 PLUS-CT spectrophotometer operated with Datacolour Datamaster software with the following settings: Illuminant D65, large area view, specular excluded, UV included, and 10° standard observer angle. The color difference (ΔE*) was calculated using the following equation:

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

where ΔL*, Δa* and Δb* are the differences between the color coordinates lightness (L*), green-red (a*) and blue-yellow (b*) of the two samples, i.e., the sample washed with liquid detergent in the presence of HP and PAA and the sample washed with liquid detergent only.

RESULTS AND DISCUSSION

Disinfection activity of HP

Results of the HP disinfection activity are presented in Figure 1. Addition of HP in the main wash cycle efficiently inactivated all the tested bacteria. As expected, the best results were obtained when HP was in a concentration of 3% in the washing bath. The highest disinfection activity was obtained against *E. coli* with a growth reduction of 7.62 log, followed by *P. aeruginosa* with a reduction of 6.61 log and *S. aureus* with a reduction of 6.58 log. The results clearly show increasing the concentration will result in higher reduction although significant differences among bacterial strains can be detected (Figure 1).

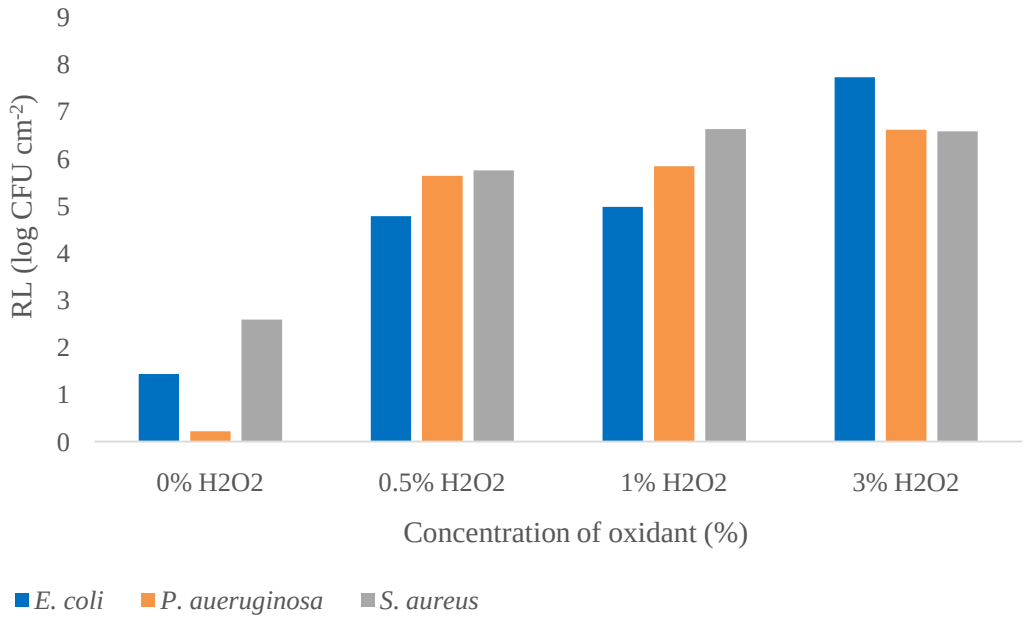

Figure 1: Disinfection activity, RL (log CFU cm^{-2}), of 0%, 0.5%, 1% and 3% HP added in the main wash cycle against tested bacteria E. coli, S. aureus in P. aeruginosa

The addition of 0.025% PAA to 0.25% HP resulted in a disinfection effect comparable to 0.5% HP alone against P. aeruginosa and S. aureus, while the bactericidal effect against E. coli improved significantly (Figure 2). Moreover, a single increase in the concentrations of both oxidants (0.5% HP + 0.05% PAA) resulted in better disinfection activity than 3% HP alone, clearly demonstrating the additive effect of both components in the mixture. It should also be noted that P. aeruginosa proved to be the most resistant to the bactericidal action of HP and PAA, showing the lowest reduction rate.

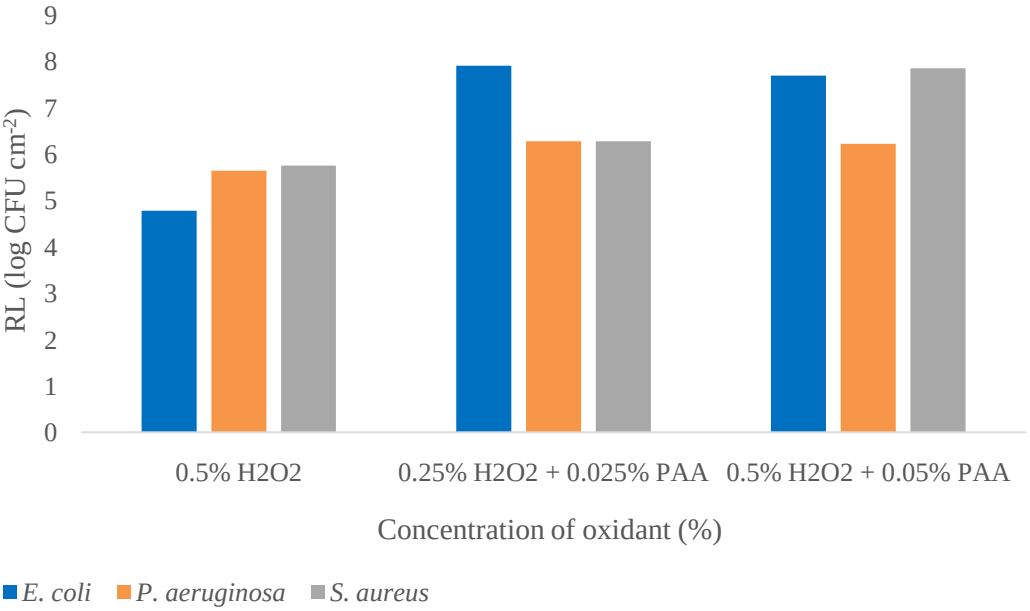

Figure 2: Disinfection activity, RL (log CFU cm^{-2}), of 0.5% HP and a combination of HP and PAA in 0.25%+0.025 or 0.5+0.05% added in the main wash cycle against tested bacteria E. coli, S. aureus in P. aeruginosa

In Figure 3, the ΔE* values of the washed blue fabric show that the color change during washing is minimal. ΔE* < 1 is known to be invisible to the human eye. As can be seen from the results, neither the studied concentrations of HP in the main wash nor the mixture of HP and PAA had higher ΔE* values than 1. Accordingly, their addition in the low-temperature wash has an insignificant effect on the color change of the laundry.

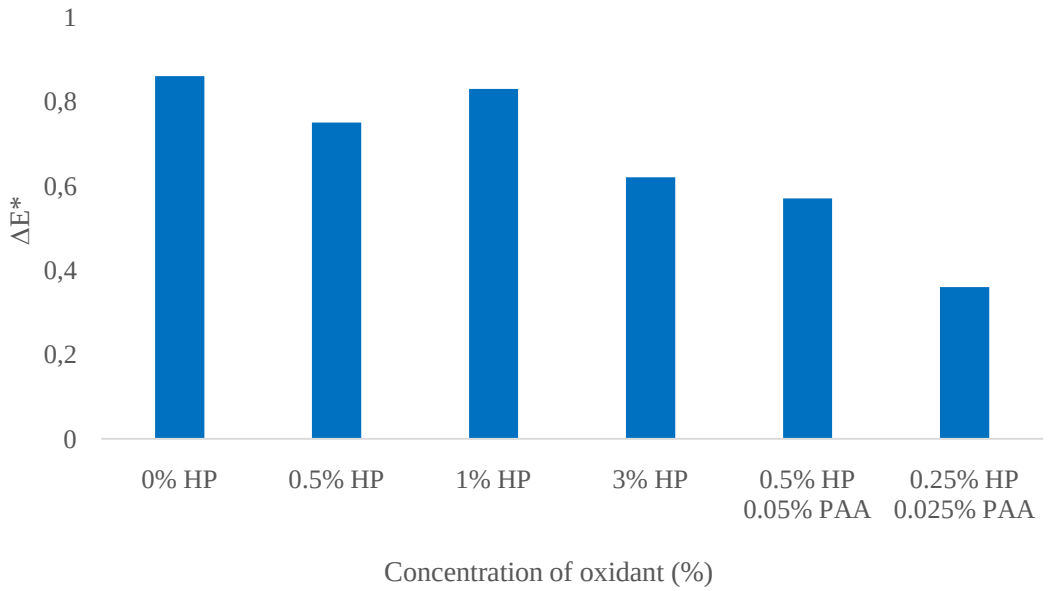

Figure 3: Colour difference, ΔE, between blue cotton fabric washed with liquid detergent only and those washed with liquid detergent and added hydrogen peroxide and peroxyacetic acid of different concentration*

CONCLUSIONS

The introduction of HP in household washing processes can significantly improve the hygiene of washed textiles and the hygiene of the internal parts of the washing machine by eliminating microorganisms without damaging the textiles. In this case, the highest disinfection activity against the tested bacteria *E. coli*, *S. aureus* and *P. aeruginosa* was obtained by adding 3% HP to the main wash cycle, corresponding to a reduction of > 6.6 log. This study demonstrated that HP can achieve bacterial reduction according to standard disinfection criteria.

The addition of HP and PAA to the household wash cycle at 40 °C with a liquid detergent increased bacterial reduction, especially of *E. coli* and *S. aureus*. In this case, a mixture of 0.5% HP and 0.05% PAA acted additively, as reflected by a greater reduction in the growth of these two bacteria than the addition of 3% HP alone. Importantly, the mixture of HP and PAA also did not cause discoloration of a dyed cotton fabric.

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CONFLUENCE OF STREET CULTURE WITH CLOTHES: CASE OF MAVI ICON

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ABSTRACT

City streets are the places through which the life and culture of a society are reflected best. The music heard in the streets of the cities, the alluring smell of food, the appearance of the chaos and confusion caused by the never-ending activities become an integrated part of life. In all this chaos, the concept of 'street chic', formed by the clothes that reflect the identities of people, has emerged and become colorful reflection of the streets. Characteristic features of a city such as architectural structures, objects, monuments, colorful graffiti have been a source of inspiration for designers in the fashion world. The city of Istanbul is one of the cities where the street culture is relatively more intense due to the symbiosis of different cultures. This paper explores the design process of clothes created with the inspiration from the street, food and music culture of Istanbul for Mavi-Icon collection. Mavi is a a global lifestyle brand with strong denim roots yet started its brand story in Istanbul in the 90's. Thus, the Mavi-Icon collection had a unique place in brand communications. The colors, textures and patterns were designed through the inspiration by the photographs and observations from the streets of Istanbul. The clothes, for which comfortable fits are used to form integrity with street life, are combined with colorful patterns and the Mavi-Icon collection has emerged. To reflect the confusion and color chaos of Istanbul on clothes, where many cultures coexist, the Ikat pattern, which originates from India, was used on printed fabrics. The Mavi-Icon collection has emerged as a reflection of city's lively and entertaining street story through clothes. This study provides valuable insights in the reflection of local identity and culture on clothing through fashion design.

Key words: Istanbul streets, street chic, ikat technique, pattern design…

INTRODUCTION

The social, cultural, socio-economic and technological developments play vital roles in the development and evolution of daily life in the society. Fashion is strongly influenced by these social aspects and also has a constructive structure in different cultures of the society and thus, it is also seen as a factor that shapes the daily life of people. Fashion has a versatile structure, yet it was perceived for a long time as means for addressing the need for dressing. Fashion is an element that reflects popular culture by transmitting our social identities. Music, cinema and street culture spread through various means of media and allow fashion to become globalized (Yağlı, 2013).

The choice of clothing is the external reflection of the tastes, characters and inner worlds of people from different cultures and form the basis of street fashion. The streets of cities are the places where brands and designers get inspiration while creating their collections. Cities such as Paris, Milan, Tokyo, New York and London are considered as centers that have a tremendous impact on fashion in the world. In Türkiye, Istanbul stands out in the fashion world with its street styles (Taşkın, 2015).

In addition to being an indispensable city with its complex urban life, culture, history and visual treasure, Istanbul has also become a source of inspiration for many artists and has been the subject of many art works (Alkan, 2017). The authentic locations and social characteristics of the cities have an important role in the emergence of art works. In this context, Istanbul is described as a city that nourishes art. Also, this richness in every aspect of the city, especially the architectural forms, is a great source of inspiration for fashion design and offers great inspiration. The textures, colors, patterns and geometric structures in architecture are extensively used in the creative process of

clothing designs (Ceyhan and Şener, 2018). Within the scope of the Mavi Icon collection, the street culture and lifestyle of the city of Istanbul were meticulously explored and examined. Inspired by the collected data and visuals as a result of this process, various refined designs were created. Istanbul, as a city where the brand story of Mavi began in the 90s, was used in designs from time to time. Yet, in Mavi Icon collection for the first time, it is aimed to reflect the whole culture of the city in clothes, especially for the 30th anniversary of the brand. The iconic architectural structures of the city are emphasized by tonal prints on denim jackets and trousers. Forms that reflect the comfort of the street spirit were preferred in the different type of clothes. Being a metropolitan city, Istanbul exhibits many different cultures besides Turkish culture. The best way to reflect the harmony created by the combination of these cultural differences in clothes was found to be the combination of colors. Inspired by the 'Ikat' pattern belonging to the Indian culture, printed pieces created by combining blue tones and many colors are included in the collection. This study provides valuable insights into the creative process of fashion design inspired by a metropolitan city. This will contribute to the better understanding of inspiration sources used in creative fashion design process.

Streets of Istanbul and Clothing Culture

Developments and urbanization in big cities such as Istanbul, have a significant impact on society. City streets are the main areas where people meet, communicate and socialize with each other. The city of Istanbul, as a metropolitan city, offer many occasions and opportunities that will enable individuals to socialize on its streets. In addition to all organized events, public spaces such as streets, parks, cafes, trains, subways and buses can also be places where the society coexists and communicates.

In ancient times, people used speeches to attract attention in public spaces, yet today, clothing and appearance have gained more importance in this context (Erdönmez, 2007). Particularly, clothes allow individuals to create social identity with different styles and colors. Clothing can have various meanings and codes in different cultures and cities (Parlak, 2022). Street wear fashion has also various meanings and used as a source of inspiration by many designers. Street fashion generally consists of the clothing style of young individuals living in cities. Some of the main characteristics of this trend are to feel free, comfortable and happy. City streets are the best platforms where young people reflect their clothing trends, the local culture as well as economic circumstances. Thus, designers create their collections inspired by the streets. Thanks to the streets fashion, it is clear today that fashion is not just about creating elegance. Brands also emphasize the importance of street fashion by creating collections with combining styles and forms used by certain group of people in the society with their own design perspective (Taşkın, 2015).

Ikat Weaving

The exact place where the Ikat weaving art first started is still not known, yet, the first samples were dated back to the 5th and 6th century and found in the Ajanta Cave of India (Teker 2016).

Picture 1: Ikat weaving loom (Yarmacı, 2019)

Ikat weaving is produced by dyeing yarns using different production techniques. In this weaving technique, dyeing tools, looms, shuttles and warp system are used as creative tools. Also traditional

looms are generally prefered instead of mechanical looms in Ikat weaving (Yarmacı and Akpınarlı p. 2020). The looms are used with or without whip. In looms with whips, the shuttle moves by pulling a whip instead of the hand method (Yanar and Akpınarlı 2016). The dyeing of the fabrics is done while the threads are on the loom (Picture 1). To create the desired pattern, some of the warp and weft yarns covered and thus cannot absorb dye. Then, the dyeing of the remaining yarns is carried out (Aydoğan and Oyman, 2021).

METHODS

The purpose of this study is to explore the design process of a collection inspired from Istanbul and its street culture. With the qualitative method as a strategy, the study used a case study design to develop an understanding of the fashion brand's collection development process. The material for the study was acquired by means of participant observation and by document analysis. Document analysis includes examination of written and visual materials relevant to the phenomenon to be investigated. In qualitative research, document analysis can be used as a single data collection method or can be used to seek corroboration with other data collection methods (Yıldırım and Şimşek, 2008). Document analysis is particularly applicable to qualitative case studies as additional means of collecting data and, thus, it was used to support the data collected by participant observation (Bowen, 2008). Participant observation was relevant as a data collection method since three of the authors were part of the design team in Mavi Design Center and thus, it enabled to learn about collection design and development process in a natural setting through observation and participation in those activities. The material collection process was started with an analysis and reviewing of all documents related to the corresponding collection including photos, text, news, announcements, and all other relevant information used by the designers. Concerning the observation period, the author only pointed out observations that are relevant to Mavi Icon collection. The findings from two data collection methods were summarized in Results section.

RESULTS

For the Mavi-Icon collection, designers got inspired mainly from the iconic architectural monuments of Istanbul (Maiden's Tower, Galata Tower, Rumeli Fortress, etc.), modern architectural forms as well as the typical transportation vehicles (tram, ferry, ship, etc.) (Picture 2 and 3).

Picture 2: Istanbul Inspiration Denim Jacket

Picture 3: Istanbul Inspiration Denim Jacket 2

Also, the cats which are inevitable part of Istanbul streets were included in the collection as a symbol. Knitted fabrics were produced with patterns inspired from two typical cat furs. Oversized cardigan t-shirt models, in which orange and green tones are used predominantly used, were included in the collection to reflect the free spirit of cats and their unique comfort and fun nature (Picture 3, Picture 4 and Picture 5).

Picture 3: Cat Inspiration Pattern Picture 4: Cat Inspiration Pattern 2 Picture 5: Oversize Cardigan

Icons can be defined as tangible and intangible signs or symbols that can describe and represent various things. Icons have been historically used as a tool to reflect the characteristics of cultures and thus, often become a tool to be used fashion designers. Icons not only affect design and creativity, but also inspire designers because of their social and cultural heritage (Erkan, 2019).

The iconic forms and items of Istanbul were visualized according to the fabric texture and colors and transferred to the fabrics using different printing techniques. In general, printing can be defined as patterns and shapes transferred onto objects. Although the basic principle of printing did not change much throughout the history, various types of printing techniques have been developed. Today, one of the most commonly used printing technique is digital printing due to the possibility of producing large variety of patterns and colors (Erim and Gezicioğlu, 2019). Thus, in Mavi Icon collection, especially for prints inspired from the Ikat pattern which has a large variety of colors, the digital printing technique was employed (Picture 6 and Picture 7).

Picture 6: Mavi X Istanbul – Ikat Print *Picture 7: Ikat Print*

With the Mavi-Icon collection developed by Mavi, the never-ending energy of the city was revealed as if a design cooperation was made with the city of Istanbul. The elegance of the street, the chaos of

colors, the confusion of patterns, the surprising harmony of incongruities, the reality and freedom are represented in every piece of the collection.

CONCLUSIONS

City life has a dynamic structure. From a designer point of view, it has always been seen as one of the greatest source of inspiration historically, even though it is, from time to time, perceived as an intense rush with heavy socio-cultural and economic chaos. Individuals generally desire to be at the forefront with their appearance to express their personality in society. People have transformed the clothes to the means by which they reflect their identities and communicate with their surroundings. As a metropolitan city, Istanbul where street culture is intensely experienced, has inspired designers. Thanks to the Mavi Icon collection, street elegance and the spirit of the streets were integrated in clothes and presented to consumers. The Mavi-Icon collection has emerged as a reflection of city's lively and entertaining street story through clothes. This study provides valuable insights in the reflection of local identity and culture on clothing through fashion design.

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THE INFLUENCE OF CHINESE CULTURAL ELEMENTS IN FOOTWEAR DESIGN

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ABSTRACT

The Chinese culture is extensive and profound. Chinese people advocate "Taoism is natural" and pursue "family and everything is prosperous". The spirit of Confucianism and Taoism for more than 2,000 years has already been integrated into all aspect of Chinese life. In traditional costumes, patterns are mostly based on animal and plant elements, expressing the pursuit and yearning for beautiful things. Chinese traditional costumes show different Chinese culture and elements. Based on the historical and cultural background, this paper analyzes the shoe design with Chinese cultural elements in the main development period, and compares it with the modern shoe design. Through analysis and thinking, it aims at providing original practical experience and design method reference for the development of footwear brands with Chinese cultural elements.

Key words: Chinese culture elements, Confucianism and Taoism, Chinese Zodiac sign, original design, IP design

INTRODUCTION

Traditional Chinese culture embodies the creativity of civilization, and is the integration of moral inheritance, cultural thoughts and spiritual ideas. In China, traditional culture normally consists of Confucianism, Buddhism and Taoism. Among them, Confucianism is nurtured by Chinese local culture, and Taoism, as the complement and opposite of Confucianism, complements and shapes the Chinese people's world outlook, life value, core structure of cultural psychology, artistic ideal and aesthetic interest (Jiang & Zhang, 2020). "Complementary between Confucianism and Taoism" is the internal matrix and external representation of Chinese traditional culture, and it also reflects the spiritual concept and living style of the Chinese people (Jan, 2018). In the Book of “I Ching”, Confucianism and Taoism have been inseparable. This book is actually a source of traditional culture, and it is a classic admired by both Confucianism and Taoism. It is the theoretical source of natural philosophy and humanistic practice in Chinese traditional thought and culture, from which hundreds of scholars and schools originated (Schwaetzer, 2022). Only by having a clear understanding of the source culture of Chinese traditional culture can we better excavate and design products. Therefore, this paper focuses on the spirit of Confucianism and Taoism to carry out the research on design application.

Confucian Cultur

Confucianism is the dominant culture, and the core of the culture is benevolence, of which "benevolence" means loving people, and the heart of "loving people" is the ideological core of the footwear design in this paper. In Confucian culture, there is a saying of "cultivating one's body and keeping one's family in order". "Self-cultivation" refers to cultivating one's own morality, that is, changing one's behavior and habits. "Qi Jia" means that family members can work together and live in harmony (Kim, 2012). The applied footwear design in this paper is applied panda images, and the parent-child footwear itself is based on the emotional perspective. Through product interaction, family affection can be exchanged and extended, and the spirit of "harmony at home" and "love" can be expressed.

Taoist Culture

Taoist culture uses "Tao" to explore the relationship between nature, society and life. "Tao" was first proposed by Taoists in the history of Chinese philosophy. It is an important category of ancient Chinese philosophy and is used to explain the origin, noumenon, law or principle of the world. The original meaning of Tao refers to the road, the smooth road, and later gradually developed into the truth to express the regularity of things (Seiryu, 1958; Tang, 2019). Taoism advocates the harmonious coexistence of nature and nature, conforming to nature and not being too deliberate. "Tao follows nature" and the Taoist philosophical view of the unity of heaven and earth has not only influenced Chinese traditional culture, art, medicine and other aspects, but also has a great influence and reference value on all aspects of people today. Therefore, as a designer, we should draw inspiration from these traditional wisdom to create and design, starting from China's local philosophy, and on this basis to inherit and serve consumers.

THE INFLUENCE OF CULTURE ON FOOTWEAR IN CHINA

China has a long history and different cultures in different historical stages. Different cultural conditions will have an impact on clothes, food, housing and transportation, and so will footwear. The shape, material and design of shoes are deeply influenced by the historical stage culture. In this paper, several historical stages and the significance of footwear in different cultures will be introduced.

The Concept of Class Embodied in Footwear

In the slave society, the class hierarchy of slave owners and slaves is evident in clothing and shoes. Shoe decorations indicate the identity of the wearer through different materials, shapes, colors and other information symbols. Fine silk shoes have become a symbol of the wealth and status of the slave owners.

The Qin dynasty established the first centralized feudal state in China. In order to consolidate the feudal empire, Qin Shihuang set up all kinds of uniforms of clothes, crowns and shoes. The feudal thoughts of respecting men and women appear in shoes. According to the theory of "the heaven and earth are round" at that time, men wore square-toed shoes, which shows that the yang falling from the sky is powerful and noble. Women could only wear round toe shoes, which meant round, gentle, gentle and submissive husbands.

The Impact of Ethnic and Cultural Integration on Footwear

During the Spring and Autumn Period and the Warring States Period, King Wuling, the monarch of Zhao State, introduced the clothing of the northern Shanxi ethnic group (collectively known as Hu people at that time) - short coats and short boots, to promote a great revolution in the history of Chinese clothing - Hu clothing and archery. It has become the most successful product of introduction and reform in the history of China's footwear industry. After that, leather boots were popular for a long time. They were worn almost from generation to generation in Sui, Tang, Song, Yuan, and Ming Dynasties. It was not until the Qing dynasty that they were changed to silk satin boots.

The Wei, Jin, Southern and Northern Dynasties were a period of great population flow before the Sui and Tang Dynasties. The cultures of the Han and ethnic minorities blended together, and the folk cultures of the Central Plains and the South of the Yangtze River penetrated each other. Clothes and footwear are re-integrating. At that time, the most common basic form of northern peoples was leather boots and high shoes. At that time, clogs and silk footwears were the most popular in the south.

The Influence of Ancient Culture on Footwear

The Song dynasty was a feudal dynasty dominated by Neo-Confucianism. Clothes, accessories, crowns, and footwear are all conservative and restrained. In the court at that time, the emperors and nobles often wore silk shoes, and even fine silk shoes were often worn at court meetings. The shoes worn by ordinary people include straw sandals, cloth shoes, etc., which are named according to the materials used. With the development of shoe culture, shops selling shoes have also appeared in the society.

From the historical review of footwear development above, it shows that different classes, different regions, different historical periods, and different cultural forms of footwear have diverse cultural meanings (see also Figure 1). In addition to function, shoes can also express identity and status. Different shapes can understand different cultural backgrounds and functions, and different patterns can also understand different cultural meanings.

Figure 1: Flowerpot shoes in the Qing Dynasty

DESIGN PROCESS AND APPLICATION

The images of animal plays a very important role in Chinese traditional culture. For example, in traditional costumes and even utensils, there are many objects with animal images as the theme (Yuan, 2007). For example, the Chinese Zodiac, which is familiar to everyone, is the twelve animals in China. Their birth years match the twelve Earth Zodiac. The zodiac is not only integrated into Chinese people's life as an ordinary animals, but also its natural habits are endowed with many cultural meanings by people, rising from animals to gods and being respected and worshipped by people (Caroline, 1983; Falleiros, 2018). Dragon robes, phoenix crowns, the imitation hat of the tiger's head and the imitation shoes of the dragon's head (see also Figure 2 and Figure 3) in traditional costumes are typical examples of the combination of animal images and clothing items, and their integration into culture and life (see also Figure 4).

Figure 2: Tiger head imitation cap

Figure 3: Dragon head imitation shoes

Figure 4: Other types of imitation shoes

Selection of Color

In traditional Chinese culture, colors are divided into five positive colors - red, yellow, blue, white, and black. These five traditional colors are the crystallization of the ancient people's philosophical ideas and wisdom, and are part of the traditional Chinese culture like the five elements (Zhang et al, 2012). Black and white is the color of the beginning of the universe and the beginning of humanity. The application of black and white color is vividly reflected in many fields such as ceramics, calligraphy, and painting in Chinese culture.

Selection of Image

As China's national treasure, panda has a distinctive image. Their plump and round body lines, innocent and lovely demeanor, and scattered black and white colors create a naive image, which is very popular among adults and children. The design of "Panda" as the design theme and material element of shoes is very suitable for the development of shoes, both from a cultural point of view and the design point of view. In the design process, the traditional Chinese ink and wash method was used to express the design. By sketching the panda photos, we finally finished the renderings and atmosphere pictures of this series of parent-child shoes (see also Figure 5 and 6).

Figure 5: Product renderings of this ink technique (Parent-child series)

Figure 6: Black and white panda ink image (left) and shoe product (right)

Selection of Styles

The design of this panda shoe not only considers the culture, shape and comfort of the product, but also involves the material, last, base material, category and structure of the vamp and shoe. After a comprehensive analysis of the design, indoor toddler shoes, outdoor toddler shoes, women's casual shoes and women's ballet shoes are designed from the perspective of function. These kinds of shoes not only have their own functions, but also can form parent-child shoes from an emotional point of view. They not only have practical functions, but also cultural connotations.

FOOTWEAR DESIGN ANALYSIS

Target Market

In the design process of panda parent-child shoes, the main people to be considered are infants and mothers. Baby shoes mainly consider the toddler function and are divided into indoor and outdoor toddlers scenes. Shoes for adults should be comfortable and easy to match. According to the mother's identity, many considerations have been made on the function and wearing of adult shoes when designing, and it is easy to put on and take off and walk.

Transformation of Design Elements

In the application of panda elements, the most representative features of panda's five senses, such as black eyes and black ears, are extracted and shown in shoes. Among them, the interesting design points are the flattening of panda's eye and the semi-stereoscopic treatment of panda's ears. This contrast makes the panda's image look fuller on the shoes. The fixed eyes and the semi-separated ears form a dynamic harmony (see also Figure 6). The static contrast makes the shoe decoration more layered and rhythmic, and the panda image is more vivid.

Figure 6: Extraction of design elements of panda eyes and ears in parent-child footwear design

IP IN FOOTWEAR DESIGN

Intellectual property, referred to as IP, refers to the exclusive rights of intellectual achievements created by human beings in the practice of social labor. With the development of media technology, the concept of IP is now more abundant, mainly concentrated in comic books, games, movies and other fields. Animal IP, with its bright and interesting visual effects, gradually entered the public's field of vision and become a popular trend through artificial personality feelings. As far as the panda IP in the parent-child shoes is concerned, the IP image of the panda does not depict the five senses of the panda from the beginning to the end, but extracts the most representative features of the panda-

oval black eyes, small semicircular ears and round white eyes. The bright black-and-white tones combined with the flattening of the eyes and the semi-stereoscopic treatment of the ears make the overall image simple and lovely, but easy to identify (see also Figure 7). This IP image can not only be applied to parent-child shoes, but also be combined with products in clothing, home, food packaging and other products such as T-shirts, pillows, candy, cups and so on.

Figure 7: Process from image of panda to IP design

In the process of development, we not only refined the panda image elements, but also created a series of panda images. We hope that we can not only enrich footwear products, but also expand to other products. We also tried other image creations, such as clothing (T-shirts) and card sets. Regarding the IP image, we are still in the experimental stage. We hope that the influence of the product in the market will continue to expand, so that the spread of an IP image will be more meaningful. It is also expected that this IP segment can be accepted by consumers, forming the IP image that we expect to have commercial value (also see Figure 8).

Figure 8: Ink panda image for footwear design

CONCLUSION

Through the understanding and interpretation of traditional culture, combined with the footwear design of panda, a unique animal image in China, the unique attributes and manifestations of the design under the influence of Chinese culture, as well as the cultural core contained in it, are reflected. When using the elements of Chinese traditional culture to design, we should not only reflect the appearance of Chinese color symbols and the appearance of pandas, but more importantly, the design of last and structure should combine the uniqueness of Chinese feet. Considering the growth morphology, bone condition and functional requirements of different age, it is necessary to optimize the design by combining materials and technology. Draw inspiration and design elements from Chinese traditional culture, and develop and design products through the transformation of abstract and concrete, so as to ensure reasonable functions and wearing characteristics and environmental protection. The research and development of panda shoes began in 2018. After repeated trials and market tests, the products are becoming more and more mature, and they are loved by many children, parents and adult. The products not only has the cultural implications and design features of panda elements, but also the concept of parent-child and "home" are recognized by consumers and the market. Therefore, a good product design has both connotation and extension. Panda parent-child shoes are extensible in time and space, which also reflect the combination of Chinese culture and footwear products and the optimized design. It could provide reference for designers and product development, and integrate Chinese culture into contemporary design.

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NEW CONSUMER TRENDS IN SUSTAINABLE FASHION

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ABSTRACT

The fashion industry has always been known to cause major problems to the sustainability of our planet with pollution in terms of landfills and also the release of tonnes of plastic microfibers into the ocean further because of the endless consumption of fashion products that can be also found as an uncontrolled waste. Unfortunately, fast fashion is one of the most important causes of pollution in the world. Huge amounts of greenhouse gases, the depletion of non-renewable resources, and bad workplace environments are all present in the production of fast-fashion garments. The resulting impacts on the planet are huge, which is why it's so essential to work on ways to reduce these impacts and use a circular model of production and consumption. But during this, a minimum of say bad scenario, an encouraging fact coming to the rescue is – generation z and millennials starting in support of sustainable fashion brands and are willing to pay a price to remain greener.[3] Their impact is taken seriously on many levels ranging from fashion companies up to the marketing strategies and also the way media is using its influence. This paper explains the way the new young generation is becoming a turning point for fashion businesses to become more sustainable.

Key words: consumer, sustainable fashion, generation z, millennials, trends

INTRODUCTION

Understanding new trends in consumers' practice of shopping in the sustainable fashion market is becoming a significant factor when it comes to creating strategies in the design and marketing sector. The pandemic period had an important role in bringing awareness about sustainability to an open market of different products from the beauty industry, food as well as fashion. By World Economic Forum and its 2020 survey that covered 21000 people from 28 countries, they found that 86% of individuals are eager to see products on the market that are more sustainable and have ethical values. WGSN analysis states that sustainability remains a most important consumer priority. Consumers are eager to see real change from companies, and many are ready to take an active part in building a better present and future starting by making the right choice of brands. In IBM Institute's 2020 report, 6 out of 10 consumers are ready to change their shopping habits to reduce their impact on destroying the environment. This has particularly intensified during the pandemic. The pandemic showed the weakness of the globalized system, raised awareness of the need for sustainable paths, and accelerated a shift in preferences from global and centralized, to local and decentralized. Local economies and services now have a role to enable customers to access and assimilate sustainable choices on a micro-land. Open-source, decentralization, and decolonization will shift from exclusive concepts to mainstream realities.[4] Major companies will have to scale their systems, products, and services that have these values. Major brands will seek to leverage their global power, networks, and infrastructure to increase environmental solutions, accelerate innovation and democratize sustainability. The future of sustainability lies in collaboration, adaptation, and integration.[5]

[3] Munoz, M., 2021, *The future of sustainable fashion – Gen Z and Millennials*
[4] WGSN report, 2020
[5] WGSN report, 2019

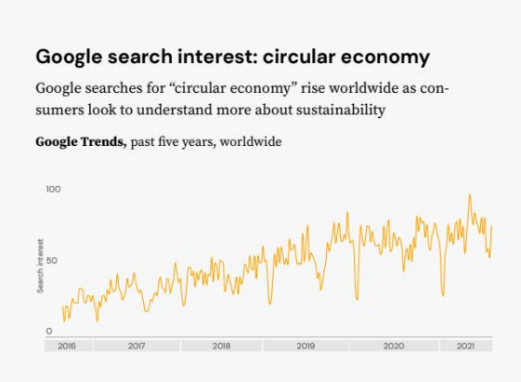

Figure 1: Rise of the consumers interested in sustainability (WGSN report, 2021)

Figure 2: Sustainability topics rated on social media (WGSN report, 2021)

Younger generations as consumers are also seriously concerned with social and environmental issues, which many think are the most important issues of our time. They now more and more back their beliefs by pursuing different shopping habits, favoring brands that are aligned with their values, and passionately avoiding those that don’t. Being aware of this fact can be a significant factor of use for fashion brands and media to develop better strategies for sustainability in fashion. Understanding the flow of the interest and thoughts of Generation Z and Millennials becomes crucial for creating these strategies.[6]

Consumption of Generation Z versus Millennials

The world economy is becoming more and more under the influence of the younger generations and their domination is becoming obvious to everyone as sustainability matters more than ever. Generation Z, which has everyone born after 1996, for example, will conjure the most important portion of the U.S. population and economy within the coming years. They are being exposed to the web and modern technology since birth, together with experiencing the drastic social and social changes from the 2010s that have shaped a generation that’s extremely interested in world changes and under the influence of a large number of world issues. One of the highest issues Gen Z cares about is global climate change and sustainability. This is already very visible in the way Generation Z spends their money, where they decide to live, even whom they choose as their employer, and the environment where they will be working. Being aware of the pending impact of Gen Z on the world economy is being aware of the importance of sustainability that will dictate the paths of success of future businesses and the fashion industry is a huge field of action.[7]

[6] Furbee, C., 2021, *Gen Z Makes Sustainability Important for All Businesses*
[7] Furbee, C., 2021, *Gen Z Makes Sustainability Important for All Businesses*

Before we get into the true power of Generation Z, let's clarify some obvious differences between these very important categories of young generations. The generation called millennials defines as those born between 1981 and 1996, while Gen Z considers those born between 1997 and 2012. There are versatile interpretations of those terms and lots of sources use slightly different ranges to define each term, so for this paper, we'll consider millennials as being born between 1980 and 1999, and Gen Z as those born in or after 2000. The oldest millennials are now over 40 years old and therefore the youngest is 26, meaning that their spending power is increasing as they climb the career ladder. Stereotypes about millennials often depend on claiming that this generation is consuming an enormous number of traditional industries, but we've to take into consideration that millennials hold fewer assets and have less wealth than previous generations, so they are very conscious about how they spend their money. Generally, this generation takes priority in health, well-being, convenience, and ethics, with 73% willing to pay more for products or services that are sustainable or promote a positive impact on the planet.[8]

Generation Z is currently either still in school or has recently entered the workforce, so their earning power is yet to succeed in its full potential. However, there are some key trends to require if brands want their business to be successfully appealing to the current generation now and in the future. Fashion dominates spending for Gen Z, with around 75% of their purchases being done in this sector, compared to 65% of millennials.[9] Similar to the generation before them, Gen Z is likely to prioritize price as a purchasing factor, focusing more on the moral, practical, and eco-friendly aspects of products and services.

If we compare it with the habits of Millennials, seems that less attention has been spent looking at the spending power of Gen Z maybe because of the uncertain facts connected with the future and trends yet to be made. There are also a lot of grey zones in analysis considering figures of these "generations". It is seen frequently on the internet that Gen Z only in the United States spends $44 billion a year on themselves and influences another $600 billion in spending by others. Unfortunately, in most cases, these statistics lack detailed explanation or context as well as support from the references they cite. The statement that Gen Z spends $44 billion on average each year is coming from a Mintel study that used population estimates and average self-reported allowance to calculate the spending potential of kids and teens. The problem with this study is that Mintel was looking at kids and teens ages 6 to 17, which covers a lot, but not all, since that Gen Z age range goes from 7 to 21. Second, the $44 billion statistic is the total estimated earnings for kids and teens in the U.S. using 2012 data and an average allowance at that time of $16.90. Concerning this, it represents the total spending potential of these kids and teens but, it is unlikely that this group will spend 100 percent of its earnings, actual spending is considerably less. In fact, the same Mintel studied how much this group actually spends each week and they found out that it is actually 66 percent of their earnings on average. This would make the estimate of actual direct spending for 6- to 17-year-olds at $29 billion. This number exists in the Mintel report, but it is rarely cited and used as information. While useful, it still doesn't include the impact of spending on Gen Zers ages 18 to 21. By 2020, Gen Z represented 40 percent of all consumers. It is clear that the future of the market is in this generation's hands. Considering their sheer size and influence, whether direct or indirect, marketers cannot afford to ignore these empowered young consumers. Their peak formative years are already here, and brands should act now as Gen Zers build their brand preferences and continue to hone their market behaviors – which, as we've proven, impact consumer spending across all generations.[10]

[8] CB Insights, 2020, 14 Industries Experts Say Millennials Are Killing – And Why They're Wrong'
[9] Francis, T. & Hoefel, F., 2018, '*True Gen': Generation Z and its implications for companies*
[10] Francis, T. & Hoefel, F., 2018, '*True Gen': Generation Z and its implications for companies*

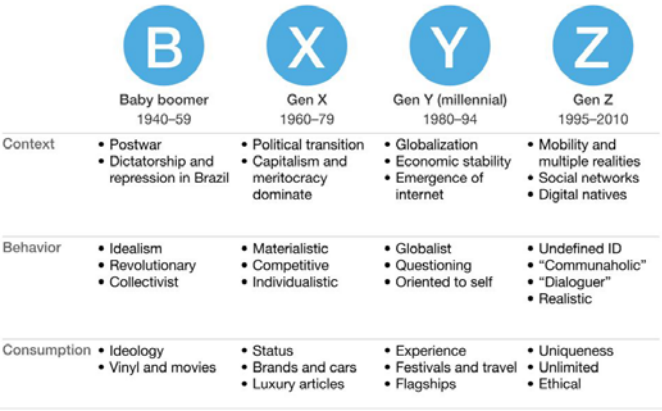

Figure 3: Characteristics of each type of generation from the 1940s till now (Mckinsey.com)

Generation Z is on the brink of becoming the most important consumer base within the U.S. and global economy. With about 90.5 million members just within the U.S, the path of Gen Z into the economy creates an extremely large market with a considerable amount of buying power. It is obvious that the companies which will be able to best recognize the unique buying preferences and habits of these consumers are going to be able to take advantage of this young market. The eagerness Gen Z has, surrounding a mess of social and environmental issues has influenced heavily how they create purchasing decisions.[11]

The young generation influences turning fashion businesses toward sustainability

Businesses that have had modest track records of environmental trends as far as fashion consumers are starting to feel the pressures and real power influence of Gen Z and their buying habits. This is especially visible in the retail sector, where many “fast fashion” brands putting bad production quality and cheap materials over sustainable sourcing have begun to fail. The bankruptcy of several big-name brands such as Forever 21, Aeropostale, and J. Crew along with retailers like H&M and Zara is showing the impact of the changes. Gen Z is not only showing a negative attitude towards unsustainable brands but is showing a great wish and attention to pay more for sustainable products. As stated above Gen Z members 73% of them are willing to pay more for sustainability, a majority of which were willing to pay up to a 10% premium type of product. These buying preferences do not just define retail but in general all choices of Generation Z.[12]

The way brands are trying to answer this Gen Z influence is by integrating social and environmental themes into their products and services and highlighting their importance. It is clear that this approach is the benefit but many brands do this in a very controversial way and many fail to get it right. By the State of Fashion report, written in partnership with the Business of Fashion (BoF) nine in ten Generation Z consumers think companies have a responsibility to take into concern environmental and social issues. Millennials had a greener approach but Gen Z is taking it to another level asking for more action. The change in approach can be recognized in campaigns reflecting important social issues such as #metoo, #blacklivesmatter, and #timesup, and many of them already have entered the mainstream vocabulary over the past couple of years. Gen Z will take 40 percent of global consumers by 2020 but it is important to notice that concern over environmental and social issues is not restricted only to younger consumers. Some two-thirds of consumers worldwide state that they would change or avoid total brands based on their performance on controversial issues. Half of these consider themselves activists, driven by passion, and the other half are less dogmatic, taking their decision

[11] Furbee, C., 2021, *Gen Z Makes Sustainability Important for All Businesses*
[12] Furbee, C., 2021, *Gen Z Makes Sustainability Important for All Businesses*

about the situation at the moment. New global ethical issues are emerging, and many people worldwide are using consumption as a way to express their deep beliefs.[13]

There are some signs that not only consumers but also brands are taking “new” ethical issues seriously. Fashion companies are getting “woke” (a phrase that calls for “alert to injustice in society”, popular on social media). For example, Nike is supporting Colin Kaepernick, the face of the NFL’s “anthem protests”, and Levi’s promoting a campaign against gun violence. Even luxurious fashion houses like Gucci have also supported that cause, supporting a student-led march calling for more gun control. On the other hand in Asia, famous for fast retailing, the parent company of Japanese retailer Uniqlo, has made efforts to hire refugees and, since 2016, has donated more than $5 million to support refugee initiatives in Asia. British ASOS has taken a different approach to supporting refugees, launching an exclusive lingerie line in partnership with designer Katharine Hamnett and Help Refugees, a nongovernmental organization that will receive all profits from the initiative. H&M took a different topic into account launching the Pride collection in 2018 in support of the LGBTQ+ community, and Balenciaga collaborated with World Food Program, donning its slogan “Saving Lives, Changing Lives”. Some companies are taking even more important actions, putting purpose as the main cause of their strategy and operations. The number of B-Corporations, which are certified is growing and the main goal is to consider the impact of their decisions on people, society, and the planet. Significant data shows that between 2010 and 2018 number of B-corps had risen to almost 200 when it comes to the fashion, apparel, and beauty sector.

Figure 4: Project “Choose-love-help-refugees-the-story” (Katharine Hamnett)

CONCLUSION

New generations are led by a sense of mistrust in institutions and by misinformation, and those at least uncomfortable feelings are pushing them towards not only taking responsibility for minimizing personal environmental impact through new behaviors but also putting their expectations on businesses to take further steps and make the key environmental transformation. The Edelman Trust Barometer stated in 2021 that business is perceived as the only trustworthy institution over, NGOs, government, and media by 61% of over 33000 respondents in 28 countries.[14] Consumers demand companies and business leaders to show a higher interest in socio-environmental challenges, with 68% of those surveyed saying that they expect CEOs to take a step in when the government does not fix societal problems. This becomes a great opportunity for businesses to establish themselves as thought leaders, guiding their customers to a more responsible future.[15] Investments in sustainability will provide companies with great economic opportunities, transforming the financial recovery from the pandemic into a green revolution, and restoring trust and hope among this consumer group. In

[13] Francis, T. & Hoefel, F., 2018, *’True Gen’: Generation Z and its implications for companies*

[14] WGSN, WGSN x CPHFW, 2021.
[15] WGSN, 2021

Southeast Asia alone, the green economy could generate more than $1trn in financial opportunities by 2030.

Staying with the true quality information standards will be an important part of rebuilding trust among consumers. According to a State of Plastic Recycling report, two-thirds of over 5,500 adults do not recycle all their plastic waste due a to lack of information and confidence in the recycling system. Brands along with governments and media will need to provide truthful, and reliable content about sustainability, helping customers navigate in the right way with the complex issues related to it. Gaining trust and confidence with the young generation when it comes to sustainability in fashion is a great challenge for fashion brands especially due to changes that are part of the fashion cycles so it should be taken with great attention and fast reaction to be able to truly make a change that is honest and valuable.[16] With complicated layered global issues above all climate emergency as well as financial anxiety, the behavior of the consumers especially the new generations changes and has a great influence on brands who need to imagine alternative ways of living. Gen Z transitions from the youth market and it is becoming an important key influence demanding not only all gender inclusivity but asking brands to change from sustainable to regenerative pushing the limits to the new unknown future.

“The consumers of today are not the consumers of yesterday and they are not the consumers of tomorrow. In a world where the only constant is constant change, being able to balance the needs of today with the demands of tomorrow is a careful balancing act that anyone who cares about the future survival of their brand must juggle.“[17] (Buzasi, C. 2022)

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RESEARCH ON DIGITAL SKILLS NEEDED FOR THE FASHION AND CLOTHING COMPANIES IN EUROPEAN COUNTRIES

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ABSTRACT

In times of mass customisation, e-commerce and advances in virtual prototyping applications, virtual garment development is in high demand to optimise the design and development processes in the garment industry. In order to compete globally, apparel manufacturers are forced to redesign their production processes and set up a more flexible production system to keep up with the rapid changes in the global market and reach a new technological level through the advances in digitalisation. Therefore, the Erasmus+ project DigitalFashion – Collaborative online international learning in digital fashion investigated the digital skills required for virtual prototyping technologies for fashion and clothing companies in four European countries of the project partners. The survey on the digital skills required for fashion and clothing companies and the state of adoption of virtual fashion technologies is based on data collected from 35 fashion and clothing companies. The results of the survey of clothing and fashion companies aim to assess the level of knowledge of key digital skills and the use of virtual prototyping and to develop a methodology for collaborative international online learning in the field of digital fashion.

Key words: digital skills, virtual prototyping, fashion and clothing companies, E+ DigitalFashion project

INTRODUCTION

Digital fashion is gaining more and more attention, from virtual garment simulation to digital communication and e-commerce. This dynamic, related to both the fashion market and new technologies and means of communication, requires well-prepared and qualified employees who are able to adapt to this ever-changing environment with the necessary skills, up-to-date knowledge and fashion creativity. A part of digital fashion that refers to virtual prototypes and simulations of virtual garments, with the aim of developing suitable garment pattern designs and presenting them on the market to promote sales. The recent pandemic has further accelerated the digitalisation process of fashion companies, leading to many necessary changes in the industry to adapt the new technologies. This results in the need for qualified 3D designers with the required skills and up-to-date knowledge in the new era of fashion creativity.

In the study by (Kalbaska, N., & Cantoni, L., 2019), the current market needs in the field of digital fashion are investigated by analysing job vacancies posted on LinkedIn. It examines the skills and competences required for entry-level positions in digital departments of fashion companies. It is believed that the field of digital fashion will see further significant growth and advancements that will impact the fashion industry as a whole. Another conclusion of this study is that fashion educators must therefore ensure that ICT-related skills needed in the labour market are adequately addressed in curricula and courses. Digital education and training in the fashion industry must therefore aim to improve the ability of its students to use a wide range of tools to increase their efficiency and respond to dynamic market demands.

The Erasmus+ project *DigitalFashion - Collaborative Online International Learning in Digital Fashion* is the fifth in a series of successful projects dedicated to e-learning in the wider textile sector, coordinated by the National Research and Development Institute for Textiles and Leather, INCDTP - Romania. Previous projects were as follows: *E-learning course for advanced textile fields - Advan2Tex* (2014-2016), *Knowledge matrix for innovation and competitiveness in textile enterprises - TexMatrix* (2016-2018), *Smart Textiles for STEM training - Skills4Smartex* (2018 -2020) and the fourth project *Software tools for textile creatives - OptimTex*, which is still ongoing (2020-2022).

DigitalFashion is a new three-year project that started in February 2022 and will end in January 2025 (DigitalFashion project Application, 2021). The project is co-funded by the European Commission's ERASMUS+ program under the Strategic Partnerships for Higher Education. The project's partnership includes National Higher School of Arts and Textile Industries – France, Hogeschool Gent – Belgium, University of Maribor – Slovenia, Textile and Clothing Technological Center (CITEVE) – Portugal, Gheorghe Asachi Technical University in Iasi – Romania. The main outputs of the project are:

R1. New methodology for a common framework on Collaborative Online International Learning in the field of Digital Fashion.
R2. Library of knowledge (the three databases) for virtual fashion design and technology.
R3. Training platform of fashion design by personalized 3D virtual garment fitting.
R4. Curricula for Collaborative Online International Learning in the field of Digital Fashion.

The partnership will develop the following activities within 36 months: *Methodology:* new methodology for a common framework for collaborative international online learning in the field of digital fashion; *Knowledge library:* three databases on textile materials, colours and clothing styles that will be built and integrated into the platform; *Platform:* supporting platform that will allow fashion students and fashion lecturers to collaboratively design a garment for a specific client in an interactive way; *Online module:* new collaborative online module in digital fashion with new training and assessment methods for fashion co-design based on a 3D garment visualisation platform; *Training:* training of the target group by implementing the new collaborative online module in digital fashion; *Testing:* testing and implementing the technology-based platform for fashion design; *Dissemination:* dissemination of the project results and project coordination and management.

METHODOLOGY

Investigating the digital skills needed by fashion and clothing companies in European countries was part of the first project deliverable. The aim was to assess the level of key digital fashion skills, industrial application and needs and to develop a methodology for collaborative international online digital fashion learning in five partner countries: Belgium, France, Portugal, Romania and Slovenia.

The research is based on the analysis of a survey of European fashion and clothing companies and will be addressed in a joint report. The first part of the joint report presents the results at the European level, which are presented in this article, and the second part at the national level of the partners. The results of the required digital skills for the fashion industry and the industrial application of virtual fashion technology at the national level in Slovenia were presented in (Penko, T. et al., 2022).

A new methodology for a common framework for collaborative international online learning in digital fashion will be developed based on (a) a survey of European fashion or clothing European companies, (b) interviews with representatives of fashion and clothing companies in all partner countries, and (c) a study of the learning needs of disadvantaged groups to identify guidelines for the required teaching methods in digital fashion so that learning is accessible to all groups of people.

Survey on digital skills for the fashion and clothing companies in European countries

The survey was conducted with 35 European fashion or clothing European companies in 2022 using the online tool Google Forms in all partner countries (at least five companies per partner).

The questionnaire was divided into three groups: (1) company data and respondent profile information, (2) company experience with virtual fashion technologies and (c) digital skills required for virtual fashion technologies, job profiles. The questionnaire was answered anonymously and contained different types of questions, such as dichotomous, multiple choice and open questions, in order to obtain the best possible opinions. The survey was analysed using descriptive statistics as the main purpose of the questionnaire was to identify a clear need for digital skills for the fashion industry and the industrial application of virtual fashion technology in Europe.

RESULTS WITH DISCUSSION

The survey on the digital skills for the fashion and clothing companies was completed by 35 companies from the five partner countries Belgium, France, Portugal, Romania and Slovenia. 43% of the companies produce fashion clothing, 17% protective workwear, 11% women's outerwear, 11% underwear, 6% men's outerwear, 6% sportswear, 3% children's outerwear and 3% knitwear. Of the fashion companies surveyed, 37 % are larger companies with more than 249 employees. 14 % of the companies have 50 to 249 employees, 29 % of the companies have 10 to 49 employees and 20 % of the companies have 1 to 9 employees. In addition, 40% of the companies export 75% or more of their products, 11% of the companies export less than 25% of their products, 6% of the companies export 50 to 74% of their products, 17% of the companies export 25 to 49%, and 26% of the companies do not export their products. The turnover of the European companies surveyed is: 15% of the companies have an annual turnover of more than 100 million euros. 29 % of the companies have an annual turnover between 10 and 50 million euros, 6 % between 50 and 100 million euros and 21 % of the companies have an annual turnover between 1 and 10 million euros. 29 % of the companies have an annual turnover of less than 1 million euros.

In the first part of the questionnaire, the surveyed companies also defined their attitude towards innovation as no innovation, very low innovation, low innovation, medium innovation, high innovation, very high innovation, Figure 1. The survey responses show that the majority of companies evaluate innovation from the perspective of products, technologies, design and research, while IT and distribution are mostly evaluated as medium innovation.

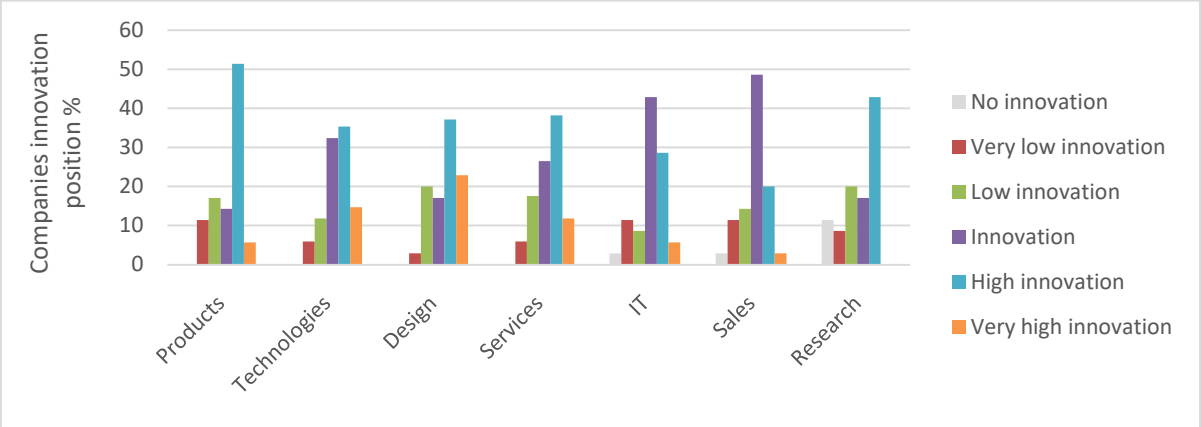

Figure 1: Innovation position of the European companies surveyed

The proportion of revenue spent on promotional activities by the European companies surveyed is shown in Figure 2. 13 % of European companies spend more than 15 % of their share on promotional activities, while 19 % spend about 10 % to 15 %, 31 % about 0 % to 5 % and 37 % of companies about 5 % to 10 % of their share for this purpose.

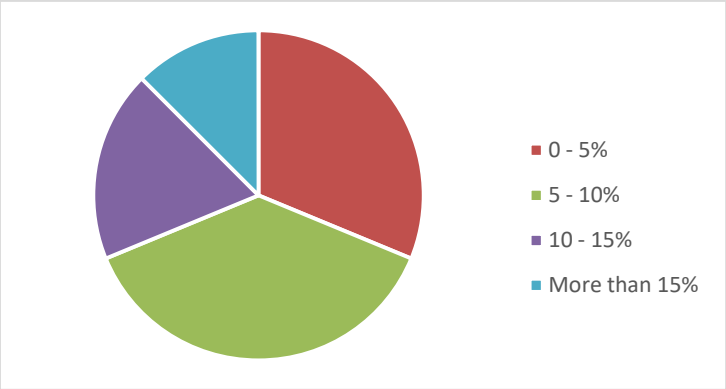

Figure 2: Share of revenue spent on promotional activities by the European companies surveyed

All European companies surveyed have a high innovation strategy, Figure 3. For 64 % of the companies, it is very important to increase market share (29 % rank increasing market share as the highest importance and 35 % as high importance). Increasing profit is very important for 58 % of the companies (29 % rated increasing profit as highest importance and 29 % as high importance). Introducing new products into the production process is very important for 55 % of the companies (26 % rated this as highest importance and 29 % as high importance). Increasing production capacity is very important for 54 % of the companies (17 % rated it as highest importance and 37 % as high importance).

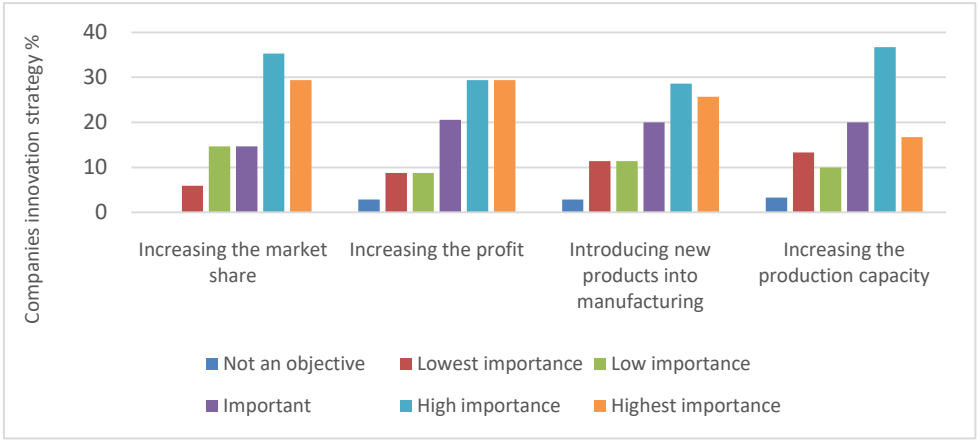

Figure 3: Innovation strategy of the European companies surveyed

The experience of European companies with virtual fashion technologies

The questions in the second part of the survey related to companies' experiences with virtual fashion technology. The survey revealed that 71% of European companies have no experience with virtual fashion technologies. Of those companies that do not have experience, 65% of the companies intend to introduce virtual fashion technologies, 13% of the companies do not intend to introduce them and 22% of the companies do not yet know whether they will introduce virtual prototyping technology. The European companies surveyed that have experience with virtual fashion technologies also have varying lengths of experience with these technologies. 25% have experience from 1 to 3 years, 25% from 4 to 5 years, 17% from 6 to 10 years, 11% from 11 to 20 years and 8% less than 1 year.

The European companies surveyed use the following software: 31 % of the companies use software for drawing and illustrating fashion, 29 % of the companies use specialised software for technical drawing, 24 % of the companies use software for designing garment patterns on the computer and 16 % of the companies use software for virtual prototyping, garment fitting, and visualising garments. The most commonly used software for drawing and illustrating fashion is Adobe Illustrator (33 %), followed by Adobe Photoshop (24 %) and Corel Draw (14 %). Companies also use Corel Photo-Paint

(4 %), Kaledo (6 %) and 3D Design for Illustrator (10 %). 9 % of the companies use other software for pattern design such as GRAPH6+, Procreate, Clo and Clo3D. For technical drawing, companies use Adobe Photoshop (25 %), Adobe Illustrator (21 %), CorelDraw (20 %), 3D Design for Illustrator (12 %), Corel Photo-Paint (5 %) and Kaledo (5 %). 12 % of companies use other pattern design software such as GRAPH6+, Lectra and Solidworks. European companies use Lectra (28 %), Gerber (22 %), Gemini (19 %), Assyst (5 %), Clo (6 %) and Browzwear (6 %) software to design 2D garment patterns on the computer. 14 % of the companies use other software to design patterns: Apex3, Shima Seiki, Photoshop, Illustrator and Gerber AccuMark.
For virtual 3D prototyping, fitting and visualisation of garments, European companies use Clo3D (42 %), Lectra/Modaris (19 %), Browzwear/VStitcher (8 %), Gerber/AccuMark (11 %), Gemini (8 %) and Optitex 3D (4 %), Figure 4.

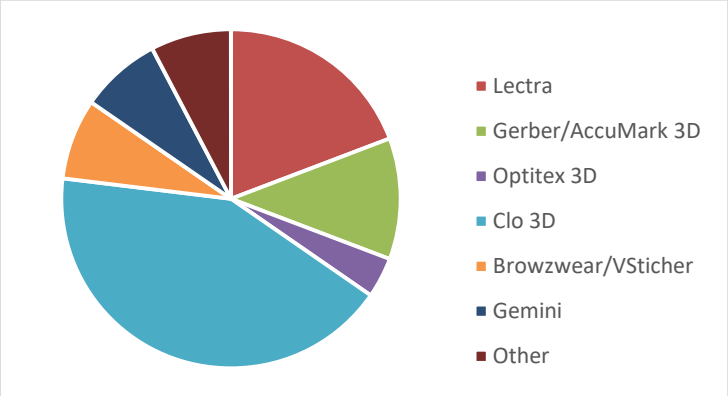

Figure 4: Use of software for fitting and visualisation of 3D virtual prototypes

Required digital skills for virtual fashion technologies and required job profiles

The third part of the survey focused on questions about the digital skills required for virtual fashion technologies and the associated job profiles required. The level of digital and other skills of the companies' employees varies according to the purpose, Figure 5. The companies mostly report the level of digital and other skills in fashion drawing and illustration, technical drawing, anatomy of the human body/body measurements, textile materials and garment sewing as high and medium. Knowledge of virtual prototyping of garments varies among the companies surveyed. 21 % of companies rate knowledge of virtual prototyping, fitting and visualisation as high, 32 % as medium, 24 % as low and 24 % as not at all.

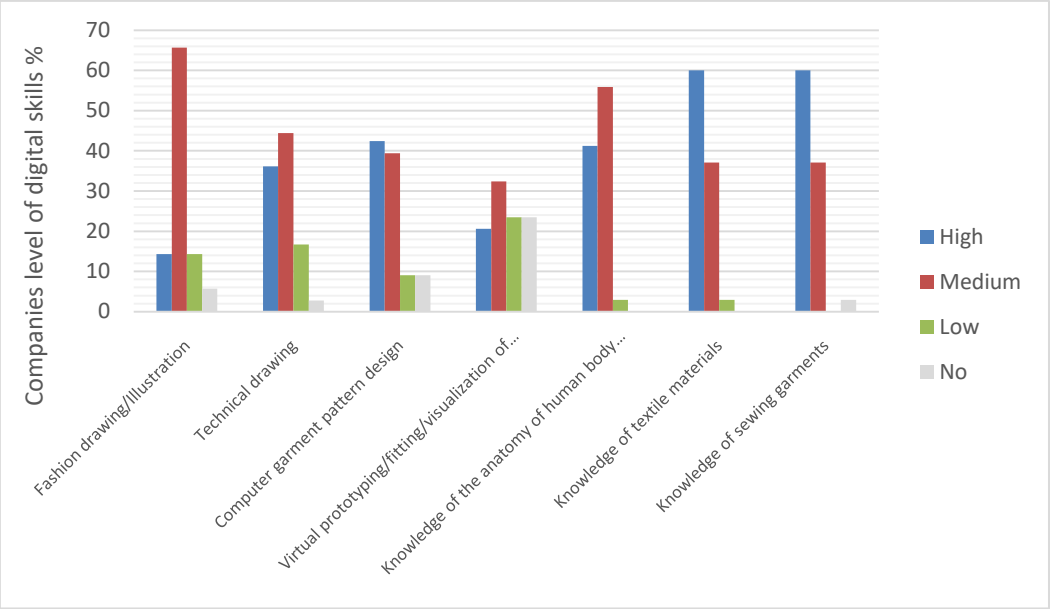

Figure 5: Level of digital skills for virtual fashion technologies the European companies surveyed

In the European companies surveyed, 74 % of the companies work with fashion designers and 71 % with technical designers. 80 % of the companies have computer pattern making designers and 28% have 3D designers. In most companies, 3D designer is the most needed profession (72 %), Figure 6. The age expectation of the needed professional profiles is: 21 % under 25 years, 53 % between 25 and 30 years, 21 % between 31 and 40 years and only 5 % 40 years and older.

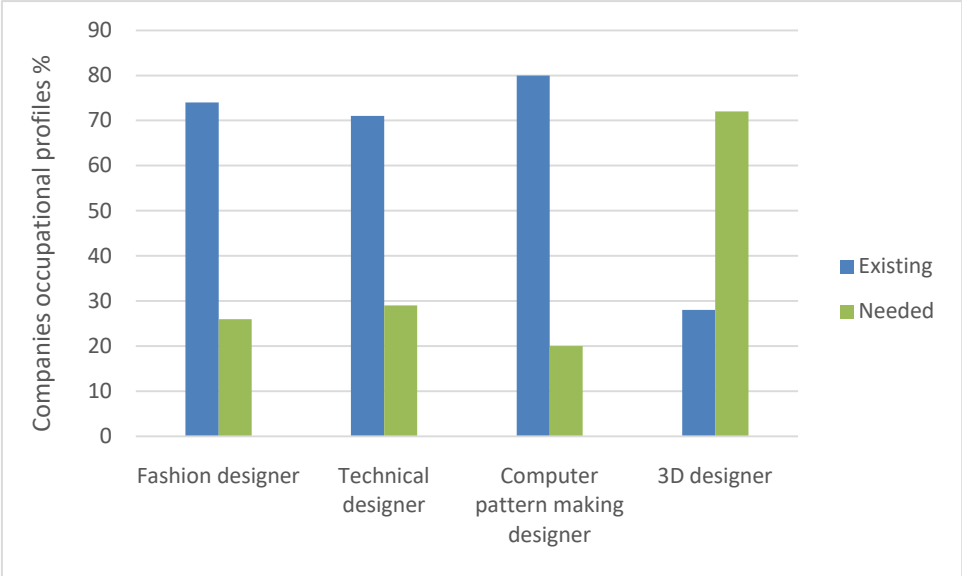

Figure 6: Existing and required occupational profiles in the field of garment design

The European companies surveyed are interested in virtual 3D prototyping of garments in future development. 41 % of companies are interested in using virtual garment prototyping technologies in the future, especially for the development of garment patterns designs, 23 % for virtual 3D presentation of collections to customers, 15 % for virtual try-on, 9 % for offering/selling personalised garments through virtual presentation/selection and 12 % for other purposes, especially for training.

CONCLUSIONS

This paper presents the research on the required digital skills in the fashion industry and the industrial application of virtual fashion technology in European countries. The analysis of the survey shows that the use of virtual fashion technologies is still a young and new branch in the development process of clothing and for the presentation of clothing on the fashion market for the European companies surveyed.

The survey among the European companies has shown that there is a need for training in the field of digital fashion, which the project partners will develop in the next project results with the help of a training platform for personalised virtual 3D fitting of garments.

FUNDING

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QUALITY CONTROL MACHINE DEVELOPED WITH ARTIFICIAL INTELLIGENCE IN TEXTILE

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ABSTRACT

Quality is one of the most important issues for the enterprises manufacturing in the textile industry. Quality targets are shaped in line with customer demands and continue to increase day by day. Quality is the most important issue not only in the textile industry but also in all sectors engaging in production. In the textile industry, the fabrics manufactured contain defects due to various problems occurring in the machinery. Detection of defects in fabrics is a crucial quality control step in the manufacturing industry. Generally, fabric quality control process is performed manually by operators(employees). With Machine Vision Techniques and Image Processing, continuous improvement, the operator collects information by detecting defects in fabrics, as well as deterioration in quality and takes actions accordingly. Systems regarding the detection of defects and classification increase production quality; meet customer demands at a higher level, increase productivity and reduce the costs resulting from the second quality products, reduce the time in defect detection and provide accurate detection. In this way, higher quality products are manufactured in a shorter time. With this project, it is aimed to make domestic production by ensuring sustainability and to reduce our country's foreign dependency.

Key Words: Textile, Home Textile, Outerwear Textile, Textile Machine, Production, Knitting, Weaving, Fabric, Defect, Quality Control, Artificial Intelligence, Machine Vision Processes, Artificial Vision Processing System, Virtual Fabric Map, Automatic Defect Classification, Artificial Neural Networks

INTRODUCTION

In the manufacturing sector, defects are inevitable for knitted fabrics as in every item produced. Defects in knitted fabrics are deviations that occur regionally, affect the fabric appearance, change the fabric structure and cause special variations limited to certain zones. Due to the concerns of financial loss arising from the faulty production, it is very important to detect these defects that may occur. Defect control of raw or finished fabrics is carried out visually and manually on control tables. However, the visual inspection process is very exhausting and takes a long time. The operator performs the quality inspection of the fabric on a light board moving at a speed of 8 to 20 meters per minute; when s/he notices any defect, s/he stops the motor that moves the fabric, marks the location of the defect on the fabric and starts the machine again. When the entire fabric is inspected, the fabric is classified according to the number of defects per meter of length [1,2]. If the operator finds an abnormally high number of defects of different types or a high number of defects of the same type during the inspection, the operator warns the production department and ensures that the possible defect in production is corrected. Inspection results can be reliable for large and obvious defects. However, while most small defects are overlooked, sometimes even large defects can be overseen during the inspection. The width of the fabric is usually between 1.60 and 2.00 meters. Therefore, it is very difficult for a human to detect defects in a fabric that is this wide and moving at a speed of 10 m per minute [3]. In the artificial intelligence-based visual quality control system, the cameras to be integrated on the quality control machine will display the fabrics flowing from the belt, while the artificial intelligence-based image processing software to be developed in the background will create a virtual map of the flowing fabric from the camera records. When an error is detected, its location will be determined on the map and a warning will be given and recorded in the reporting system. When the fabric roll is finished, the operator will be able to review the report from the system and make the necessary changes and feedbacks, as well as stop the machine and intervene when the first warning is given [4]. With the Artificial Intelligence Based Visual Quality Control System, it is aimed to contribute to the realization of economic growth, to produce high-tech products and to gain international competitive advantage with the competence.

EXPERIMENTAL: MATERIALS AND METHODS

Since the developed system will be an integrated in the existing machines, the feasibility report of the machine has been prepared. Upon completion of the mechanical system and purchase of the the camera, the imaging phase have been initiated. The images have been recorded on disk for later removal of defective areas from the collected fabrics. Defects have been extracted from the video images. This process has been recorded by scanning the videos and finding the defective regions. In this study, data extraction from defective fabrics has been repeated for more data. After the defective fabrics have been segmented from the video, they have been classified. Classification has been performed together with quality control employees. The aspect ratios of the classified images are different [5]. For this reason, the images have been re-dimensioned. This re-dimensioning process has been performed with the same aspect ratio. INTER_AREA was used. This algorithm reduces distortion errors due to multi-dimensioning. There is a lot of data in the resized defective images. Some of these data are extracted because they are used in artificial intelligence. The first one is the color values of the defective images. In addition, the extraction of this color information has increased speed and optimization as it allows working with much less data. Two different data systems were used in artificial intelligence training. These are gray images and images with threshold values. The algorithms used here to obtain images with threshold values are Canny and Otsu threshold algorithms. Canny algorithm has the ability to detect sharp edges. The Otsu threshold algorithm is less affected by the light value. A median filter has been used to remove noise from the images. After filtering, we have images with gray fabric defects and images with fabric defects with threshold values. With these images, different artificial intelligence training has been performed and the most appropriate model has been obtained by comparing time performance [6]. Once the data for training has been acquired, artificial intelligence training modeling will be started. Due to the large number of data and error classes, training a single AI and processing the data have caused a lot of time and processing loss. This problem has been solved by training one AI for each class. Supervised learning method has been used for the AIs. The performance and efficiency of the trained artificial intelligence models have been analyzed. This performance test has been calculated with the available data. The data have been determined as 70% and 30% for each error class and the data have been randomly selected from the error images. Thus, a more accurate performance test has been carried out. Accuracy, precision, and recall have been used to calculate the performance correctly.

Table 1. Current & Innovative Situation Comparison

Technical Specification	**Project Output**	**Human Eye - Manual**
Maximum Fabric Control Speed	120 m/min	50 m/min
Fault Finding Rate	%98	% 40
Micro Fault Finding Scale	0,3 mm	1 cm

Table 2. Project Success Criterion

Success Criterion	**Target Value**
Finding the Fault Type	% 98
Time	120 m/min
Clear Image Acquisition	%100
Workforce Reduction	%50
Locating the Defect on the Fabric	%95

RESULT AND DISCUSSION

Defective fabric images have been taken from the quality control device, which is equipped with automation capability, to classify the types of defects and to create an artificial intelligence model. It has been ensured that the designed PCB circuit boards and meter counter system fit properly into the quality control system and the data from the meter counter has been received accurately.

Preparatory work has been carried out to start taking image recordings of the flowing fabric from the quality control device to be used in the training phase.

Using Python programming language, a program has been developed to record the flowing fabric images as video through the camera library. Flowing fabric images have been recorded by means of cameras positioned on the quality control device and the developed program.

The images taken have been stored in computer environment based on the recording date.

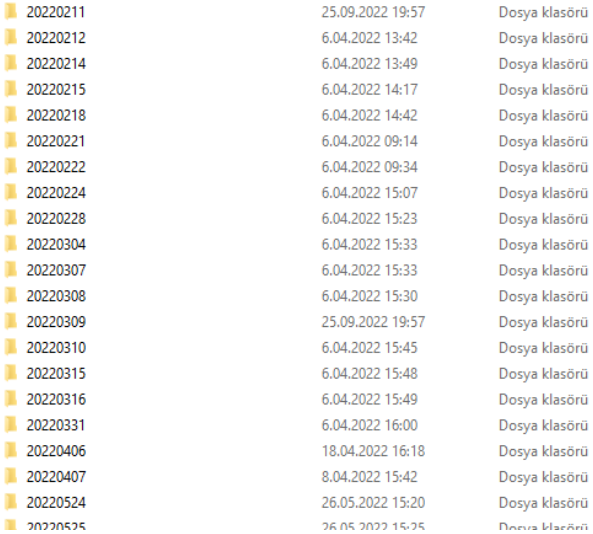


Figure 1: Storing received faulty fabric images according to the recording date

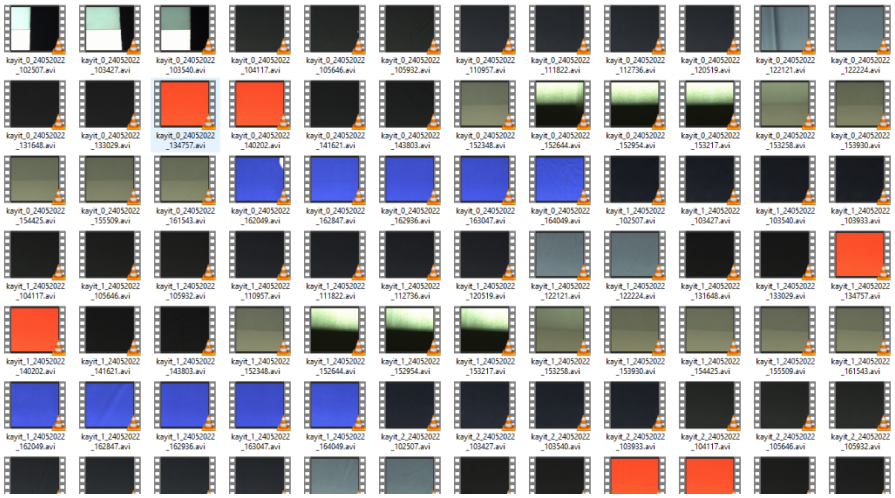


Figure 2: Faulty fabric image recordings taken for 10 cameras

The defective fabric images recorded have been analyzed using image processing techniques with filtering processes such as threshold operations, histogram operations, blurring and morphological operations such as contour detection, erode and dilate.

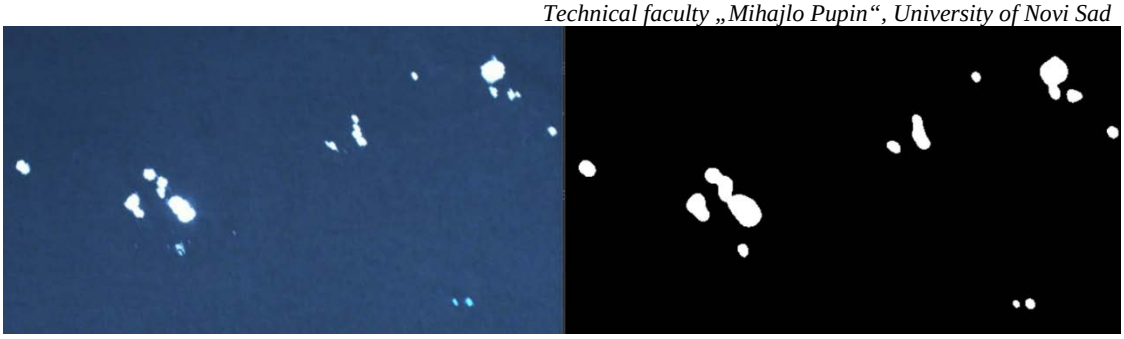


Figure 3: Hole Fault

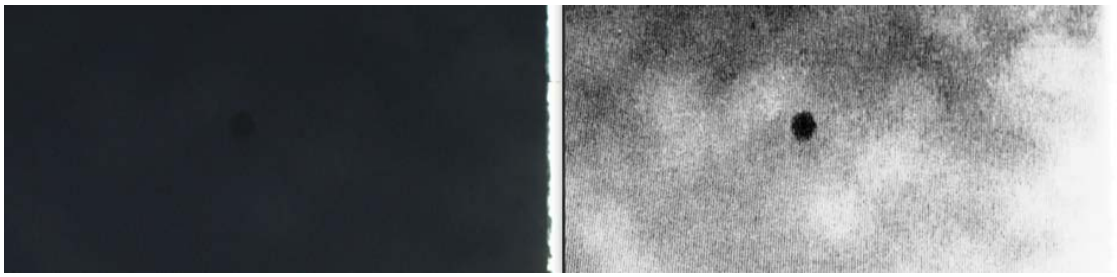


Figure 4: Oil Stain

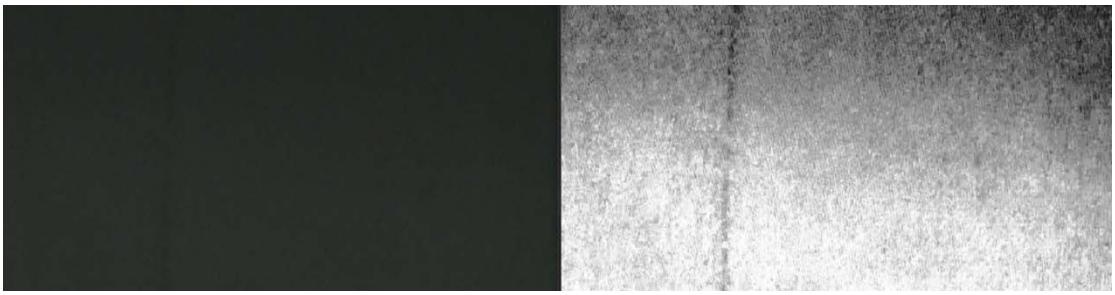


Figure 5: Broken Fabric Fault

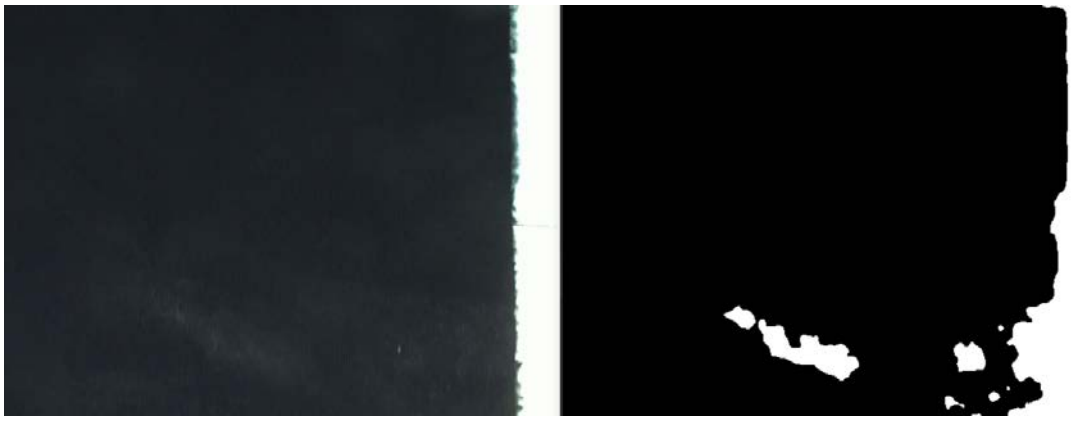


Figure 6: Fading Stain

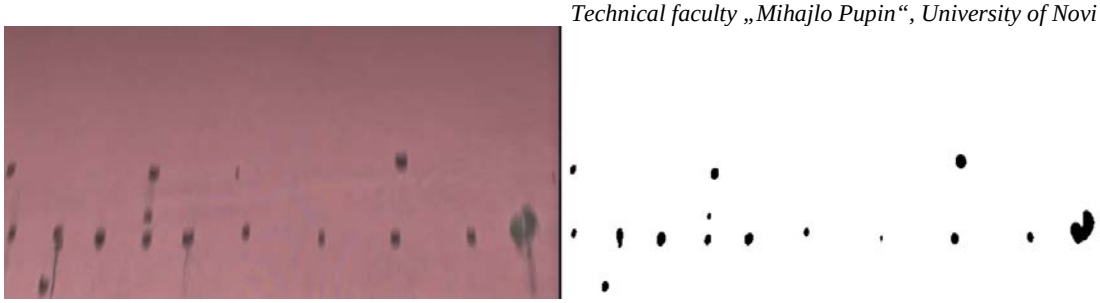


Figure 7: Needle Fracture

Figure 8: Cola Stain

Defective fabric images have been extracted from the videos using image processing techniques and manually.
With the help of quality control staff, the types of defects have been identified.

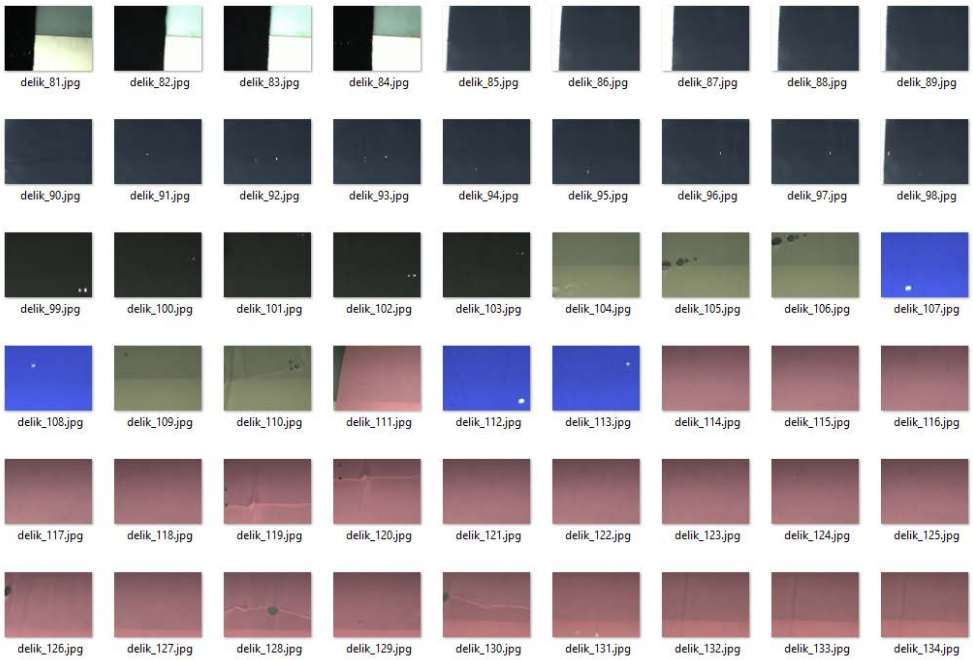


Figure 9: Image Processing techniques from videos and manually received fault pictures.

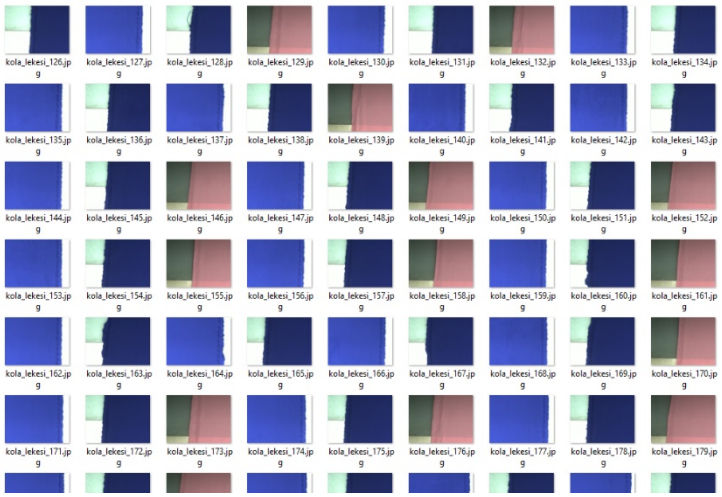


Figure 10: Classification of received fault images by type

Images with defects have been classified manually according to the type of defect.

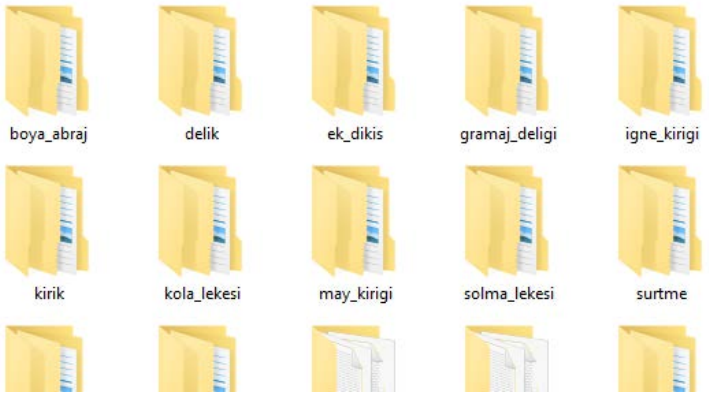


Figure 11: Parsing Classified Images Into Folders

The collection of images has continued until a sufficient data set has been obtained.
The coordinates of the defects in the images have been identified and labeled.

Figure 12: Label and Fault Coordinate Operations

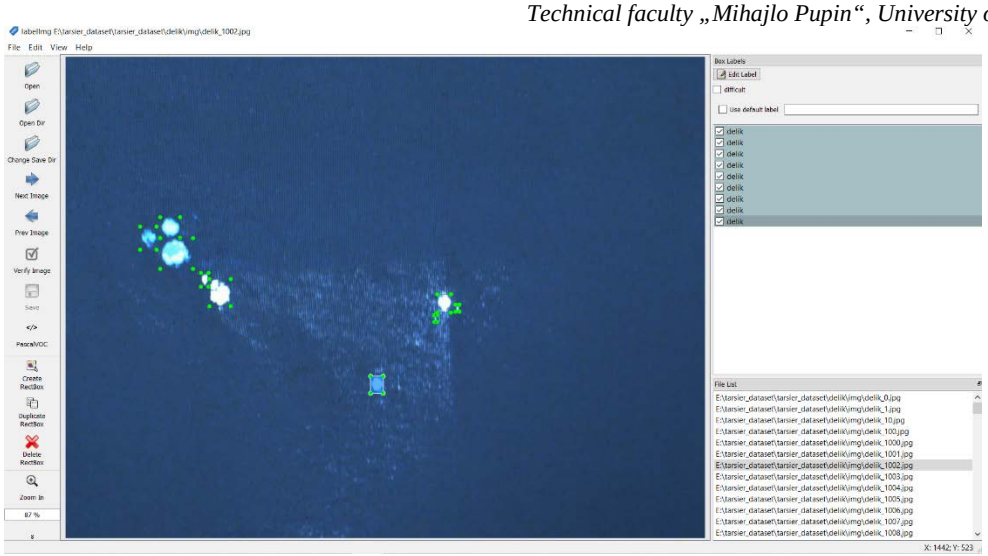


Figure 13: Label and Fault Coordinate Operations

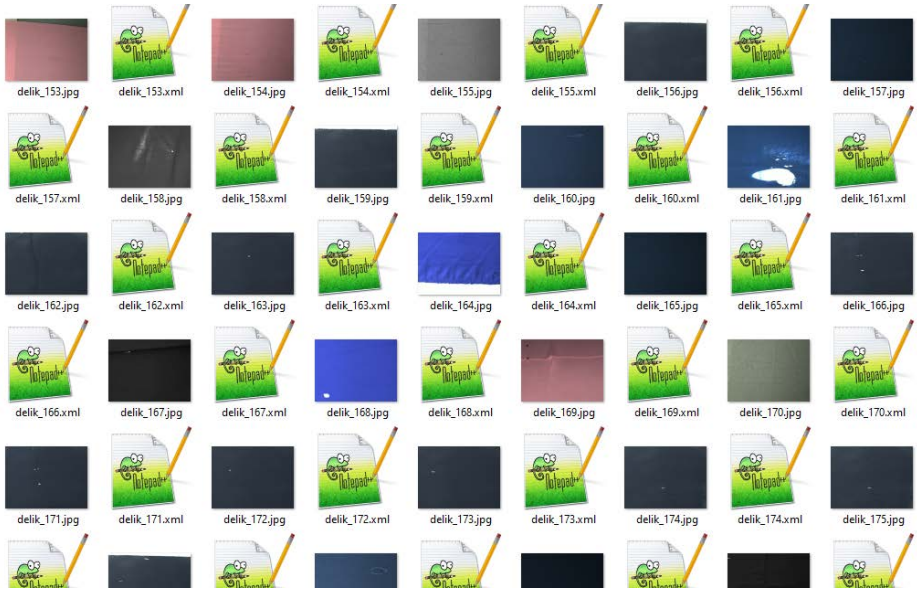


Figure 14: Generating XML files Containing Tag and Fault Coordinates

Artificial intelligence models have been researched and appropriate models have been selected.
In line with the selected artificial intelligence model, the data set has been converted into a format suitable for model input.

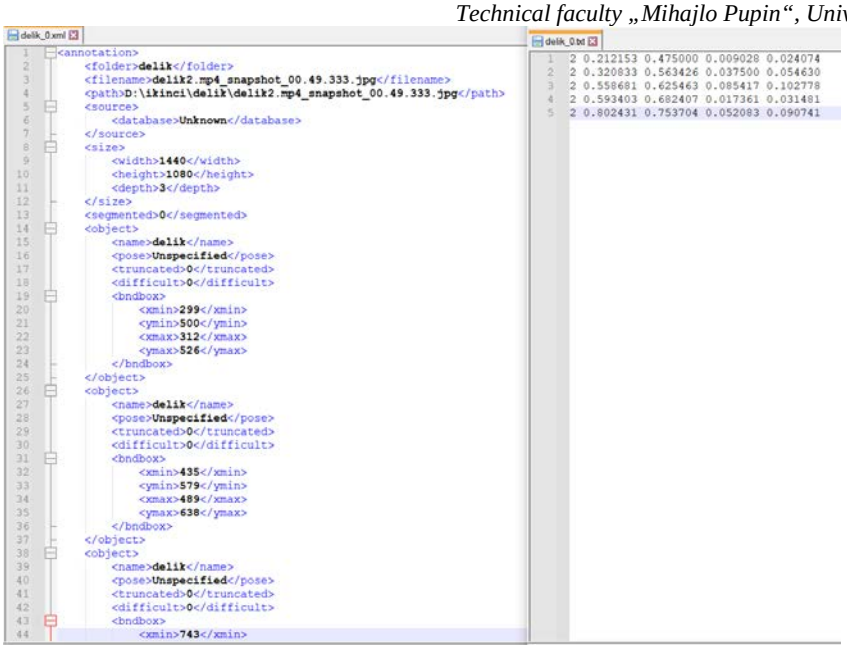
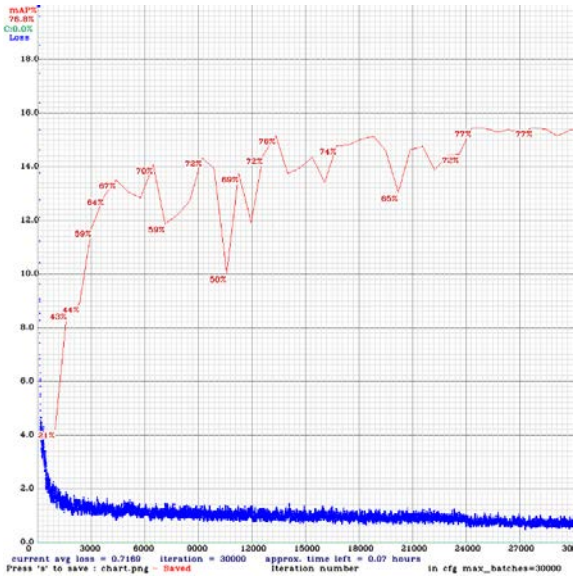


Figure 15: Generating Tag and Fault Coordinates in Pascal VOC xml and YOLO txt format

The data set has been divided into training, testing and validation according to the requirements of the model to be used.

In the selected artificial intelligence models, many trainings have been performed for various defect types.



Graphic 1: Training Output

As a result of the trainings, it has been observed that the number of data is insufficient for some defect types. Synthetic images have been produced with data augmentation techniques and the data set has been increased. Trainings have continued over the increased data set.

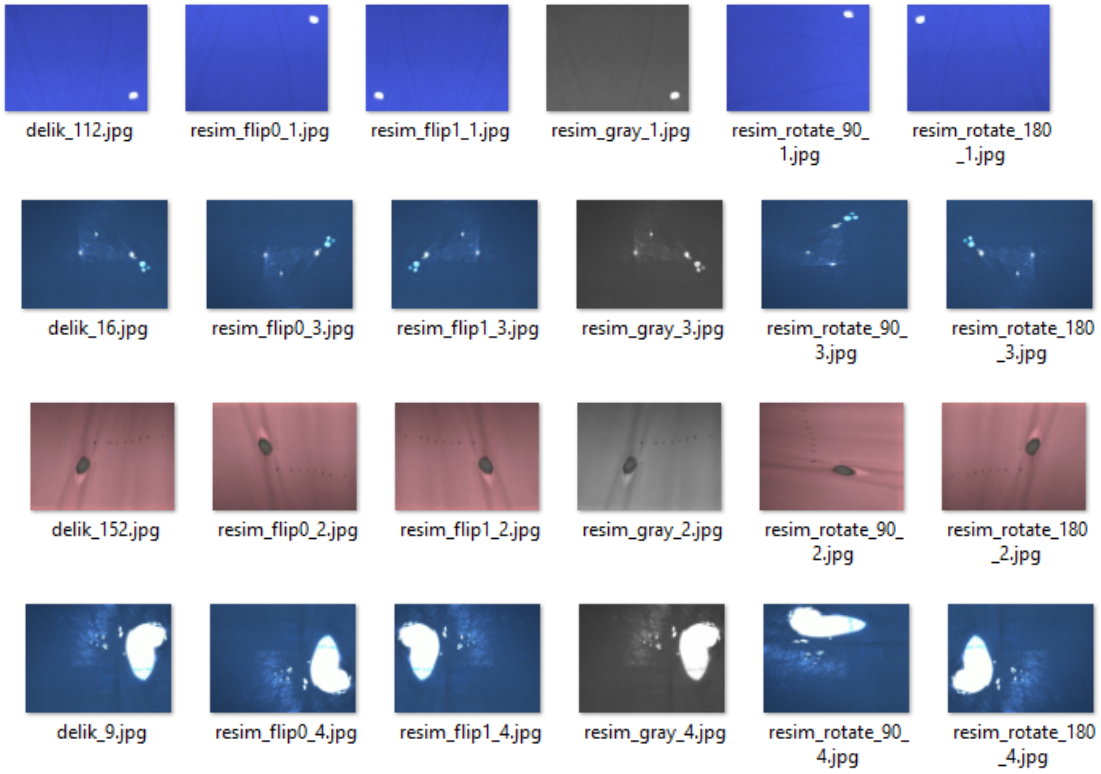
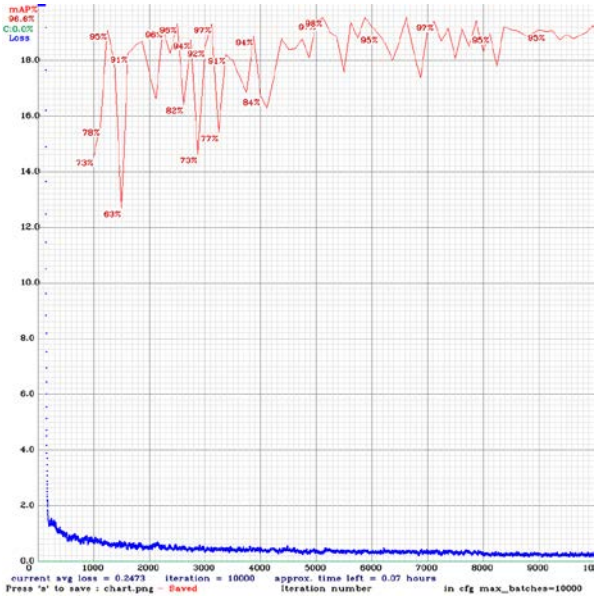


Figure 16: Data Increase with Synthetic Data Generation

In line with the outputs obtained from the trained models, model trainings have been repeated with transfer learning and fine-tuning techniques to increase the success rate.



Graphic 2: Training Output

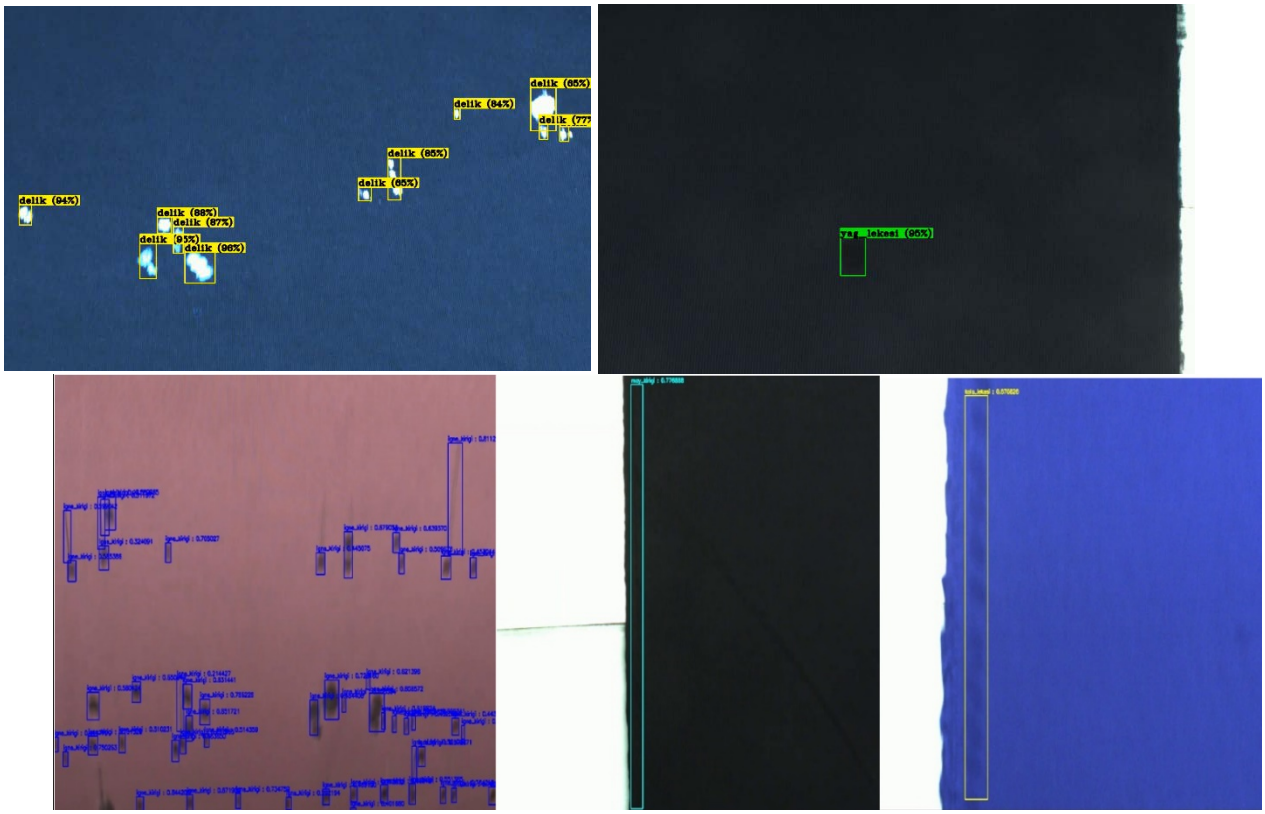


Figure 17: Testing of Training Completed Models

Tests using the obtained models and increasing the dataset by collecting faulty images are ongoing.

CONCLUSION

- Automatic control of the fabric has been established with loom monitoring and instant remote instant.
- Highly accurate fabric defect and type of defect have been found.
- The workload in the raw fabric control department has been reduced.
- Through virtual mapping of the fabric, defect occurrence is identified and prevented instantly and defective fabric production is prevented.
- Self-learning capability has become a capability.
- The abrasion defect that causes disruption in the textile production and apparel industry has been detected and the production of 2nd quality fabric has decreased.
- It has been possible to instantly and visually report the size of the defect in which quantity of the fabric rolls and to work integrated with existing ERP systems.
- The likelihood of producing substandard fabric has been effectively minimized by 95%.

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STANDARD OPERATING PROCEDURES FOR PRODUCT DESIGN

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ABSTRACT

Standard operating procedures (SOP) is a research method of operation, product designer represent the themes by doing the SOP chart; it can combine the design and the research in order. The purpose of this paper is when the research of product design work in the SOP chart, the SOP charts' symbol was performance by creative technique and it goes to analyze the research paper, extend to the main design's performance, and use on the design of product. The SOP chart combines with designing product, researching background and motivation, survey to product design requirement, build research architecture, analyzing data, perform main design, and complete the main product design. A good product design is by using a standard SOP design. This paper is base on the "Law of Standard SOP." The way of managing product designing process is by using the "Law of Standard SOP." This system can help to design works compiled and find a suitable team and tools. Product designer require the theme represent by making the SOP share the goal, details in system, and complete the step by step designing preparation.

Key words: Standard operating procedures, product design, SOP symbol design

INTRODUCTION

Product design research is a term for innovative design and development, and standard operating process structure is a norm. Changes in the structure affect the innovative development product model of the technical and vocational education system. In technical and creative design, product performance, static product performance and dynamic product performance are required (Bruseberg & Philp, 2000). Performing arts performances can apply standard processes to target product design and development research goals, research product design innovation and implementation results, and finally a research structure production flow chart. Before publishing a product design, they will be exposed to the development steps of brainstorming, and the research and development of various products is collectively referred to as product design in this research, so usually the first thing designers face is the needs of consumers. The application of standard processes is conducive to a basis for unifying research and development, including start, process, decision, end, path, document, predefined process, connector and comment (Lin, 2014). The research background of flowchart structure is described in a deconstructed way, which is a shortcut to accelerate product designers to develop product processes.

The flow chart structure meaning, grammar, application timing, and structural applicability of product design have processing procedures with the characteristics of sequential occurrence, and the upper and lower order of drawing graphics is the order in which processing procedures are performed. For grasping the idea of product development at the first time and finding literature for discussion, different processing procedures can be carried out in a short period of time according to the binary selection structure (basic structure) process and according to the conditions of literature discussion, so that the selection or decision-making results can be discussed according to the literature. Choose one to carry out different processing procedures, you can use "Yes, No" to enter the research reference materials to describe and explain the path processing procedures, and there must be complete workflow planning and management. Efforts related to standard operating procedures can be a huge design project from domestic and foreign markets relating to both designers and consumers. Only through careful planning by professional designers can they be accurately implemented according to design requirements. The tedious content of the product design business in the executive room, the work content of product design, is divided into planning stage, design stage, and execution stage. product development methodology. They divided the entire product design and development process into six stages, combined with the standard operating process semiotics, took the concept of cross-domain cooperation as the structure of the product development process, and elaborated the

marketing, design and execution departments in each stage to solve problems together. The way of integration is quite able to reflect the practical needs of product design and development. In addition to understand the connotation of each stage in the product development process, this paper could help people to be familiar with the roles that members of each unit in the product development team should play, it can also provide operators and product design managers with reference. Immediate effect. This is the concept of a general product development process.

In this paper, the flowchart structure of product design operation is fully integrated with the research operation process of designers and consumer information. The profound experience of product design can surpass that of professional designers or executive development engineers. It is necessary to understand the operating procedures; that is to say, the symbolic graphics of the operating flow leads the trend of product design and can be applied to the design of other products.

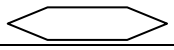
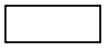
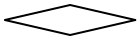
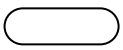
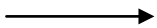
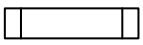
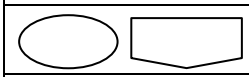
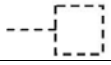
METHODOLOGY

Product designers must have the ability to process and integrate all kinds of information in their minds in an instant; so the product design and development process is definitely not just to provide a direct and short-term answer under the requirements of the society, but should also start from the symbol diagram of the product design and development process. To explore the potential and difficult to see dialogue between the technicians and social requirements, and to propose forward-looking solutions to this demand. If product designers can carry out product design planning work according to the concept of standard operating flow chart structure, designers must actively participate in and contribute their opinions, and integrate the above-mentioned forward-looking vision into the concept of product design.

Standard Operating Procedures

Standard Operating Procedures (SOP) is an operating method commonly used in the industry. Its purpose is to make each operating process clearly presented which can assist relevant operators to manage the overall workflow. The advantage of making a flow chart is that all the processes are clear and the staff can grasp the overall situation (Johnston, 2017). When changing staff, it is easy to get started by following the diagrams. When all the processes are drawn, it is easy to find mistakes, and they can be adjusted and corrected in time to make each operation more convenient. rigorous. The processing program must be drawn with a single entry and a single exit. X. The path symbols should avoid crossing each other, and the standard symbol analysis (Single-Entry, Single-Exit) characteristics of the system flow chart should be developed (see also Table 1).

Table 1: Analysis of standard symbols for formulating system flowchart

Symbol	Name	Meaning
	Start	Flowchart start
	Process	Processing
	Decision	Plan selection
	End	Flowchart terminated
	Path	Indicates the direction of the path
	Document	Input or output file
	Predefined Process	Use a defined process
	Connector	Exit from a flow chart to another flow chart; or entrance from another place
	Comment	Indicates the use of notes

Product Design Process

The product design process refers to all planning behaviors to discover the needs of consumers, generate ideas or solutions, and use them as a guideline for new product development, so that the products can meet the potential needs of consumers. That means the process of product planning starts from grasping the needs of consumers, develops ideas to meet the needs of consumers, and goes through product quality requirements and cost constraints until the idea is determined. Since the planning work starts from meeting the needs of consumers and develops ideas, it is very important to obtain and interpret consumer demand information.

Flowchart Symbol Design

After establishing the requirements for graphic or figurative symbols, it is necessary to select or design a set of suitable symbols. In order to achieve the effect of use, the symbols and their messages should be easy to associate, the symbols should be easy to distinguish from each other, and the symbols should be pleasing and non-controversial. , and adapt to various cultures and situations, the newly developed symbols should not contradict existing domestic or international standards. The process of image design can be divided into the following stages: (1) the conversion of literal and pictorial meaning: the association of graphic meaning and the expression of graphic meaning; (2) the representation of graphic representation: the conversion of graphic representation and graphic representation Expression; (3) Graphical Construction Mode: Characterization combination, color combination, and graphic base map creation; (4) Graphical trimming: The matching and adjustment of the style and color of the graphic map (Guan & Hsieh, 2000).

Image symbols play an important auxiliary role in the visual communication of product design. The expression of image visual information transmission can be divided into three types: words (Words), images (Icons) and symbols (Symbols). Such as symbols and abstract symbols and a mixture of the two, their characteristics are widely used in man-machine interface buttons and instruction signs, which are indispensable elements in communication; beyond the shortcomings of simple text communication, it can be quickly and effectively It is the most direct and effective way to complete the communication work; to assist the operation instructions, to improve the recognizability of the keys, and to use the text form as a tool to transmit information is the most direct and effective way; but images and symbols are an expression method that transcends language and cultural barriers, and are text communication tools. impossible. Therefore, it is necessary to provide an appropriate and good application mechanism in the design of the image, so that users can understand the functional meaning behind the icon, so as to achieve the purpose of good information transmission and human-computer interaction.

ANALYSIS

In the product design standard operating process stage, the collection, analysis and evaluation of relevant information, and the production of a plan and execution design with incisive content and high feasibility, and providing the execution unit as an action criterion is the key to whether the new product design can be successfully marketed and sold well. Product design refers to all planning behaviors to discover consumer needs, generate ideas or solutions, and use them as guidelines for new product development, so that products can meet consumers' potential needs. That is to say, the process of product planning starts from grasping the needs of consumers, develops ideas to meet the needs of consumers, and goes through product quality requirements and cost constraints until the idea is determined. Since the planning work starts from meeting the needs of consumers and develops ideas, it is very important to obtain and interpret consumer demand information (Juan, 2010).

Phase I: Market Opportunities Identification

The main work of this step is to analyze market demand factors, that is, to discuss factors such as social background, economic status, and technological development from subjective and objective perspectives; whether it is a new product or an improvement of an existing product, both We should start from this angle and look for market opportunities.

Phase II: Product Development Process

Before product design work, users' opinions and experiences should be incorporated by means of questionnaires, observations, interviews, etc., and an in-depth discussion of user needs should be conducted. Whether the user needs have been discussed in the drafting stage of product design and development sketches, we should still take a different angle to enter the research; Whether the design can create an engaging user experience will have a decisive impact.

Phase III: SOP Symbol Design

The communication in the standard operation process of product design is before product design. Only good communication can create good new product marketing. For example, when you see the product, you know who the designer is. The product design project standard process (SOP) is very important. A professional ability, designers can quickly grasp the key points, grasp the situation of the meeting, and achieve the main purpose of leading the owner. As a communication tool, Standard Operating Procedure (SOP) can effectively help designers understand customer needs, quickly grasp the key points of questioning, and shorten communication time. However, it is not necessary to follow the table to achieve good results. Product designers should gain the "trust" of customers as the primary purpose. The relationship between customers and designers must be based on "trust". A business relationship can be established.

SOP FOR PRODUCT DESIGN

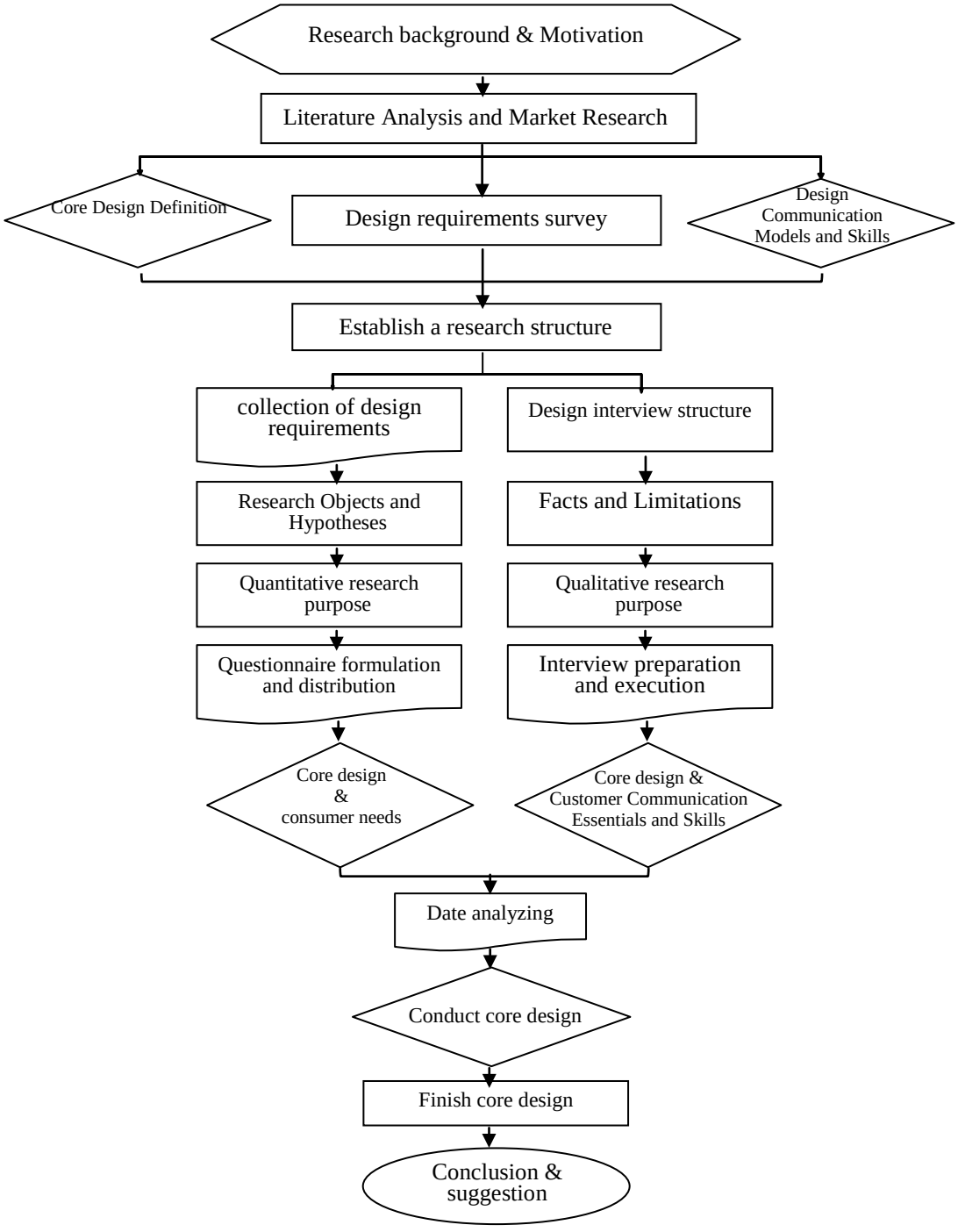
The standard operating process is applied to the product design process table (see also Table 2), which is directly related to the goal of innovative production. From qualitative research, during the interview process, the interviewer should maintain a neutral attitude and do not give their own opinions. To the interviewees, otherwise it will affect the authenticity of the data, set the interview structure, try to adopt the same questioning method, grasp the theme and direction in a timely manner, and prevent the interview from deviating from the investigation theme, so as not to affect the efficiency. Quantitative research includes basic data questionnaires and basic needs surveys. In terms of data collation structure, the demand for government and innovative products is generated according to the categories of analysis. This table is mainly applicable to standard operating procedures. In each subdivision, a process symbol will be given to each designer at the development stage, which can increase the integration of data analysis, and develop new products in future product design, or Do product technical analysis research basis.

CONCLUSION

The image symbols of the standard operating procedures generally refer to all the image symbol designs that must undergo the semantic conversion process. Therefore, the Ministry of Education, Ministry of Education, to establish the readability and consistency of the operation standardization (SOP) flow chart, refer to the American ANSI system process Figure standard symbols, and the standard process of "efficiency meeting" of Daoqin Enterprise Management Consulting Co., Ltd., making symbols and examples. The results of consensus and cluster analysis can be used to design guidelines for graphic symbols, including nine flowchart symbols for preparation, processing, decision, termination, path, file, defined processing, same/form connection, and annotation, and their importance percentages are available Numerical reference for various types of image symbols in the

selection of the final design scheme. This study is only for the application of standard operating procedures in product design. It is suggested that subsequent researchers can use the design criteria of image symbols in this study to verify image symbols in other categories to increase the objectivity and appropriateness of the form. The main purpose of this study is to discuss the differences in the form of research process conversion of image symbols in product design. It does not individually focus on the application of a product design range to produce products. Therefore, it is suggested that subsequent researchers can conduct research in the direction of product development to make the study of image symbols more extensive and precise.

Table 2: Standard operating process for product design



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APPLICATION OF THERMOCHROMIC INKS IN THE PRODUCTION OF SPORTSWEAR

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ABSTRACT

Sports and physical activity play a significant role in the daily life of modern people. Therefore more and more people are engaged in some kind of physical activity. The possibility of monitoring the vital signs of sports that reflect their physical and physiological condition enables the improvement of sports results and, at the same time, protects them from possible injuries. Since the athlete's body is in direct contact with the clothing, textiles are recognized as an excellent medium for implementing additional features that expand the clothing's capabilities and give it smart properties. One way to add smart features to textiles is to use thermochromic dyes. Textiles enhanced with thermochromic dyes are characterized by a change in the molecular structure of the pigment on the fabric with a change in temperature, which causes a difference in the color of the print. This paper aims to present the application of thermochromic colors in the production of sportswear.

Key words: thermochromic inks, smart textile, sport, sportswear

INTRODUCTION

Sport and physical activity play a significant role in the everyday life of a modern man. The increase in the number of people involved in sports has caused the growth of the sportswear market. This directly affected the textile industry, especially the part that deals with the production of sportswear. The athlete's body is in direct contact with the clothes, therefore, textiles are used as a medium to implement additional features that expand the possibilities of the clothes and give them smart features. The possibility of monitoring the vital signs of sports that reflect their physical and physiological condition enables the improvement of sports results and, at the same time, protects them from possible injuries. In addition, sportswear should maintain its basic requirements, including flexibility, durability and breathability. Different sports activities require different aspects of taking care of the athlete's condition. For example, an increase in heart rate and body temperature in marathon runners should suggest excessive energy expenditure and high exertion (Potuck et al., 2016; Sun et al., 2020).

Thermochromic dyes have found application in the field of monitoring the physiological conditions of sports through the possibility of color changes under the influence of temperature. Depending on the temperature transition, the pigments can appear colored or colorless on the textile material. To apply this technology to the design and production of clothing, thermochromic dyes can be applied to the surface of the textile material. Unlike smart clothing that has already been developed, thermochromic dyes offer a new design solution for functional sportswear that does not require external electronic components, but the color change is based solely on physiological indications given by the user. Therefore, thermochromic dyes can improve activewear by preventing fatigue during athletic exercise while providing elements such as appearance and functionality. Using thermochromic dyes that change color in the temperature range of elevated skin temperature during exercise, the athlete can assess whether he is expending too much energy based on the visible color on his clothes (Potuck et al., 2016). This paper aims to present the use of thermochromic dyes in the production of sportswear.

CHROMIC MATERIALS

Traditional textile dyes should provide predictable, reproducible, and permanent color in terms of exposure to external effects such as light and washing. Any variation in the color of dyed fabric, for

example, when exposed to a change in temperature or light, would normally be considered highly undesirable. Chromic materials can gain, lose or change color after exposure to an external stimulus (Ramlow et al., 2021). They also offer significant potential for providing specific functions in smart textiles and clothing designed to sense and respond to environmental conditions. Since color plays an important role in people's daily lives, a color change can serve as an important visual signal. Textile materials with the ability to change color can be used to visualize changing environmental conditions and can facilitate optical recognition when a change occurs. Chromed textile materials have become a powerful tool for monitoring the physiological and physical state of the user while at the same time providing a high degree of safety and comfort (Z. Rasmin Thahani, 2021). Due to the possibility of developing new creative design solutions, color-changing smart textiles are attracting huge interest due to their interaction, responsiveness, and ultimate functionality.

The development of smart textile materials has become a research effort and a challenge to industrial production. In this way, different areas of engineering and design should work together to turn chrome textiles into technologically and economically affordable smart materials. The growing interest in smart textiles has increased the need for further research (Sadeghi et al., 2020). Smart textile materials have been categorized according to their characteristics, distinguishing between passive, active, and ultra-smart textiles (Stoppa & Chiolerio, 2014). Passive smart textile refers to a material that can only detect changes in the external environment with the help of specific sensors but does not adapt to external changes. Therefore, chrome materials can be classified as passive smart materials. Active smart textiles can sense stimuli from the external environment and react accordingly. Ultra smart textiles are also known as super smart textiles or adaptive smart textiles. They can sense stimuli from the external environment, react based on those stimuli and eventually adapt and reshape themselves according to the stimuli or environmental conditions (Z. Rasmin Thahani, 2021).

The most important division of chromed materials is made according to the type of stimuli that act on the manifestation of the effect of changing the color of the material. The most important types of chromism used in the textile industry are thermochromism (color change due to temperature change), photochromism (color change induced by sunlight or UV light), electrochromism (color change due to the flow of electric current) and ionochromism (color change caused by ions) (Ramlow et al., 2021; Sengupta & Behera, 2014).

THERMOCHROMISM

Thermochromic dyes are the most popular chromatic dyes used in the textile industry. These types of dyes and pigments depend on a reversible change in hue with relatively little change in temperature, which can be used as a temperature indicator, such as measuring body temperature (Figure 1) (Elmaaty et al., 2018). Optical change in thermochromic materials occurs in response to a thermal stimulus and manifests as a change in color, color intensity, or transparency. The phenomenon of thermochromism occurs either gradually based on a gradual increase in temperature (continuous) or suddenly at a specific temperature (discontinuous) (Sadeghi et al., 2020).

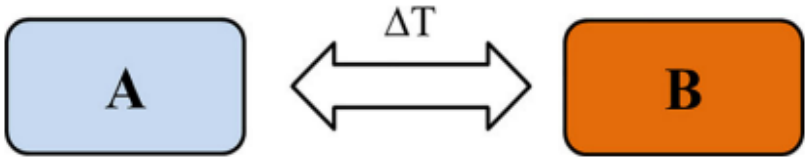

Figure 1: Reversible color change from type A to type B (Sadeghi et al., 2020)

The temperature at which a thermochromic dye begins to change in response to temperature stimuli is known as the critical or activation temperature and is particularly important because the ultimate use of thermochromic dyes depends on the required temperature. By choosing one or more

thermochromic dyes for use on textiles whose critical temperature is close to the temperature of the human body, textiles that respond to human touch could be created.

The two main types of thermochromic inks are (Elmaaty et al., 2018; Kooroshnia, 2013):

- Liquid crystal and
- leuco dye.

Liquid crystals and leuco dyes contain active material dispersed in a suitable binder. For this reason, they require microencapsulation in order to protect the active ingredients from the environment to which these thermochromic substances could be sensitive (Shahid & Adivarekar, 2020; Tomašegović et al., 2021). Leuco dyes show a monochromatic change with molecular rearrangement, and liquid crystal types have a spectrum of color changes. Because liquid crystals are more sensitive to temperature changes than leuco dyes and require highly specialized printing techniques, they are difficult to work with. Leuko dyes are easier to handle and are more commonly used in screen printing.

Thermochromic leuco dye

Thermochromic dyes based on leuco dyes are specialized dynamic dyes that change their properties due to exposure to different temperatures, i.e., below the activation temperature, the color is visible. In contrast, above the activation temperature, the colors are less visible or not visible at all. These paints can react to temperatures ranging from -15°C to 60°C, depending on the need (Kooroshnia, 2014). Leuco dyes consist of color formers, color developers, and hydrophobic, non-volatile organic solvents. The thermochromic transition occurs around the melting point of the solvent and possesses excellent reversibility. When the temperature reaches the melting point, the solvent undergoes a phase transition from solid to liquid. Meanwhile, the color former and developer dissolve in the solvent, resulting in a color change due to the breaking of hydrogen bonds between the color former and the developer. Conversely, when the temperature is reduced to the freezing point, the solvent turns into a solid state, and the colors can return to their original color due to the formation of hydrogen bonds (Zhang et al., 2017). The color developer is a weak acid that acts as a proton donor to create the colored state of the leuco dye components. The most commonly used developers are bisphenol-A, gallates and phenols.

Nowadays, with the introduction of thermochromic inks based on leuco dyes in textile and fashion design, new types of challenges arise to effectively use thermochromic inks (Kooroshnia, 2013). Figure 2 shows a textile pattern that was obtained by printing with two thermochromic dyes with different activation temperatures (27°C i 15°C).

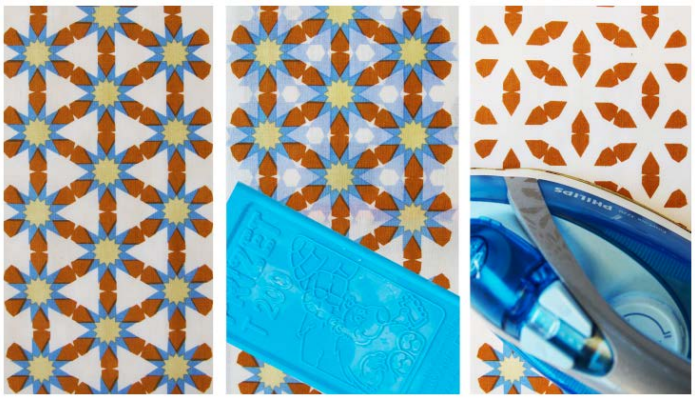

Figure 2: Application of thermochromic leuco dyes on textiles (Kooroshnia, 2015)

Thermochromic liquid crystal

Another type of thermochromic system that can be applied to textiles is based on liquid crystals. Liquid crystals, often referred to as the fourth state of matter, exhibit liquid-like behavior. Still, the molecules tend to line up in an ordered pattern, unlike normal (isotropic) liquids where there is random orientation. The thermochromic effect of certain liquid crystals is quite different from that of the leuco dye types. They provide a continuously changing spectrum of colors over a range of temperatures (called color gamut) when viewed against a dark (ideally black) background. The colors result from changes in the orientational structure of the liquid crystal with temperature and from the way light interacts with the liquid crystals to produce colored reflection by interference (Potuck et al., 2016; Zhang et al., 2017). Below their activation temperature, they are colorless, but as the temperature rises, they change color. For example, the color changes from colorless to red at one specific temperature, and, as the temperature increases, a series of other colors of the visible spectrum are displayed in sequence (orange, yellow, green, blue, violet). The color changes are reversible, and as they cool, the order of color change occurs in reverse order (Kooroshnia, 2017).

There are three main sub-divisions of liquid crystal states: smectic, nematic, and chiral nematic. The molecules are arranged in raft-like layers in the smectic mesophase with parallel molecular axes. In the nematic mesophase, the molecules are also placed in parallel, but there is no separation into layers. The main feature by which chiral nematic differs from the nematic phase is that the molecular structure is chiral, i.e., it is impossible to see her image in the mirror. A chiral nematic is the most critical type of liquid crystal for thermochromic systems, and the chirality causes the molecules in the phase to adopt a twisted structure, resulting in a screw-like helical arrangement (Christie, 2013). The refractive index of the liquid crystal and the height of the spiral arrangement of the molecules determine the wavelength of the reflected light. When the temperature varies, the stride length also varies. As a result, the wavelength of the reflected light changes, leading to a progressive change in the color spectrum (Chowdhury et al., 2014).

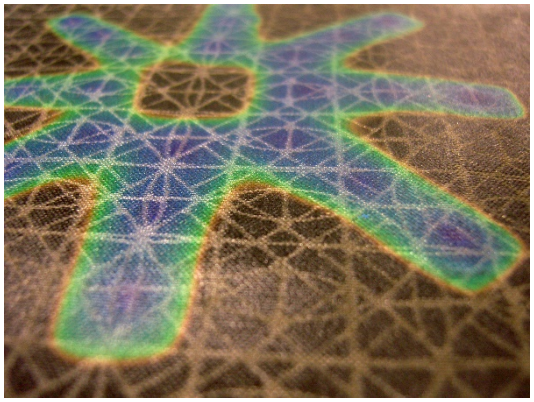

Figure 3: Application of liquid crystals on textiles (Yao, 2016)

APPLICATION OF THERMOCHROMIC INKS

Thermochromic inks, which can change color under the influence of temperature, are most often used as a visual indicator of temperature variation. Clothing is an excellent example of the integration of intelligent functionalities because it is ubiquitous, worn by everyone, covers a large percentage of the human body, and has direct contact with the skin (Potuck et al., 2016). The application of thermochromic dyes in the production of sports clothing is exciting, because the clothing can be used as a sensor to monitor the athlete's physiological state.

It has been established that athletes face physiological changes during physical activity after the temperature of their skin changes (Americos, 2020). These physiological changes must be monitored,

which is not feasible without technologically innovative devices such as Bluetooth watches and wristbands, which connect heart rate and pulse to assess the user's health electronically. However, their radiation and connection with the electronic medium are harmful. To assess the level of physical exhaustion of an individual, it is essential to have a suitable medium that will perform the function without affecting the comfort and health of the athlete (Tadesse et al., 2021). Thermochromic inks are ideal for this purpose because they do not affect the skin or the outer/inner part of the athlete's body, they can prevent exhaustion during the activity, and at the same time, they will ensure an attractive appearance and functionality of the clothes. Also, they can be printed on different substrates, including spandex and nylon, as the most common fabrics for producing sportswear (Potuck et al., 2016).

The use of thermochromic inks in the production of sports clothing enables the display of heated body parts, which will serve as an indicator of training intensity for the user. Also, with thermochromic inks on textiles, it is possible to show muscle movements and the functioning of the cardiovascular system during physical activity. During training, there is an increase in body temperature, which is displayed on the clothes and can be used to analyze muscle movements (Figure 4) (Americos, 2020; Radiate Athletics, 2016). In addition to the functional application, thermochromic inks can accentuate a part of the clothing that will attract the attention and interest of the environment.

Figure 4: Heated body parts on men's t-shirt (Radiate Athletics, 2016)

In addition to clothing, the sports industry can use thermochromic inks in various other accessories. Such sports accessories may include bracelets, bottles, sunglasses, etc. (Americos, 2020).

CONCLUSION

With the development of modern sports, the design and production of sportswear play an essential role, especially in many modern sports. Choosing the suitable fabrics for sportswear is the most crucial factor as it affects performance and efficiency while providing protection and physical comfort. Given that the sports industry is constantly striving to improve sportswear, thermochromic inks have enabled the implementation of smart features without external devices because the color change is based solely on the physiological changes that occur in the user's body. The property of changing color due to temperature changes provides new opportunities for developing smart sportswear that will provide users with an improved experience of using the product. Also, by monitoring the color changes on the clothes, the athlete’s performance can be monitored, such as the functioning of the cardiovascular system and the analysis of muscle movements.

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MULTI NEEDLE CHAINSTITCH SEWING MACHINES

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ABSTRACT

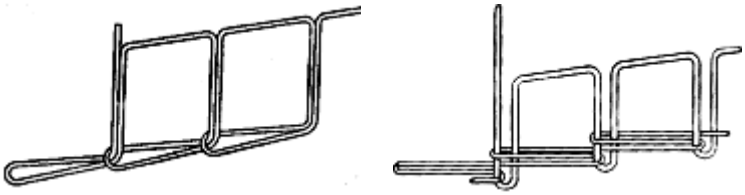
The multi needle machines are important equipment for industrial garment manufacturing process. They seriously increase work productivity and parallel seam quality. All of them are chainstitch machines which create stitch types 101 and 401. The material is fed by bottom feed system and a rear puller. Using different needle gauge sets and attachments, the machines can be used for different applications. 4-12 needles machines with metering devices or tension rollers can attach or insert an elastic band in sport or casual clothing. The machines with up to 50 needles and special devices can be used for material shirring, pin-tucking or smocking operations.

Key words: multi needle sewing machines, chainstitches, bottom feed system, metering devices, shirring, pin-tucking, smocking

INTRODUCTION

Different kind of sewing equipment is used in clothing industry. The most part of them perform stitching process with a single needle [1]. However, there are also well-known machines which use two, three and more needles (see Fig.1). The multi needle machines are very important equipment in industrial garment manufacturing process as, stitching two or more seams simultaneously, work process productivity and parallel seam quality seriously increases. There are operations which simply cannot be performed with single needle machines.
All multi needle sewing machines are chainstitch machines which create single thread stitches 101 or double thread stitches 401 (see Fig.2), [2]. Comparing with lockstitch machines, chainstitch machines can easy ensure delivery of top and bottom threads directly from large capacity cones what is very important when the machines has large number of needles and are used for long seam stitching.

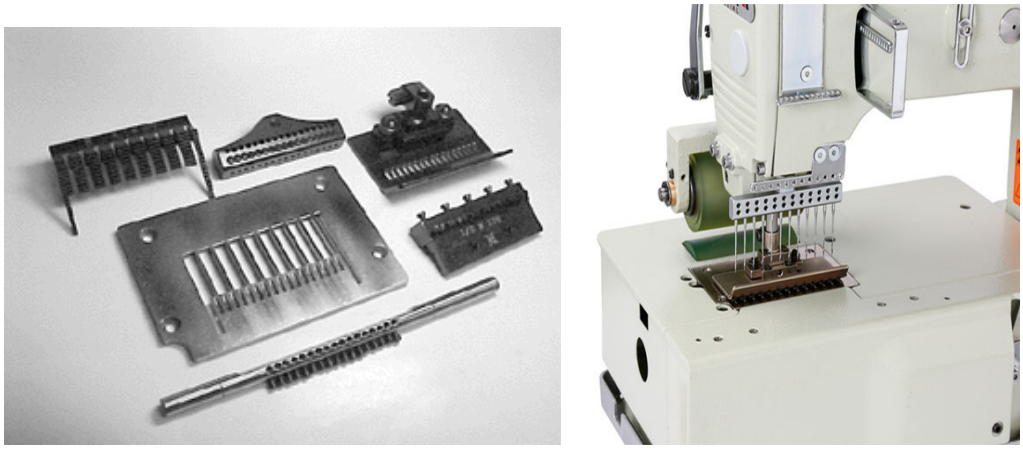
Figure 1. Multi needle sewing machines



a b

Figure 2. Stitch type 101 (a) and stitch type 401 (b)

These machines are mostly multifunctional as can use different *needle gauge sets* with different total number of needles (see Fig. 3a). Changing the needle gauge sets and number of needles set in them, as well as, using appropriate attachments, the machines can be used for different applications: elastic attaching/ inserting, shirring, pin-tucking and material smocking.



a b

Figure 3. Full needle gauge set

The multi needle machines use *bottom feed system* [3]. To support it creating simultaneously large number or parallel seams, *rear pullers* are used (see Fig. 3b). Steel teethed rollers are used for heavy material feeding, flat surface rubber pullers - for light delicate material feeding.
Advanced multi needle machines (Siruba, Yamato, others) can be equipped with *pneumatic under thread trimming device*. It cuts needle threads and looper threads under the fabric (under the needle plate) at the end of sewing cycle. After the threads are cut off, a wiper of the machine blows them up over the presser foot to start a new sewing cycle.
The most part of the machines use centralized /automatic lubrication system [4]. They can be equipped with a clutch or a servo motor [5].
Depending on the application several other devices use to be mounted on the machines: a top or bottom metering device, elastic expander rolls, a pin-tucking device, a smocking device [6]. Multi needle sewing machines are manufactured by companies: Kansai Special, Siruba, Sakura Stitch, Japsew, others.

ATTACHING OR INSERTING ELASTIC BAND

Multi needle machines can be equipped with several special devices to attach or insert different width elastic band in waistline of different type of casual, sport and underwear (see Fig.5).
The machines use 4-12 needles, distance between parallel seams can be varied using neighbor needles or every second needle. Material use to be fed by bottom feed and also with needle feed system.

Figure 5. Elastic band attached to sport shorts

The machines can attach end-less elastic band or pre-closed tubular elastic band. *Top or bottom metering devices* are used to feed the end-less elastic band controlling its amount and tension. (see Fig. 6).

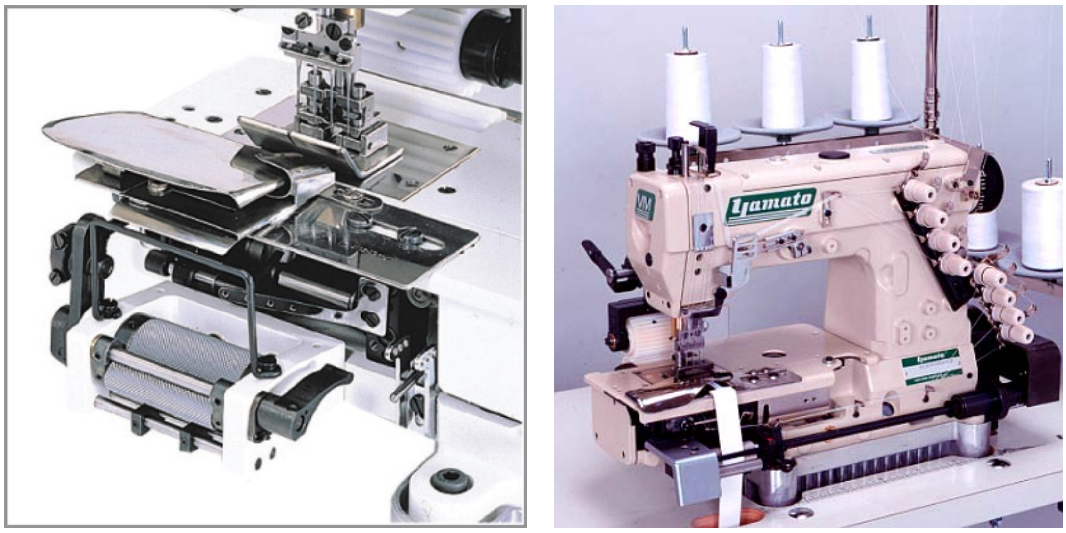


FIGURE 6. LOWER/BOTTOM FEED METERING DEVICE (A) AND *YAMATO VM1804P WITH THE METERING DEVICE (B)*

Attaching or inserting pre-closed elastic band an *elastic expander* is used. It consists of 2-3 rollers which hold the tubular elastic and the processed article, feeds them during sewing, and with it, ensures proper and evenly distributed tension (see Fig.7).

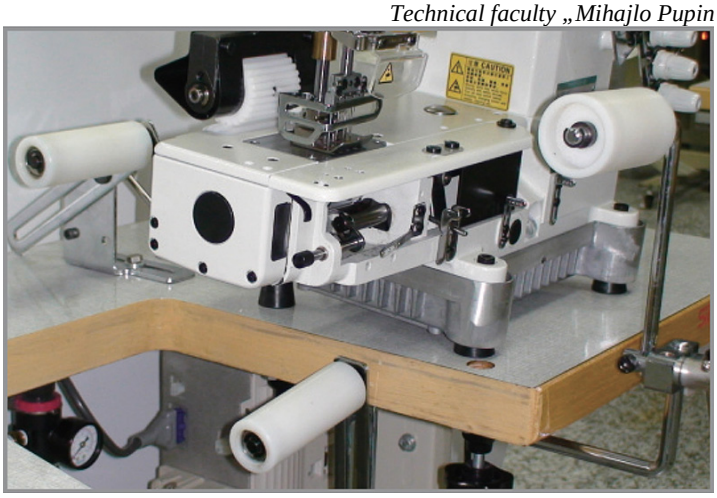


Figure 7. Tension rollers on a machine

SHIRRING

Multi needle machines can also perform material shirring. Shirring is creation of two or more rows of gathered seams on the material to decorate different parts of garments (waist, sleeves, others), (see Fig.8).

Figure 8. Fabric shirring

The machines for fabric shirring create single thread chainstitch 101 or double thread chainstitch 401 using one elastic thread. There are three different shirring methods used: elastic thread inserted in needles; elastic thread as a looper thread; elastic thread as the third thread.

PIN-TUCKING

A tuck is a fold or pleat in fabric that is fixed by stitches. When the tucks are very narrow, they are called pin-tucks. The process to create small parallel tucks is called *pin-tucking*. Small tucks in parallel lines are used to decorate clothing and home textiles (see Fig.9).

a b

Figure 9. Pin-tucks (a) and a blouse decorated with pin-tucks (b)

Pin-tucks can be sewn with the multi needle chainstitch machines equipped with *pin-tucking attachment* which folds the tucks in front of the needles (see Fig.10). The height/width of the pin-tucks is adjustable: 2mm, 5mm and 8mm. Detaching every second needle wider tucks (11mm, 14mm) can be created, too. Adjustable is also folding direction - left or right. The distance between tucks can be changed changing *needle gauge*.

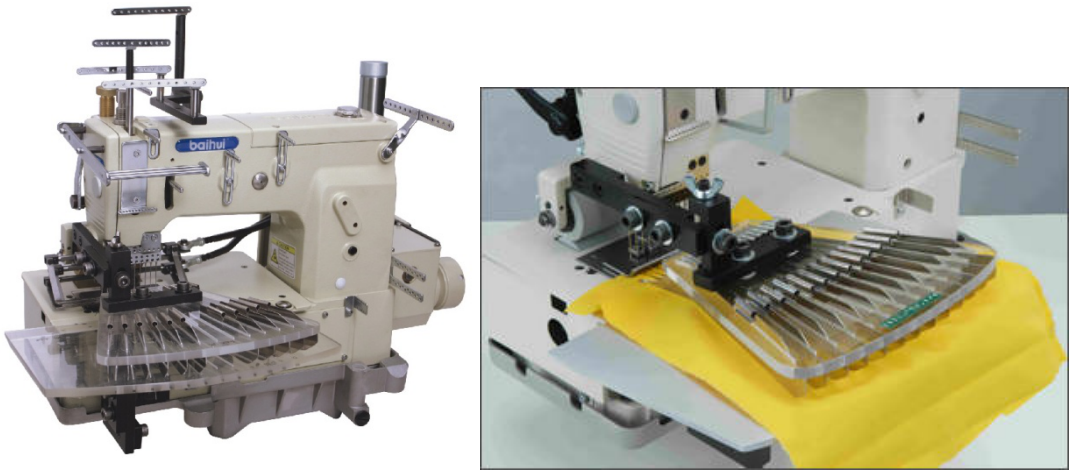


Figure 10. Multi needle machine with a pin-tucking device

SMOCKING

Smocking is a embroidery technique when decorative ornaments are created on the surface of fabric which is tucked, ruffled/pleated, gathered or shirred. The smocking is used to decorate garments and home textiles.
Industrial multi needle machines for smocking differ in number of needles and the second operation performed by the machine - plain stitching, shirring, pleating or pin-tucking (see Fig.11).

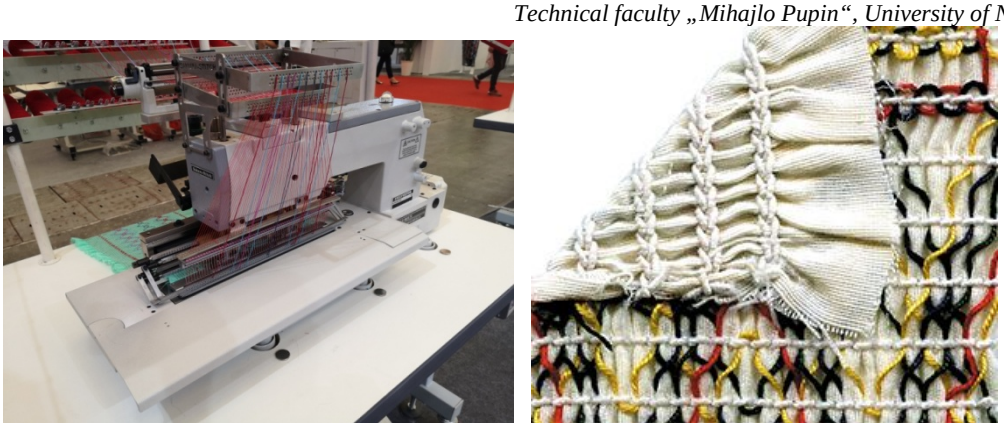


Figure 11. Multi needle shirring and smocking machine (a) and shirred and smocked fabric sample (b)

Smocking stitches are created by help of special device called a *smocking device/spreader* which is mounted on the machine. The main parts of a smocking device are *thread push rods* and *pattern cams.* The *push rods* are placed in front of the needles. They have holes in front of every needle. Ornamental threads are thread through these holes (see Fig.12a). By help of the *pattern cams* - the *thread push rods* are moved left and right to move ornamental threads from one stitch line to another (see Fig.12b). Different threading positions in *push rods* and their different movement create different patterns. The machines are usually available with multiply cams to create different patterns.

a b

Figure 12. Thread push roads (a) and pattern cams (b)

The more needles the more complicate and different smocking patterns can be obtained (up to 40). (see Fig.13).

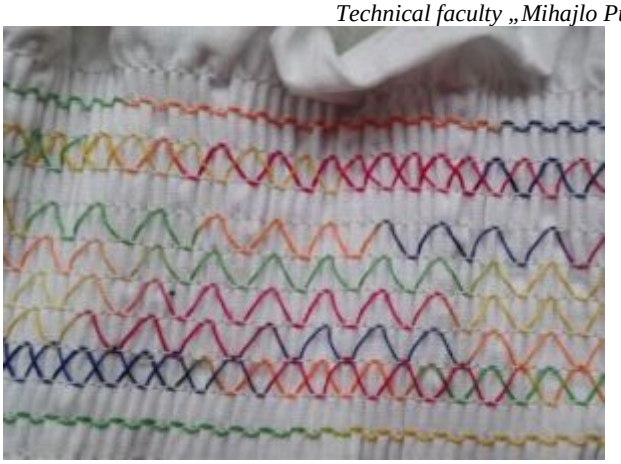


Figure 13. Smocking ornaments created by multi needles machine

CONCLUSIONS

Multi needle sewing machines are very important equipment in mass production of clothing as there ensure high work productivity and perfect quality of parallel seams. In the applications where these machines are used there are not replaceable with other equipment. 4-12 needle machines for attaching or inserting elastic waistband are well known and widely used in sport wear manufacturing. The machines with more needles are currently used rarely. However, as the machines can be used for several different applications, larger diversity clothing collections could be created using shirring, pin-tucking or smocking decorations on the garments.

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EXPERIMENTAL STUDIES OF THE DIMENSIONAL STABILITY OF SINGLE WEFT JACQUARD KNIT FABRICS

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ABSTRACT

The paper is devoted to the experimental investigation of the dimensional stability (shrinkage) of the knit structure of nine types of single jacquard fabrics and the plain knit structures. The main objective of this study is to analyze the influence of different stitch width repeats and the number of washing treatments on the dimensional change due to washing of the knit structure. The structures height repeat consists of a combination of two courses: plain and single float stitch with the different stitch width repeat, $R_b = m + n$ (m – the number of needles of action, n – the number of needles out of action). The number of needles in action or the number of needles out of action varies from 1 to 3. The fabrics are produced by the 10 gauge flat bed-knitting machine using 31 x 2 tex half-wool yarn. This study demonstrates the importance of stitch width repeat R_b on the dimensional change due to washing treatments of the knit fabrics. This is due to a combination of a number of different elements of the jacquard stitch structure(loops and floats) in the single- jersey jacquard fabrics.

Key words: jacquard, plain, single float stitch, needles of action, needles out action

INTRODUCTION

The dimensional stability (shrinkage) of knit fabrics due to washing treatment depends on many factors, such as: fiber type, yarn type, knit structure, type of knitting stich, stich length, wet processing, finishing procedures, cut-and-sew techniques, garment care and other factors (Spenser D.J., 2001; Salov I.I., 1958; Moiseenko F.A. et.al., 2007).

The shrinkage of the single jersey cotton knitted fabrics influence the variable factors such as: linear density, twist factor, machine gauge and stitch length (Sing G., 2011). The influence of the circular knitting machine gauge on the shrinkage of the single jersey knit fabrics has shown that the best shrinkage value for both directions is obtained with the use of 24-gauge machines (Islam M.A. et.al., 2014). The investigation of the impact of yarn count (26 Ne, 28 Ne and 36 Ne) and stitch length (2.50; 2.52; 2.60; 2.70; 2.80 and 2.96 mm) of 1x1 rib knit fabrics made from 100% cotton yarn has shown that shrinkage in the length direction increases with the increase of stitch length (Shiddique M.N.A. et.al., 2018). The shrinkage of the three different single jersey knit fabrics with varying fabric tightness, yarn types, and fiber blends and double pique knit fabrics showed that shrinkage in the width direction is less, while shrinkage in the length direction is greater than the shrinkage observed in single jersey knit fabrics (Levent O. et.al., 2003).

The investigation of the influence of the three types of washing (enzyme, softener, Silicone) on 100% cotton Single Jersey T-shirt, Slub Single Jersey T-shirt, Double Lacoste (5% Lycra) Polo shirt, Single jersey CVC (T-shirt) and PC single Jersey (T-shirt) showed slight to no changes in length and width shrinkage (Solaiman, et.al., 2015).

The influence of the knit structure on the shrinkage due to washing treatments has already been investigated by several researchers. The effect of three weft knitted structures: plain jersey, single lacoste and double lacoste on several properties, such as dimensional stability, showed that width shrinkage increases with the increase of tuck stitch, while length shrinkage decreases (Asif A. et.al., 2015). The shrinkage of the interlock, single jersey, and 1x1 rib knitted structures is not caused by changes in yarn length, as the loop configuration in each relaxation state was the most significant factor (Berenguer J.L., et.al., 2021). The stitching parameters have a significant impact on the dimensional properties such as shrinkage of knit pique knitted fabrics (Ramzan M.M., 2019).

The stitch width repeat of the plain and 1x1 rib knit fabrics made from 25x2tex x 2 blended yarn (70% cotton, 30% flax) influences the main parameters of the knit fabrics structures, but doesn't influence the shrinkage due to washing treatment (Bukhonka N.P. et.al., 2007; Bukhonka N.P. et.al., 2008).
A study of the main characteristics of single-jersey weft jacquards structure has demonstrated the importance of the stitch width repeat R_b (Bukhonka N., 2010). This effect is attributed to a combination of the elements of the jacquard stitch structure (loops and floats). The different stitch width repeat of rib or plain knit fabrics depends on the structure and main parameters of weft knitted fabrics (Bukhonka N., 2008).

This paper studied the influence of different stitch width repeat R_b of the single float stitch, on the dimensional change during washing of knit structure made from half-wool yarn. In this paper R_b = m + n (m – the number of needles in action, n – the number of needles out of action).

In spite of the many positive characteristics of wool as an environmentally preferable material in production of cloths, because of higher cost of the wool in comparison to chemical and synthetic fibres, the demand for wool garments has decreased. The half-wool yarn and suitable type of knitting structures may influence a decrease in costs and increase in the market value of knitting cloths.

MATERIALS AND METHODS

Materials

Single fabrics were produced by on the 10-gauge flat bed-knitting machine using 31 x 2 tex half-wool yarn. The following parameters used in knitting were kept constant: loop length, yarn tension and take-downs.
Graphical representation and main characteristics of the knitted fabric structure of the nine types of single-jersey jacquard and plain are presented in table 1. The stitch width repeat $R_b = m + n$ (m – the number of needles in action, m = 1, 2 or 3, n – the number of needles out of action, n = 1, 2 or 3).

Methods

The main structural characteristics of the knitted fabrics were analysed through the fabric stitch density (determined according to the standard EN 14971), weight (determined according to the standard EN 12127), and thickness (Amutha K.A., 2016; Saville B.P., 2002). The values for fabric stich density *(*the number of wales and courses per 100 mm in horizontal D_h and in vertical D_v) and thickness t were determined as the average of ten measurements, while the weight value (the mass of $1m^2$ m_S in the g/m^2) was determined as the average of 5 measurements. The length of yarn of one loop in mm l was determined as the average of twenty unrowed courses of fabrics (plain – l_1, single float stitch – l_2). The average length of yarn l_a in mm was determined using the formula:

$$l_a = \frac{(l_1 + l_2)}{2}$$

The structural elements of the jacquard stitch are loops and floats. At the points of missed stitches, the yarn is drawn as a float. During knitting, the loops of plain initially have the same dimensions as the jersey loops. Since the jacquard loops (loops of plain) are cast off from the needles after knitting only one course, at the points of missed stitches loop height increases.

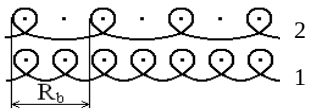
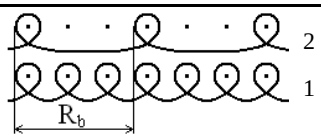
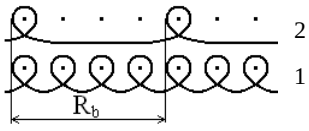
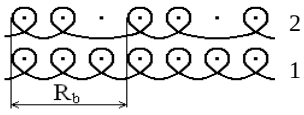
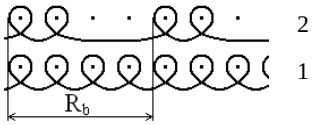
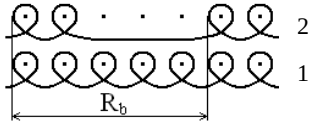
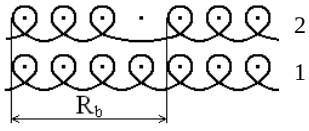
After being knitted the fabrics were laid for several days on a flat surface under a standard atmosphere to facilitate recovery from the stress imposed by knitting. The samples were subjected to 4 cycles of washing treatments at 20^0C in a fully automatic washing machine. After each washing cycle, the fabrics were laid, with minimum stress, on a flat surface under a standard atmosphere for at least 24 h. The samples were subjected to the washing treatments in accordance with the ISO 6330:2021.

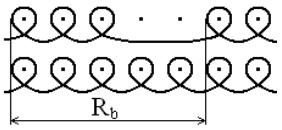
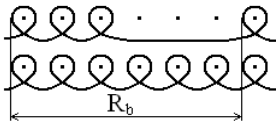
Measurements of the fabrics dimensional stability (shrinkage) in each direction were submitted in the formula:

$$S = \frac{(OM+FM)}{OM} \cdot 100, \%,$$

where: S – shrinkage (in the length S_l and width S_w), %,
OM – original measurements (in the length OM_l and width OM_w), mm;
FM – final measurements (in the length FM_l and width FM_w), mm.

Table 1. Type and main structural characteristics of the knitted fabrics

Variants of fabrics	The structure height repeat R_h	Graphical representation of single-jersey jacquard	m	n	$\frac{n}{m+n}$	D_h	D_v	l_1, мм	l_2, мм	l_a, мм	m_s, g/m^2	t, mm
1.	1 - Plain		1	0	0/1	83	91	6,18	-	-	263,50	1,27
2.	2 -Single float stitch 1+1 1 - Plain		1	1	½	95	131	5,97	8,05	7,01	305,40	1,53
3.	2 - Single float stitch1+2 1 - Plain		1	2	2/3	99	137	6,64	9,68	8,16	380,00	1,97
4.	2 - Single float stitch 1+3 1 - Plain		1	3	¾	107	154	6,89	11,18	9,04	360,50	2,06
5.	2 - Single float stitch 2+1 1 - Plain		2	1	1/3	98	121	5,85	7,78	6,81	334,30	1,64
6.	2 - Single float stitch 2+2 1 - Plain		2	2	2/4	106	132	6,51	8,21	7,36	472,00	2,00
7.	2 - Single float stitch 2+3 1 - Plain		2	3	3/5	109	138	6,86	8,28	7,57	437,30	2,16
8.	2 - Single float stitch 3+1 1 - Plain		3	1	¼	100	112	5,65	6,60	6,12	320,20	1,79

9.	2 - Single float stitch 3+2 1 - Plain		3	2	2/5	108	126	6,45	6,94	6,70	406,00	2,02
10.	2 - Single float stitch 3+3 1 - Plain		3	3	3/6	111	131	6,83	7,19	7,01	369,50	2,20

RESULTS AND DISCUSSION

The results of experimental measurements of the shrinkage in each direction are presented in table 2.

Table 2. The experimental value of the shrinkage in the length and width of the knitted fabrics after 4 cycles of washing treatment

Variants of fabrics	Shrinkage							
	in the length				in the width			
	the number of washing cycles				the number of washing cycles			
	1	2	3	4	1	2	3	4
1	-3,9	-8,9	-10,6	-12,2	-18,3	-19,4	-19,6	-19,8
2	-20,8	-23,3	-24,6	-25,9	-6,7	-8,3	-8,4	-8,5
3	-13,5	-17,6	-18,6	-19,5	-18,6	-20,1	-20,3	-20,6
4	-7,3	-19,1	-20,3	-21,4	-10,5	-10,8	-11,7	-12,5
5	-5,7	-13,8	-15,4	-17,0	-18,9	-20,2	-20,3	-20,5
6	-14,0	-16,0	-17,8	-19,6	-14,9	-15,8	-16,4	-17,0
7	-10,1	-15,3	-17,4	-19,4	-11,7	-11,8	-12,7	-13,6
8	-6,1	-12,0	-14,7	-17,3	-19,7	-20,4	-21,1	-21,8
9	-5,5	-12,1	-15,1	-18,1	-15,1	-18,1	-18,3	-18,5
10	-7,6	-15,6	-17,0	-18,3	-14,1	-14,4	-15,3	-16,1

The dimensional stability (shrinkage) of the knit fabrics can be approximated using the equation (Salov I.I., 1958):

$$S_i = \frac{x}{a + b\,x}$$

where S_i – shrinkage in the i-direction,

x – the number of washing cycles,

a, b – coefficients which depends on the type of the knit fabrics.

The maximum possible shrinkage due to washing S_{max} as the number of the washing cycles $x \to \infty$ will be

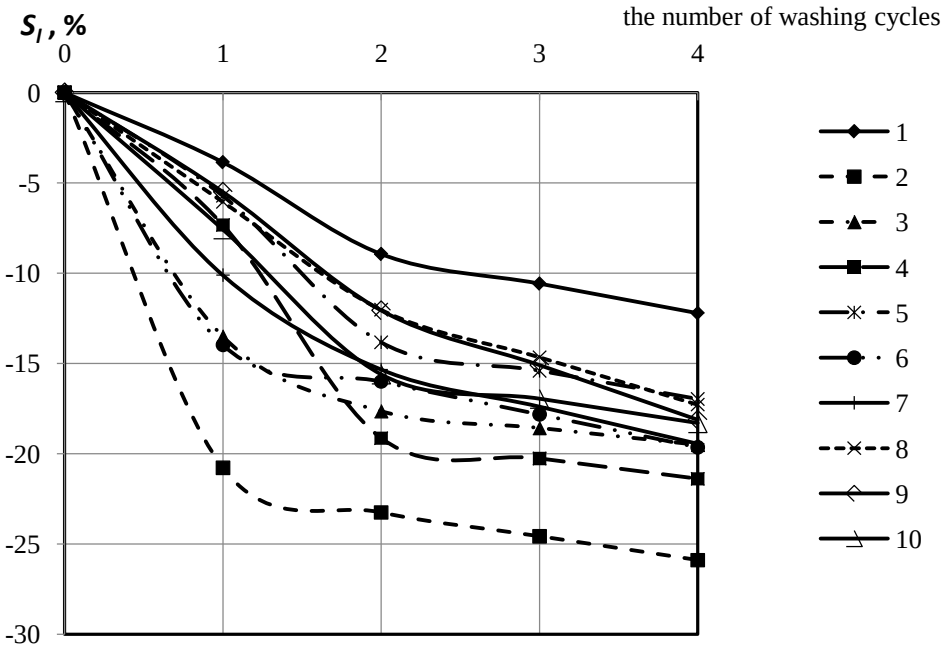
$$S_i = S_{max} = \frac{1}{b}$$

The values of coefficients a and b, the value of the max possible shrinkage due to washing S_{max} and the equations of the shrinkage in the length and width from the number of the washing cycles are presented in the table 3 below.

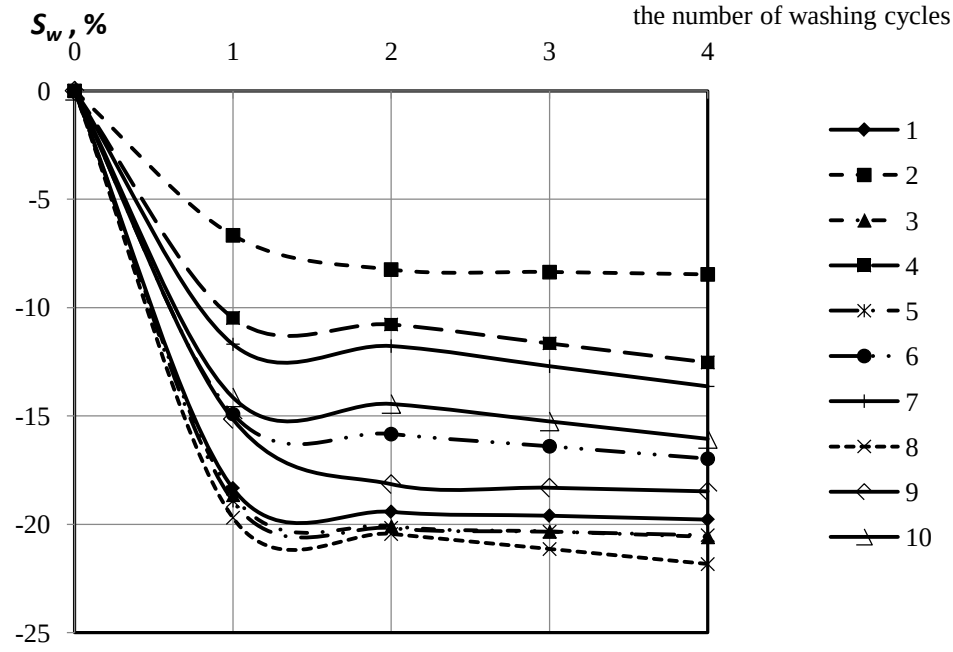
Table 3. The theoretical value of the shrinkage in the length and width due to washing treatments of the knitted fabrics

Variants of fabrics	in the length				in the width			
	the number of washing cycles				the number of washing cycles			
	a	b	1/b	the equation	a	b	1/b	the equation
1	-0,21	-0,03	-33,3	Sl=x/(-0,21-0,03x)	-0,01	-0,05	-20,0	Sw =x/(-0,01-0,05x)
2	-0,01	-0,04	-25,0	Sl =x/(-0,01-0,04x)	-0,04	-0,11	-9,0	Sw =x/(-0,04-0,11x)
3	-0,03	-0,04	-25,0	Sl =x/(-0,03-0,04x)	-0,01	-0,05	-20,0	Sw =x/(-0,01-0,05x)
4	-0,10	-0,02	-50,0	Sl =x/(0,10-0,02x)	-0,02	-0,08	-12,5	Sw =x/(-0,02-0,08x)
5	-0,13	-0,02	-50,0	Sl =x/(0,13-0,02x)	0,01	-0,05	-20,0	Sw =x/(-0,01-0,05x)
6	-0,03	-0,04	-25,0	Sl =x/(-0,03-0,04x)	-0,01	-0,06	-16,6	Sw =x/(-0,01-0,06x)
7	-0,06	-0,04	-25,0	Sl =x/(-0,06-0,04x)	-0,02	-0,07	-14,2	Sw =x/(-0,02-0,07x)
8	-0,13	-0,02	-50,0	Sl =x/(-0,13-0,02x)	-0,01	-0,04	-25,0	Sw =x/(-0,01-0,04x)
9	-0,16	-0,02	-50,0	Sl =x/(-0,16-0,02x)	-0,01	-0,05	-20,0	Sw =x/(-0,01-0,05x)
10	-0,09	-0,03	-33,3	Sl =x/(-0,09-0,03x)	-0,01	-0,06	-16,6	Sw =x/(-0,01-0,06x)

The results of the experimental value of the shrinkage in the length and width of the knit fabrics are presented on the figure 1.



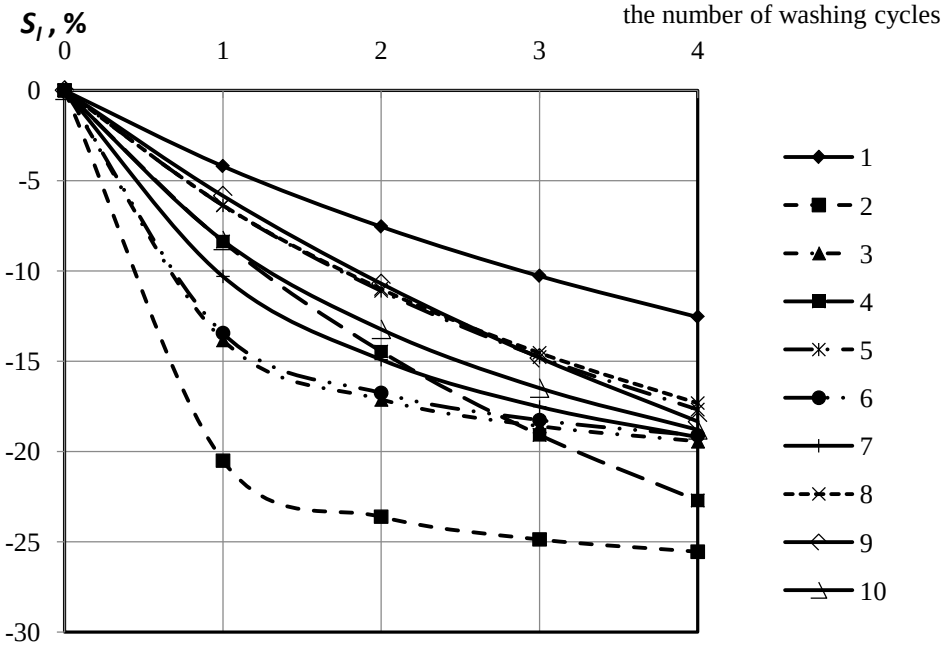
a



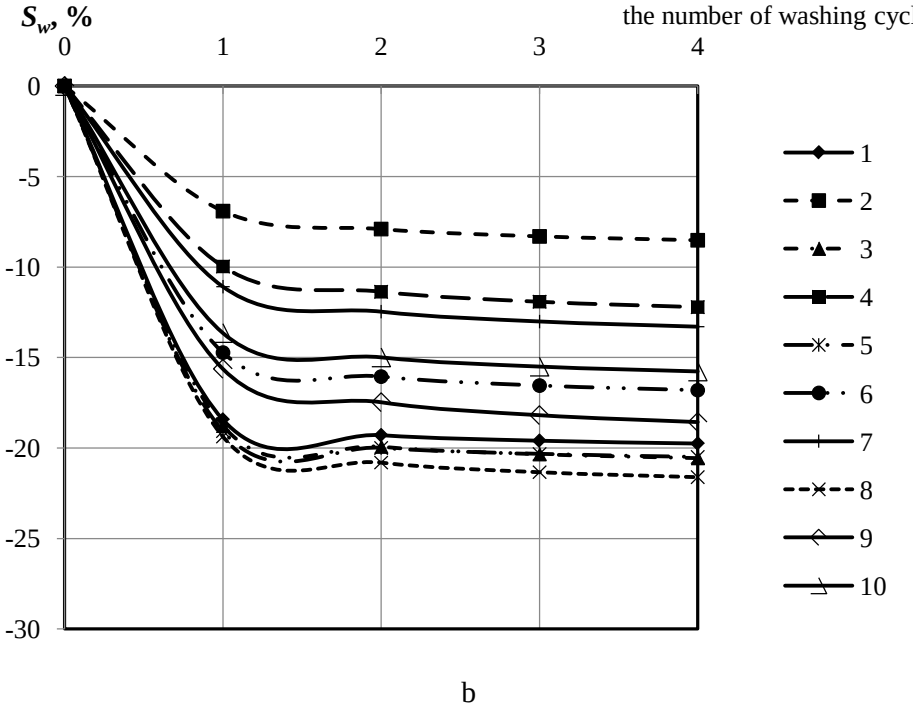
b

Figure 1. The experimental value of the shrinkage in the length S_l (a) and width S_w (b) of knitted fabrics

The results of the theoretical value of the shrinkage in the length and width of the knit fabrics are presented on the figure 2.



a



b

Figure 2. The theoretical value of the shrinkage in the length S_l (a) and width S_w (b) of knitted fabrics

From the results of investigations of dimensional stability due to the washing (table 2 and 3) and diagrams in figure 1 and 2 the following may be concluded:

- The dimensional change due to 4 washing treatments in each direction decreases.
- The shrinkage in the length and width of the knit fabrics (variants 1-10) decreases. The experimental value of the shrinkage ranges from -3.9 to -25.9% in length and from -6.7 to -21.8% in width.
- The experimental value of the dimensional change in length of the single jersey knit fabric is less than the dimensional change in width and ranges from -3.9 to -12.2% in length and from -18.3 to -19.8% in width.
- The single float stitch with a different stitch width repeat R_b = m + n (m – the number of needles in action, n – the number of needles out of action) of the knit fabrics (variants 2-10) increase shrinkage in length and decrease shrinkage in width.
- The number of washing cycles increases shrinkage in length of the knit fabrics.
- The most noticeable change in width shrinkage of knit fabrics is during the first two washing treatments.

CONCLUSION

The analyses of investigations results about influence of the different stitch width repeat on the dimensional change due to washing of a single weft jacquard's structure has demonstrated the importance of the stitch width repeat R_b.

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INTERNATIONAL PROJECT OPTIMTEX – SOFTWARE TOOLS FOR TEXTILE CREATIVES FROM THE ERASMUS+ PROGRAMME

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ABSTRACT

A group of six partner institutions from five European Union countries launched a new project in early 2020 to improve textile software knowledge and skills for students in higher education. The project OptimTex - Software tools for textile creatives was accepted for funding in December 2020 under the Erasmus+ KA2 - Strategic Partnerships Higher Education programme (2020-1-RO01-KA203-079823). The project partners started the planned activities in December 2020 and the project will end in November 2022. OptimTex is already the fourth project in a series of successfully implemented Erasmus+ projects dealing with e-learning materials for various advanced textile and garment manufacturing technologies. There are six project partners from five European countries: Romania, Portugal, Belgium, Czech Republic, and Slovenia.
The OptimTex project aims to improve the knowledge and skills of university students in software applications and increase their employability in textile companies by providing appropriate training tools for their profession. In total, the course, supported by developed e-materials, consists of five modules. The structure and content of the e-learning module Design and modelling of garments through 3D scanning and CAD/PDS software, developed by the Slovenian partners of the consortium, are presented.

Key words: OptimTex Project, e-Learning, Textile Software, 3D Scanning, CAD/PDS Software

INTRODUCTION

The project OptimTex – Software tools for textile creatives is a higher education project with underlined multidisciplinary concept. Connections between modern software applications and textiles are being investigated and explored. The main outputs of the project are: (1) Course of software applications for textiles, (2): Instruments for applying software solutions within textile enterprises, (3) E-learning tool and courses organization. The Slovenian Team has developed its module on Design and modelling of garments by 3D scanning software and CAD/PDS software. The paper presents the structure and contents of the module.

GENERAL INFORMATION ABOUT THE PROJECT

OptimTex project deals with software tools for textile creatives. It is already the fourth in the row of the successful projects devoted to e-learning in the wider scope of textiles. The projects were carried out by the consortium, consisting of the Universities and Institutes from different European countries. The first project of this kind was entitled E-learning course for advanced textile fields – Advan2Tex and was carried out in the period 2014-2016. Advan2Tex project aimed to provide e-learning content for professionals in textiles, young entrepreneurs, and students in higher education. The project consortium developed seven e-learning modules, meant to foster the involved target groups to apply the knowledge within their own textile organizations. The project Knowledge matrix for innovation and competitiveness in textile enterprises – TexMatrix followed in the period 2016-2018. It was based on an organizational management instrument named the Knowledge Matrix for Innovation, where the intangible assets of innovation capability of the involved textile companies were quantified and improved. The third project, Skills4Smartex - Smart textiles for STEM training, was also funded with the support from the European Commission. It was a strategic partnership - KA2 - Vocational Education and Training, in the field of transfer of innovation from research providers towards textile

companies and VET schools (Advan2Tex, 2019; Radulescu et al., 2017; Skills4Smartex, 2019; Blaga et al., 2019).

Project Consortium

Project consortium consists of six partners from five countries of the European Union: INCDTP - The National R&D Institute for Textiles and Leather, Bucharest, Romania (coordinator), TecMinho, Interface of the University of Minho, Portugal, Ghent University, Faculty of Engineering and Architecture, Department of Materials, Textiles and Chemical Engineering, Belgium, Technical University “Gh. Asachi” Iasi, Faculty of Textiles, Leather and Industrial Management, Romania, University of West Bohemia, Faculty of Electrical Engineering, Pilsen, Czech Republic, and University of Maribor, Faculty of Mechanical Engineering, Institute of Engineering Materials and Design, Maribor, Slovenia.

Project Objectives

The objectives of the OptimTex project are as follows (OptimTex, 2020):

- Building novel educational content by creating a course on up-to-date textile software applications.
- Improving employability of textile creatives within industry & research by means of adequate instruments.
- Fostering digital skills uptake by implementing e-learning instruments, platform, and glossary of modern textile terms.
- Creating educational synergies by enabling student mobility.

Structure of the Course of Software Applications for Textiles

The five modules of the Course of software applications for textiles are (OptimTex, 2022):

M1: Design and Modelling of woven structures
M2: Design and Modelling of knitted structures
M3: Design and modelling of garments by 3D scanning software and CAD/PDS software
M4: Design and Modelling of embroidered structures
M5: Software for research experimental design

The educational modules were conceived within a Problem-Based-Learning approach (Rădulescu et al., 2021), consisting of 4-5 practical cases on the research topic (Examples), the description of related Theory, some possible Applications of software and the corresponding Multiple-choice tests for self-assessment. This approach allows the students to learn the theory from practical examples in textiles more easily. To cope with the Problem-Based-Learning approach, the e-learning instrument was programmed with the same structure, having interactive buttons for the Examples, Theory, Applications and Quizzes, and navigating between the lessons.

DESCRIPTION OF THE MODULE, DEVELOPED BY THE SLOVENIAN PARTNERS

Each partner from the project consortium developed one of the modules of the Course of software applications for textiles according to their expertise, experiences, and available software tools/programs. The Slovenian partners have rich experiences in research fields related to 3D scanning and virtual prototyping of garments, also those for special purposes and people with special needs. Therefore, it was a logical choice to take over the task of designing/writing the Module entitled Design and modelling of garments by 3D scanning software and CAD/PDS software.

Structure of the module

The Module includes the following four examples:

- 3D human body scanning using the 3D photogrammetry
- 3D human body modelling and reconstruction
- Construction of a kinematic 3D body model
- 3D virtual prototyping of personalized smart garments.

The Module therefore displays the entire process for the needs of 3D virtual prototyping of individualized garments. Each example consists of the related theory, the application of software tools and some multiple-choice questions for self-assessment of the acquired knowledge.

The objective is on presenting the needs of digitization for the development of personalized garments, and more detailed on the presentation of software tools for 3D scanning of the human body or its individual parts, modelling and reconstruction of scanned 3D body models, construction of a kinematic 3D body model, and development of smart garment pattern design in a virtual environment by using different software tools: 3D Sense, PotPlayer, Meshroom, MeshLab, Blender and OptiTex, which enable the students to receive new digital skills and knowledge on smart garments' development.

Supplemental video presentation/tutorials have been prepared for effectively explaining the use of different software used within the Module. The entire Course will be available through the link http://www.optimtex.eu/ on the e-learning project platform http://www.advan2tex.eu/portal/. Figure 1 represents a print screen of the topics of the 4th example related to 3D virtual prototyping of personalized smart garments (in Slovene).

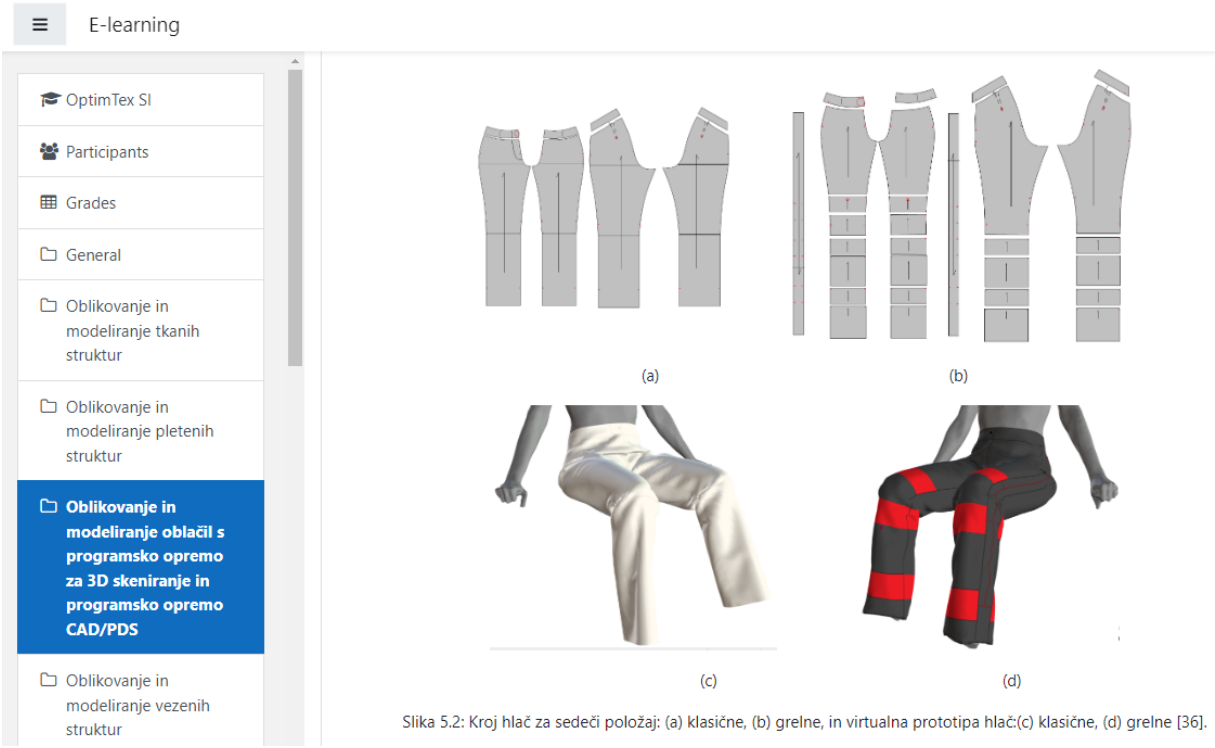

Figure 1: Print screen of the topics related to 3D virtual prototyping of personalized smart garments

Multilingual Glossary of Terms

The Glossary of terms is meant to support the courses (Intensive Study Programs) with students of various partner universities. Since the courses will be taught in English, while the e-learning materials are implemented on Moodle in national languages, the students will be able to consult the critical term's definitions in national language through the Glossary.

The Glossary was programmed in PHP with the databases of terms and definitions in MySQL. Tables with the 120 terms on the six modules for each national language (English, Czech, Dutch, Portuguese, Romanian and Slovenian) were included into the Glossary. The tables had as entries the term, the definition, an optional picture, and the module ID. The web page has free access and may be consulted either by the students during the ISPs or by stakeholders requiring a technical term in business and trade (Rădulescu et al., 2022).

OPTIMTEX INTENSIVE STUDY PROGRAMS

Three Courses, or Intensive Study Programs (ISP), with the duration of five consecutive days, were planned in the course of the project. The first one was organized by the University “Gh. Asachi” Iasi, Faculty of Textiles, Leather and Industrial Management, Romania, and was held on-line in March 2022 because of the pandemic situation. The second ISP was held at the University of Maribor, Faculty of Mechanical Engineering, Slovenia from 30 May to 3 June 2022. Four students and at least one of the teachers/professors from each of the partner institutions attended the course. Figures 2 and 3 presents the participants of the ISP Maribor and lectures/practical work with the module, developed by the Slovenian partners of the project consortium.

Figure 2: Participants of the Intensive Study Program Maribor

Figure 3: lectures/practical work with the Slovenian module of the Course

CONCLUSIONS

Erasmus+ is the EU's programme for supporting education, training, youth and sport in Europe with a budget of near billion Euro. The new 2021-2027 programme is focuses on social inclusion, the green and digital transitions. OptimTex project addresses the priorities and fully meets the requirements of the programme within the Digital education action plan and the European Skills Agenda.

The paper presents the Erasmus+ project OptimTex – Software tools for textile creatives. This is a higher education project with underlined multidisciplinary concept. The contribution is focused on the structure and contents of the module entitled Design and modelling of garments by 3D scanning software and CAD/PDS software. It is one of the five modules of the Course of software applications for textiles, which was developed and written by the Slovenian team of the project consortium. In its final form, the course is produced in a form of a modern e-learning material hosted on a project platform.

E-learning materials served as a basis for carrying out Intensive Study Programs. Three such events with the duration of five consecutive days, were planned and being carried out in the course of the project. Four students and at least one of the teachers/professors from each of the partner institutions attended each of the course. The first one was organized by the Romanian partners from Iasi and was held on distance. The second one was held on site in Maribor, Slovenia. Just in the week of the TNP 2022 conference the fourth course in being held in Gent, Belgium.

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EFFECT OF MACHINE SPEED ON TYPE OF DEFECT DURING KNITTING PROCESS OF LADIES TIGHTS

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ABSTRACT

The quality development concepts have seen a great growth over the entire 20th century. To help an organization to survive in the world class market, Total Quality Management technique was introduced. Precisely, the Statistical Process Control is one of the TQM methods that improves quality and reduces variation. Statistical methods help in monitoring of the operation and structural changes of business entities, which is the basis for market analysis and business growth. The training of the employees in the companies for the correct use of the statistical methods in the decision making as part of the quality management process is a challenge of the modern work that companies face. Methods of correlation and regression analysis serve for modeling how the change in one variable (or more variables) influences for in other variable(s). Once the association between the dependent and independent variables is quantified, the next step is to interpret this relationship. Correlation and linear regression are the most commonly used techniques for quantifying the association between two numeric variables. Correlation quantifies the strength of the linear relationship between paired variables, expressing this as a correlation coefficient. The paper investigates the concepts of the quality control tool - scatter diagram, correlation coefficient and regression analysis in the production of lady's tights. It covers the need of this tool, steps to construct them, their use and advantages.

Key words: Quality Control Tools, SPC, Correlation coefficient, Regression analysis

INTRODUCTION

Quality has been identified as one of the competitive strategies for improving business performance in a global market. Organizations all over the world are using different techniques for quality improvement (Nagarajan R. *et al*., 2013). The quality has many dimensions which are the various features of a product or service (Mystica A. *et al*., 2019). For best quality, every organization should nurture a standard, organized procedure (Saravanavel P. *et al*., 2010). The best proposed tool for better quality product is Statistical Process Control (SPC). SPC tools are required to control and improve the process. SPC is useful in identifying the reasons for quality problems and reducing variability in product output, in making delivery, in maintenance, in equipment use etc. (Subburaj R., 2012).. The goals of SPC are collection of data, finding out variations, analyzing through brainstorming, finding out the causes and effects, continuous improvement (Saravanavel P. *et al*., 2010). 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 (Heleta M., 2004).

Correlation is a statistical method used to evaluate potential associations between variables. The first useful step in correlation analysis is plotting a scatter plot to visualize the potential relationship between the variables in question (Gillings M. *et al*., 2020). The scatter diagram helps to find out the relationship between two factors. With the help of independent variable, the dependent variables can be controlled. It is used in explaining the behavior of process and the means of controlling it (Bhaskar S., 2011). The resulting correlation coefficient can be any real number between -1 and 1. A perfect linear association (where all points can be connected through a straight line) will have a magnitude of -1 or 1, depending on the direction of the correlation. In reality, the linear relationship between the variables of a data set will almost always be imperfect meaning that the points will not sit neatly on a straight trend line and the correlation coefficient will get a value between -1 and 1, where a strong negative association will be close to -1 and a strong positive association close to 1. Importantly, a correlation coefficient value of zero does not mean that there is no correlation between the variables in question but rather that there is no linear correlation (Hazra A. *et al*., 2016). A scatter plot is

essential before embarking on any correlation- regression analysis to show that this is indeed the case. If the association is “strong” then an attempt may be made mathematically to develop a predictive relationship between the two variables so that given the value of one, the value of the other may be predicted from it and vice versa. Defining this mathematical relationship as an equation is the essence of regression analysis. Correlation and regression analysis are therefore like two sides of the same coin (Kirtan P., 2022). Regression analysis produces a regression equation where the relationship between each independent variable and the dependent variable is represented by the coefficients (Kirtan P., 2022).

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 (Petrović V.M., 2000). 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 (Salerno-Kochan R., 2008). The speed of the machine plays an important role in fabric defects. Thus, an optimum speed should be maintained for optimum production. The efficiency of weft knitting machine is related to knitting parameter, yarn quality, human skill. It is assumed that poor quality of yarn appearance, improper machine parameter causes fabric faults, yarn breakages, ultimately its effect on efficiency (Pawar H. *et al*., 2012).

Based on the above mentioned, the aim of this paper is to discover whether exists correlation between the most occurred type of defect during knitting process and the speed of the knitting machine. If it so, to find the optimum production speed.

EXPERIMENTAL PART

In the first study, by collected production information’s and presented Pareto charts, for both machines it is determined that the highest percentage of defects occurs from breaking thread 2 (Stevkovska-Stojanovska R. *et al*., 2021). 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 (Stevkovska-Stojanovska R. *et al*., 2021).
During measuring of two variables which are in correlation, the received data from analysis are grouped by mathematical function and can be found the following:

- are there any points that are unusually far from the other points,
- whether they can be divided into four sectors.

In the first case, those values (points) are removed because they are rough measurement errors. In the latter case, according to the arrangement of the points in relation to the mean values of the two properties (by x- and y- axis’s), it is determined whether it is a positive or negative relationship between. When the value of the property X increases with increasing of the values Y, there is a positive correlation, and when the value of X increases when Y decreases, the correlation ratio is negative. When the correlation between two properties is linear, it is expressed by a **coefficient of linear correlation** calculated by the formulas:

$$r_{xy} = \frac{S_{xy}}{\sqrt{S_{xx} \cdot S_{yy}}} \tag{1}$$

$$S_{xx} = \sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2 \tag{2}$$

$$S_{yy} = \sum_{i=1}^{n} \left(y_i - \bar{y}\right)^2 \tag{3}$$

$$S_{xy} = \sum_{i=1}^{n} (x_i - \bar{x}) \cdot (y_i - \bar{y}) \tag{4}$$

Where: x_i - possible values of the variable X; $\bar{x}$ - average values of the variable X
y_i - possible values of the variable У; $\bar{y}$ - average values of the variable У

The coefficient of linear correlation is a measure of the linear dependence between the two properties (values) and shows:

- If r_{xy} = 0 between the variables x and y do not exist linear correlation;
- If r_{xy} = 1 the correlation between variables is functional.

When the sign is positive there is a positive, and when it is negative there is a negative correlation.
To the question whether the correlation coefficient obtained from n pairs of x and y, according to formula (1) is reliable (i.e. whether there is a correlation or not), the answer is given by the **criterion t** which can be calculated according to the formula below and further that value should be compared with the value from Table 1 (in appendix) for some certain degree of freedom and interval of statistical confidence:

$$t_r = \frac{(r_{xy})}{\sqrt{1 - r_{xy}^2}} \cdot \sqrt{n-2} \tag{5}$$

Very often it is insufficient only qualitative assessment of the correlation between two properties expressed through the correlation coefficient, so it is necessary to describe that correlation and qualitatively, i.e. with the help of **regression analysis**. The task consists in the following: a linear correlation is assumed by extracting the best straight line, the so-called regression line which can be obtained as follows:

$$Y = a + bx \tag{6}$$

According to Gauss, the best line is the one, calculated by the formula:

$$\sum (y_i - Y_i)^2 = \min \tag{7}$$

Where: $a = \bar{y} - b\bar{x}$ (8)

$$b = \frac{\sum xy - \frac{1}{n} \cdot \sum x \cdot \sum y}{\sum x^2 - \frac{(\sum x)^2}{n}} \tag{9}$$

a - point of intersection of the line with the axis y; b- regression coefficient

$$Y = \bar{y} + b \cdot (x - \bar{x}) \tag{10}$$

The cause is always applied to the x-axis, and the consequence is applied to the ordinate- y. The **regression coefficient B** is used to assess the dependence between the two variables in the regression calculations.

$$B = \frac{\left[\sum xy - \frac{1}{n} \cdot \sum x \cdot \sum y\right]^2}{\left[\sum x^2 - \frac{\left(\sum x\right)^2}{n}\right] \cdot \left[\sum y^2 - \frac{\left(\sum y\right)^2}{n}\right]} \quad (11)$$

The coefficient of regression B is connected with the correlation coefficient- r_{xy} by the formula:

$$r_{xy} = \pm\sqrt{B} \quad (12)$$

The sign of the correlation coefficient corresponds to the sign of the regression coefficient. The regression coefficient has a value from 0 to 1 and shows what fraction of the scatter points of the regression line make up the total scatter around the mean. The higher the coefficient is, the points are closer to the regression line.

RESULTS AND DISCUSSION

The largest number of defects during the process of knitting tights occurs in the pipes. The reason for this is the tearing of the thread either in the area of the panties or in the sheet, the type of defect D (Stevkovska-Stojanovska R. *et al*., 2021). Usually the machines work with speed of n = 500 - 650 rpm, set up by the appropriate knitting program. During the process of knitting, this speed varies (is changing), depending on which part of the tights is knitted (whether it is the rubber band from the pipe, the pipe, the panties, the sheet or the fingers). At the table below (Table 1) separated on two parts are presented the data for average speed of the machine (values x) and the defects- tearing the thread performed during that speed (values y) while knitting the pipes. Further, are calculated needed data for correlation coefficient, presented in the Table 1. The purpose of this is to see if there is a correlation between the knitting speed and defects. If so, to find the speed at which the defects are the least.

Table 1: Machine speed and defects and calculation for correlation coefficient

No.	x	y	$x \cdot y$	x^2	y^2
1	540	23	12420	291600	529
2	550	22,7	12485	302500	515,29
3	555	22	12210	308025	484
4	560	20,3	11368	313600	412,09
5	565	18,3	10339,5	319225	334,89
6	570	17	9690	324900	289
7	575	16,7	9602,5	330625	278,89
8	580	15,7	9106	336400	246,49
9	585	15	8775	342225	225
10	590	15,3	9027	348100	234,09
11	595	13,3	7913,5	354025	176,89
12	545	23,7	12916,5	297025	561,69
13	540	21,3	11502	291600	453,69
14	555	21,7	12043,5	308025	470,89
15	560	19,7	11032	313600	388,09
16	565	17,7	10000,5	319225	313,29
17	570	16,7	9519	324900	278,89
18	575	16,7	9602,5	330625	278,89
19	580	15,3	8874	336400	234,09
20	585	14,7	8599,5	342225	216,09
21	590	15,7	9263	348100	246,49
22	595	13	7735	354025	169

23	560	19,3	10808	313600	372,49
24	580	15,7	9106	336400	246,49
25	580	14,7	8526	336400	216,09
sum	**14245**	**445,2**	**252464**	**8123375**	**8171,8**
26	600	16,3	9780	360000	265,69
27	605	18,3	11071,5	366025	334,89
28	610	19	11590	372100	361
29	615	23,3	14329,5	378225	542,89
30	620	26,7	16554	384400	712,89
31	625	27,3	17062,5	390625	745,29
32	630	30	18900	396900	900
33	635	30,7	19494,5	403225	942,49
34	640	35,3	22592	409600	1246,09
35	600	17,7	10620	360000	313,29
36	610	19	11590	372100	361
37	605	19	11495	366025	361
38	615	22,7	13960,5	378225	515,29
39	620	27	16740	384400	729
40	625	29	18125	390625	841
41	630	30,3	19089	396900	918,09
42	635	32	20320	403225	1024
43	640	35	22400	409600	1225
44	645	37,3	24058,5	416025	1391,29
45	630	30,3	19089	396900	918,09
46	600	16,3	9780	360000	265,69
47	640	34,7	22208	409600	1204,09
48	620	26,7	16554	384400	712,89
49	640	35,7	22848	409600	1274,49
50	650	36,7	23855	422500	1346,89
sum	**15585**	**676,3**	**424106**	**9721225**	**19452,33**

Based on the obtained results in the table below are presented all performed calculations:

Table 2: Calculations for correlation and regression analysis

Machine speed	$S_{(xx)}$	$S_{(yy)}$	$S_{(xy)}$	$r_{(xy)}$	t_r	$\bar{x}$	$\bar{y}$	b	a	Y	B
540 - 580 rev/min	6574	243.7	-1210.9	-0.96	15.8	569.8	17.8	-0.18	122.7	$\mathbf{122.7 - 0.18 * x}$	0.92
600 - 650 rev/min	5536	1157.1	2500.5	0.99	30.7	623.4	27	0.45	-254.4	$\mathbf{-254.5 + 0.45 * x}$	0.98

For the first set of machine speed, the calculated values of the coefficient of correlation indicate to **high inverse-proportional linear correlation** between the average knitting speed and the tearing of the thread, i.e. the defects that occur. The reliability of the obtained correlation coefficient is determined using the criterion t_r. The conclusion is that there is a linear correlation between the two variables, with confidence level of 99,9 %.

Next, aiming to explain the quantitative correlation between the variables, regression analysis is performed. Based on these calculations, it is designed Figure 1, a regression between the defects (tearing of the thread) and the knitting speed of the circular knitting machine for women's tights.

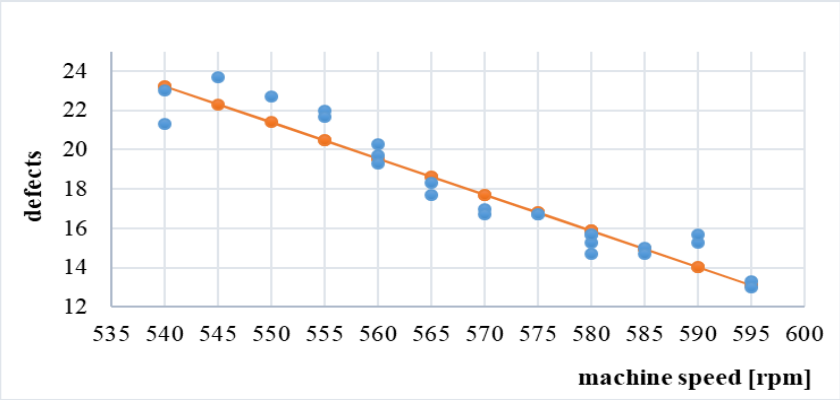

Figure 1: Regression between knitting speed and occurred defects

The result for regression coefficient indicates that 92 % of the points (values for tearing of the thread) are near the regression line. With help of this formula, can be calculated the optimum machine speed at which the number of defects will be minimal, defined in the given control limits (set by the consumer, production manager, the company owner etc.).

The same calculation as above, are performed for the second part of the obtained results, for machine speed 600 - 650 rev/min. The calculated value for the coefficient of correlation indicates to **high proportional linear correlation** between the average knitting speed and the tearing of the thread, i.e. the occurred defects.

The reliability of the obtained correlation coefficient is determined using the criterion t_r. The conclusion is that exists linear correlation between the two variables, with confidence level of 99,9 %. Then, calculations for regression analysis are performed. The regression coefficient gives the estimate of the dependence of the defects on the speed of the knitting machine. This value indicates that 98 % of the points lie close to the regression straight.

Based on these calculations, a regression diagram between the defects (tearing of the thread) and the knitting speed of the circular knitting machine for women's tights is presented (Figure 2).

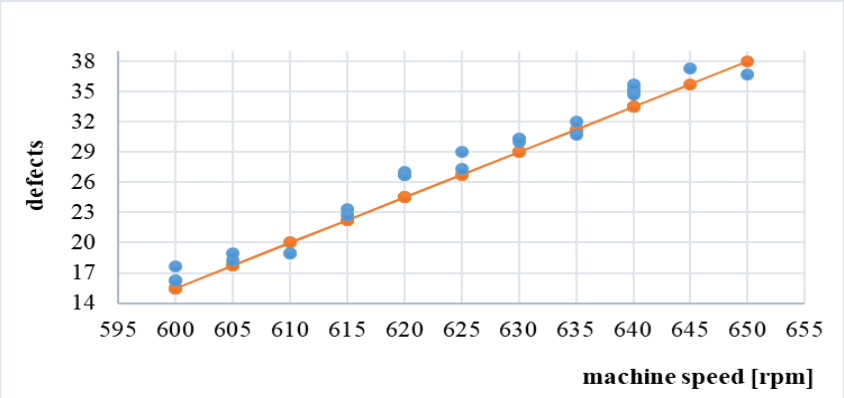

Figure 2: Regression between knitting speed and occurred defects

CONCLUSION

In this paper, the on daily basis machine speed for knitting tights was changed and the defect occurrence - thread breakages were observed. The objective of this study was to find if there is correlation between defects and machine speed. Whit this finding, improvement of the machine efficiency and production, by selecting the optimum machine speed can be achieved. So, the production of better-quality knitted fabric can be obtained as well as the reduction of fabric defects and second-class products. Conclusions from this study are:

- For the first set of machine speed, exists a high inverse-proportional linear correlation between the average knitting speed and the tearing of the thread/ defects. So, changing the knitting speed affects the defects, i.e. the percentage of non-conformities products. But, since the dependence is inverse-proportional, that means that with increasing of knitting speed from 540 to 595 rpm, the number of defects reduces.
- The reliability of the obtained correlation coefficient is confirmed with the criterion t_r, with confidence level of 99,9 %.
- The result for regression coefficient indicates that 92 % of the points are near the regression straight.
- For second set of machine speed, from 600 to 650 rev/min. The calculated values for the coefficient of correlation indicate to high proportional linear correlation. Actually, with increasing the machine speed from 600 to 650 rpm, the number of defects increases as well.
- The reliability of the correlation coefficient is determined with the criterion t_r, with confidence level of 99,9 %.
- The regression coefficient indicates that 98 % of the points lie close to the regression line.

Knowing the both results in this paper the optimum speed should be determined not only by the formulas, but also considering productivity. As the knitting process is a complex production process where many factors and correlations exist, optimum machine speed should be determined, resulting in stable process, lower production costs and increased productivity.

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SURVEYING PROFESSIONAL LOGGERS TO IMPROVE SAFETY, DESIGN AND WEARER EXPERIENCE OF CHAINSAW PROTECTIVE CLOTHING

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ABSTRACT

This chainsaw protective clothing research and design project is a response to the constant pressure to improve chainsaw protective equipment. Forestry is one of the most dangerous professions with an alarming number of injuries and accidents. The paper focuses on the online survey based on the initial research on chainsaw protective equipment, hazard scenarios in forestry, chainsaw protective clothing and its functional criteria, and market analysis. The survey focuses on the experiences, views, opinions and needs of trained and professional loggers. In order to gain a comprehensive understanding of forestry and logging, the survey needed to cover a wide range of forestry-related topics, including general forestry work practises and habits, experiences with injuries and accidents, views on personal protective equipment, an in-depth analysis of chainsaw protective trousers, and respondents' preferred labels on the market. The key findings of the survey helped us identify areas of improvement for chainsaw protective trousers, taking into account forestry ergonomics, functional textiles, improved construction details and fashion trends.

Key words: chainsaw protective trousers, protective clothing, personal protective equipment, logging, safety at work

INTRODUCTION

The first part of the research was the literature review on the hazards and injuries of foresters' work, standards for protective workwear, functional requirements and textile materials for logging protective clothing and chainsaw protective clothing. We have specifically researched some case studies on accidents during logging work. Working in the forest is defined as one of the most dangerous occupations (Potočnik I., Poje A., 2017; Klun J., Medved M., 2007) and is even among the three most dangerous occupations in Europe (Blombäck P., et al., 2003). Studies have shown that of all occupations in the forest, the work of a logger with a manual chainsaw is the most dangerous (Unver S., Ergenc I., 2021), as one in four loggers has already experienced an accident or injury (Gendek A. et al., 2020). It is therefore extremely important that they have high-quality protective clothing and equipment. Forestry protective equipment includes a range of clothing and accessories that are mandatory equipment for loggers' work due to regulations (Bryan, R., Stihl., 2019). The standard EN ISO 11393 refers to protective equipment when working with a chainsaw and is divided into several parts, with each part of the standard covering a separate part of the body (SIP Protection, 2022). The protective mechanisms of forestry protective equipment comprise three main principles, which can act independently but are usually combined: Slipping, clogging and braking of the saw chain (SIST EN ISO 11393-1, 2018). Protective trousers for foresters, which must be lightweight (Liffman K., 2015) and protect the entire leg area, are divided into three types (SIP Protection, 2022). Types A and B are for professional use only, while type C offers more safety and is intended for the average user and professionals for work in more demanding terrain (SIP Protection, 2022). Each type is further characterised by four protection classes, depending on the chain speed of the chainsaw used (SIP Protection, 2022, Freeworker, 2022). Various textile materials are used for personal protective equipment (Roshan P., (2019). Due to the specificity of different jobs, there is no one ideal textile that could protect against all hazards (Shaw A., 2014). Therefore, when selecting and designing textile materials for protective clothing, it is important to know the possible accident scenarios in a particular work environment. The design and planning of cut protective clothing includes multifunctional textile composite materials and hybrid structures (Lawrence C. A., 2014). Their development begins at the

level of fibres, which are then used to create high-performance yarns, high-performance textiles and composite structures. The textile materials mentioned are also found in the protective trousers offered by the market (e.g. Husquarna: Technical Extreme, Technical Extreme Arbor, Technical, Functional, Clasic, Technical Robust, High Viz (Husquarna, 2022), Stihl: X-Flex, X-Treem, Advance X-Light, Dynamic Vent, Protect MS (Stihl, 2022), Pfanner Gladiator II (Asteko , 2022), Sip Protection: W-Air, Samourai, Arborist HV, 1SQT, Tall Fit Arborist, (SIP Protection, 2022) etc. Based on the analysis of the above-mentioned protective trousers for loggers and individual interviews with loggers, we have found that protective trousers for loggers can be further improved.

METHODS

Based on the information gathered during the literature review and the analysis of protective trousers for loggers on the market, a survey was prepared and sent to professional loggers in Slovenia. The answers helped us to define the areas of improvement for chainsaw protective clothing and our further work, which includes the design and development of improved chainsaw protective trousers.

RESULTS

The survey, which included 63 questions, collected data on a wide range of topics related to forestry work. It was conducted between June and August 2022. During this period, 63 complete responses were collected. 95% of the participants were male, and the remaining 5% were female. 33% of participants were between 45 and 65 years old, 28% were between 35 and 45 years old, 19% were between 25 and 35 years old, and 21% of participants were younger than 25 years old.

Analysis of the survey

General Woodworking Habits

Most respondents work in the forest during the months of October (65%), November (65%), and March (63%). Between 50% and 60% of respondents reported also cutting trees in January, February, September, and December, while less than 50% of respondents also work in the forest in April (48%), May (33%), June (30%), July (32%), and August (40%). When asked how often they work in the forest during the selected season, 35% of respondents answered that they cut wood in multi-day operations that occur once a month or every few months. 28% indicated that they conduct such logging operations more than once a month. Most loggers conduct operations that last 1 to 3 days (66%), but they also reported operations that last 3 to 5 days (26%) and operations that last a full week (8%). 7% of all respondents reported working in the forest every day, 5% reported working in the forest once a month, and 3% reported logging only once in the selected season. Responses indicate that 54% of respondents work up to 5 hours continuously in the forest, 41% work 8 hours in the forest, 1% work only about an hour, and 4% of respondents reported working more than 8 hours continuously. All respondents indicated they fell timber manually with a chainsaw. The loggers surveyed mostly (60%) work in pairs, 22% work in a team of 3 to 5 members, 16% work alone, and 2% work in a team with more than 5 members. When asked what type of logging they usually perform (multiple responses possible), 74% responded that they usually perform selective cutting, 64% perform sanitation harvest, 46% perform spacing and juvenile thinning, while 2% perform arborism. Loggers reported working mostly (50%) in hilly, but clear terrain, 31% reported working mostly in hilly, unclear terrain, 17% reported working in clear, level ground and the remaining 2% reported working at height.

Hazards and Accidents

When asked to rank the various factors from least aggravating to most aggravating, respondents selected inadequate personal protective equipment as the factor most likely to contribute to an accident (Figure 1).

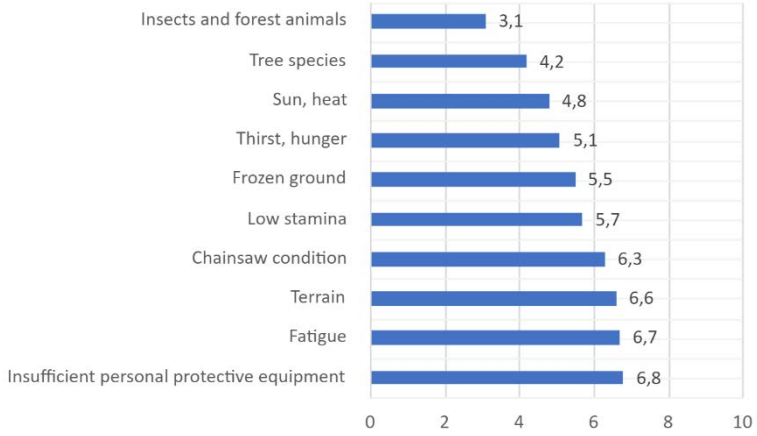

Figure 1: Survey responses to the question: rank the factors from 1 (least influential) to 10 (most influential) in order of their ability to contribute to the accident.

67% of participants reported that they had been slightly injured several times while logging, and 18% reported that they had been slightly injured once. Respondents mostly described their injuries as bruises, abrasions, small cuts with a chainsaw, sprains, and muscle strains. 5% of respondents reported having suffered a serious injury once, and 2% reported having suffered a serious injury more than once. Serious injuries described were head contusions, bruises from a fallen tree limbs, leg bruises, crush injuries, and cuts to the leg or knee from a chainsaw. They also described the most dangerous accidents they observed. They reported pressure injuries, bruises (especially from fallen tree limbs and branches), and cuts. Some even reported fatal accidents that occurred in two different scenarios. Because a tree part fell on a logger or because a chainsaw entered the neck area. 32% of respondents believe that the accident they described as the most dangerous they have ever experienced could be prevented with the right personal protective equipment.

Personal Protective Equipment

Respondents were asked how important they thought personal protective equipment was in forestry. On a scale of 1 (not at all important) to 7 (very important), the average response was 6.8 with a standard deviation of 1. Respondents were also asked to check off any personal protective clothing they use when working in the forest from the list provided. The responses, shown in Figure 2, indicate that the majority of respondents consistently use chainsaw protective trousers (98%) and standard protective gloves (63%).

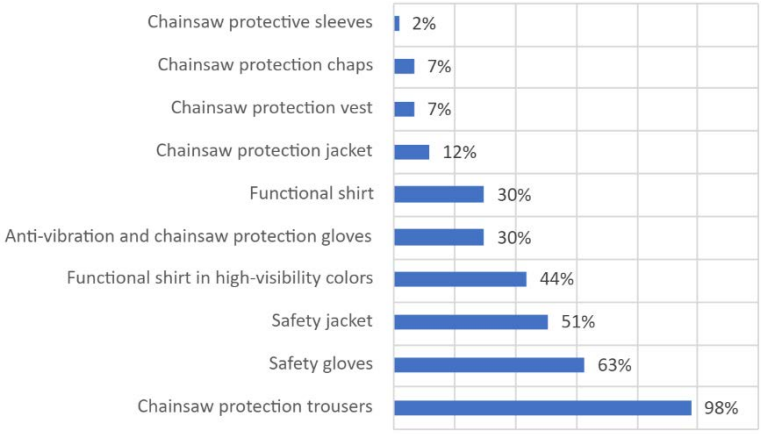

Figure 2: Survey answers to the question: What personal protective clothing do you use when logging?

72% of respondents indicated that they are aware of the markings on chainsaw protective trousers and pay attention to them when purchasing a new pair. 9% of respondents indicated that they were aware of the markings, but pay attention to them when buying new trousers. If the respondents who take the

markings into account had to buy a new pair of trousers, they would buy type A (some would buy type C), class 1 or 2.

Reviewing Chainsaw Protective Trousers

Survey participants rated various functional details of chainsaw protective trousers on a scale of 1 (not at all useful) to 7 (very useful). As shown in Figure 3, respondents rated the pre-shaped knee area, ventilation zippers on the backs of the legs, and highly visible colours as most useful, while the inverted pockets were rated the worst.

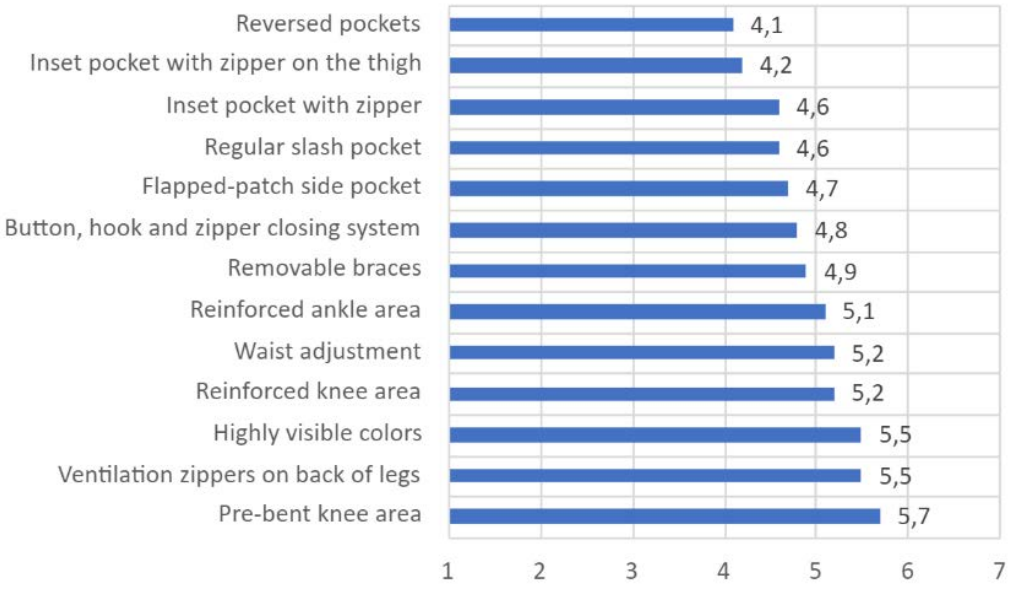

Figure 3: Survey answers to question: Grade the details on chainsaw protective trousers on a scale from 1 (not useful at all) to 7 (very useful).

Respondents also stated that the existing chainsaw protective trousers are not breathable enough, too heavy, too thick, and lack flexibility, which is especially evident when working in hilly terrain. Respondents also pointed out that maintenance and cleaning of such protective trousers is very impractical and difficult. Respondents often miss a suspension system for the logging tape and a waterproof pocket for the cell phone.

Respondents were asked to arrange chainsaw protective trousers according to their aesthetic preferences. First, they arranged the same pant model in different colours (Table 1), and second, they arranged different pant models in the same colour palette (Table 2).

Preferred Labels on the Market

Respondents indicated that they usually buy and/or use chainsaw protective clothing of the following brands. Husquarna and Stihl accounted for the largest percentage of responses, followed by Pfanner and PSS, then Profiforest and Recinko. Other brands mentioned were: Farmer, Arbortec, KWF, Prevent, Strauss and McKinley. Respondents indicated that their preferred brand is trustworthy and that the clothing it produces is durable and comfortable. They also pointed out that they like to stay loyal to a brand and expressed how important appearance and a clear distinction from other trades are to them. Stihl and Husquarna were named the best brands currently available on the market, with Pfanner coming in third.

Table 1: Chainsaw protection trousers graded based on the color.

Number of choices	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Grade	*6,3*	*5,9*	*5,9*	*5,8*	*4,9*	*4,8*	*4,6*	*3,8*	*3,2*
Trousers									

Table 2: Chainsaw protection trousers graded based on the pattern.

Number of choices	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Grade	*6,3*	*6,0*	*6,0*	*5,8*	*5,6*	*4,4*	*4,2*	*4,2*	*2,3*
Trousers									
Color ratio									

DISCUSSION

Since logging is one of the most dangerous occupations, some accidents are inevitable. Loggers reported that they often do rehabilitation work, which is even more dangerous than selective logging, for example. It is much more unpredictable, and the terrain is often uneven, rugged, and difficult. However, there is an upside. When told about the most dangerous accident they witnessed, just over 30% of loggers stated that this accident could have been prevented if proper personal protective equipment had been used. The survey participants' responses regarding their attitudes toward personal protective equipment are reassuring: they ranked inadequate personal protective equipment as the factor most likely to contribute to an accident, which tells us that they are aware of the importance of PPE and the potential hazards of working with a chainsaw. They also expressed their awareness by rating the importance of personal protective equipment in forestry as 6.8 (on a scale of 1 to 7). 98% of all respondents regularly and consistently use chainsaw protective trousers. However, they do not use any other chainsaw protective clothing. Since most (98%) regularly work on the first floor, a chainsaw protective jacket is not necessary, and a regular high-visibility vest is sufficient. There appears to be insufficient awareness of the chronic illnesses caused by chainsaw vibrations. Only 30% of loggers reported using anti-vibration gloves, which is alarming since 99% of all loggers reported working at least five hours continuously, and about 70% of all loggers work several consecutive days, if not every day.

Particular attention was paid to respondents' answers about the preferred details of the available trousers. The highest rated responses (the most important details) all relate to comfort when wearing the trousers. Pre-curved knees, ventilation zippers on the backs of the legs, reinforced knees, waist adjustment, and reinforced ankles were rated highest (all scores were above 5). The lumberjacks gave additional reasons for their decision, saying that the existing trousers were not flexible enough, not breathable enough (especially since they said they worked year-round), too stiff, and that they wore out too quickly in certain areas (especially the knees). This tells us that comfort is probably the most important criterion (besides protective function) for chainsaw protective trousers. The only exception between the scores was "highly visible colours", which ranked third (the score of 5.5), which is easily

explained by the loggers' experience and awareness of potential dangers when team members cannot see each other at all times. It was also pointed out that the existing trousers cannot be easily repaired and maintained, so many loggers use trousers that are somehow damaged or no longer have all the protective functions. When evaluating chainsaw protective trousers based on their aesthetic appearance, loggers clearly indicated that they want to differentiate themselves from other occupational groups that use high-visibility protective trousers. Therefore, their first choice was the colour red, followed by black, and the third choice was a combination of black and orange. The urge to differentiate became even more apparent when all the trousers they selected had the same colours. The preferred colour ratios were those where the majority of the colours were black or grey, with orange being the additional colour. All orange trousers were rated the worst.

CONCLUSIONS AND IMPLICATIONS

Logging is one of the most dangerous professions, mainly because loggers must operate a chainsaw. Although more and more loggers are professionally trained, some accidents are inevitable. Therefore, personal protective equipment is crucial. The results show that personal protective equipment can save lives in cases where loggers are unfocused. The survey was conducted in a group of trained and professional loggers. It included job characterization, loggers' attitudes toward personal protective equipment, and their risk of accidents. They were asked to rate the usefulness of some details on existing chainsaw protective trousers and to provide a list of trousers that are most or least aesthetically pleasing. The responses helped us understand and define potential improvements that can guide the design and development of new chainsaw protective trousers. Key potential improvements include: Comfort, care, aesthetics and functional materials

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E+ DIGITALFASHION PROJECT

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ABSTRACT

The paper presents the structure and content of the project E+ DigitalFashion - Collaborative online international learning in digital fashion (KA220 – HED – Cooperation partnerships in higher education; Grant Agreement: 2021-1-RO01-KA220-HED-000031150). The project emerged from the fact that in five partner institutions from four countries: Romania, Portugal, Belgium and Slovenia, there are no universities offering training in digital fashion co-design online. Therefore, the need for a new course in digital fashion was imperative to achieve some competitive advantages of digitalization. The project will enable education providers to offer new digital training methods that will allow students and professionals to quickly master key technologies for the design and production of customized products in a virtual environment and to fully exploit the knowledge. The project partners started planned activities in February 2022 and the project will end in January 2025. The project has the following four outputs: (a) New methodology on a common ground on Collaborative Online International Learning in the field on Digital Fashion, (b) Library of knowledge for virtual fashion design and technology, (c) Training platform for fashion design by personalized 3D virtual garment fitting and (d) Curricula for Collaborative Online International Learning in the field on Digital Fashion. As part of the first output activities, we found that most of the European companies surveyed intend to introduce virtual fashion technology and that they need to acquire digital skills for virtual garment prototyping.

Key words: DigitalFashion Project, e-Learning, virtual prototyping, digital skills

INTRODUCTION

Education and culture are essential for the development of a more inclusive, cohesive and competitive Europe. Higher education plays a unique role in this. The demand for highly skilled, socially engaged people is increasing and changing. In the period up to 2025, half of all jobs are expected to require high skills. Already there are gaps in the highly skilled workforce. Driven by digital technology, jobs are becoming more flexible and complex. Over the last decade, it has been noted that the fashion industry has changed from a resource-based industry to a knowledge-based industry. Consumer preference for fashion products has shifted from mass-produced items to customised products (DigitalFashion project Application, 2021).

The challenge of education in a digital world forces us to open up education as much as possible through flexible ways and innovative thinking so that everyone can adapt and be prepared for the unknown developments of the future. A suitable digital fashion design platform based on information technology can provide the necessary support to achieve this goal.

The Erasmus+ programme was created to help European citizens gain additional educational and skills experience and to foster their creativity in a modern knowledge society. Therefore, the principles of education and training need to be constantly adapted to new realities and provide youth with the knowledge they need to improve the EU's competitiveness. With a budget of around €26 billion, Erasmus+ 2021-2027 offers more opportunities for mobility and cooperation than ever before (Erasmus+, 2022).

E+ DIGITALFASHION PROJECT

This paper presents the Erasmus+ project DigitalFashion - Collaborative Online International Learning in Digital Fashion (February 2022 - January 2025), which focuses on the new digital training methods that enable students and professionals to quickly master the key technologies for

designing and manufacturing personalised products in a virtual environment, and to fully exploit the knowledge throughout the supply chain. The project is co-funded by the European Commission's ERASMUS + programme under the Strategic Partnerships for Higher Education. The DigitalFashion project is coordinated by the National Research and Development Institute for Textiles and Leather, INCDTP - Romania. The partners of the project include the Higher School of Arts and Textile Industries - France, Hogeschool Gent - Belgium, University of Maribor - Slovenia, Technological Centre of Textile and Clothing Industries of Portugal (CITEVE) - Portugal and Gheorghe Asachi Technical University in Iasi - Romania.

The main outcomes of the project are shown in Figure 1. The partnership will develop the following activities within three years:

- PR1_Methodology: new methodology for a common framework for collaborative international online learning in digital fashion;
- PR2_Knowledge library: three databases on textile materials, colours and clothing styles to be built and integrated into the platform;
- PR3_Platform: a supporting platform that allows fashion students and professionals to collaboratively design a garment for a specific client in an interactive way;
- PR4_Online module: new collaborative online module for digital fashion with new training and evaluation methods for fashion co-design based on a 3D garment visualisation platform;
- Training: training of the target group through the implementation of the new collaborative online module for digital fashion;
- Testing: testing and implementing the technology-based platform for fashion design;
- Dissemination: dissemination of the project results and project coordination and management.

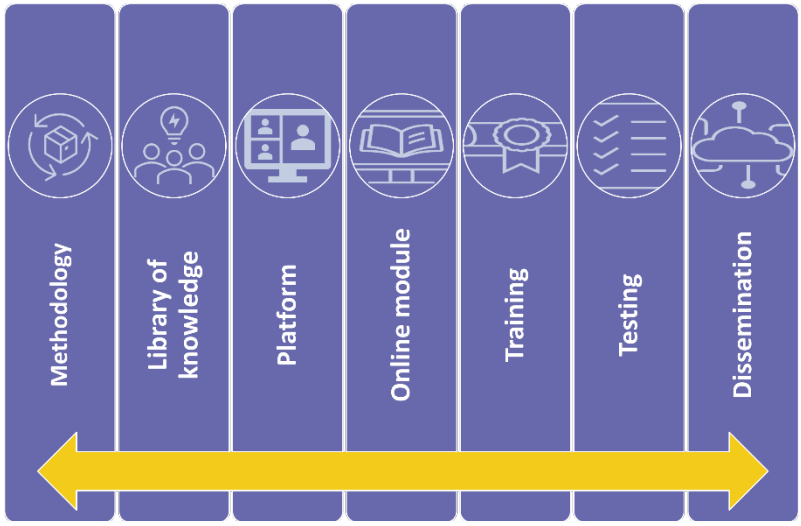


Figure 1: Main activities of the DigitalFashion project

Two project activities, PR1_Methodology and PR2_Library of knowledge, are currently being carried out in parallel. The first project deliverable, a new methodology for a common framework for collaborative international online learning in digital fashion, will be completed before the end of 2022. Work on the second project deliverable, three databases on textile materials, colours and clothing styles that will be integrated into the learning platform, has also already started.

Currently, the project partners are working hard to finalise all reports for PR1 on the following researched contents:

a) a survey on digital skills and virtual fashion technologies of fashion and clothing companies,
b) interviews on digital skills and virtual fashion technologies with representatives of fashion and clothing companies, and
c) an analysis of the learning needs of disadvantaged groups

in order to identify guidelines for the necessary teaching methods in the field of digital fashion so that learning is accessible to all groups of people.

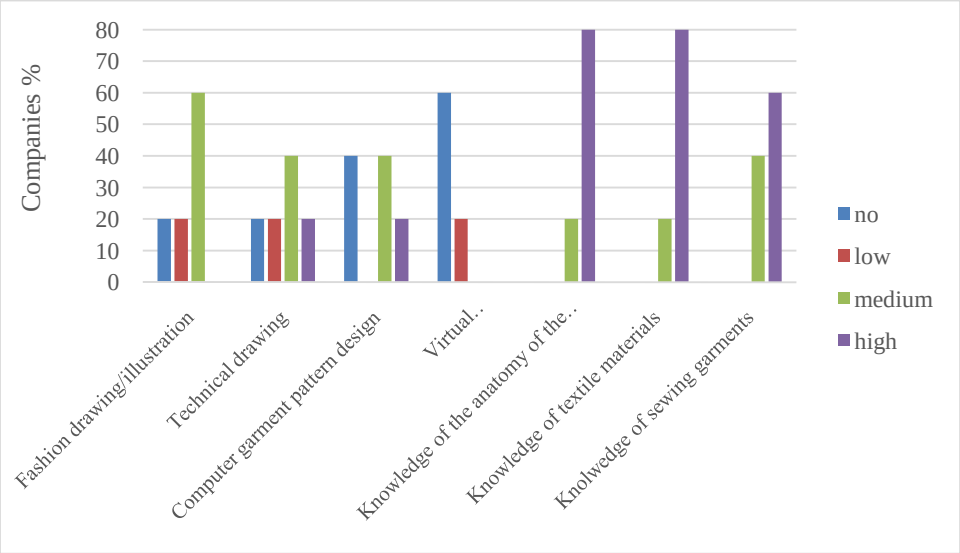
Comparison of the digital skills for the fashion and clothing companies between European level and on the Slovenian national level

A survey on the digital skills needed by fashion and clothing companies in European countries was part of the first project deliverable (Rudolf et al. (a), 2022). The aim was to assess the level of key digital skills in the fashion industry and the industrial application of virtual fashion technologies in five partner countries: Belgium, France, Portugal, Romania and Slovenia. Each partner conducted the survey in at least five companies.

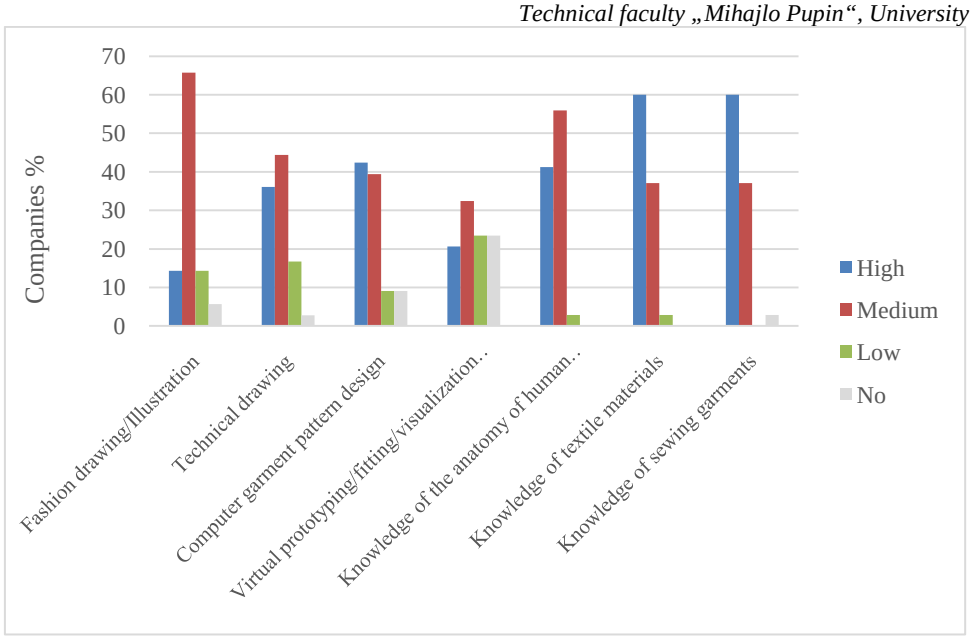
The survey on the digital skills for the fashion and clothing companies was completed by five Slovenian apparel companies; three companies mainly produce fashion garments, one produces work wear and one produces underwear (Penko, T. et al., 2022), and a total of 35 European fashion or clothing companies (43% fashion clothing, 17% work wear, 11% women's wear, 11% underwear, 6% men's wear, 6% sportswear, 3% children's wear, 3% knitwear).

The main findings of this survey show that the Slovenian companies surveyed have no experience with virtual fashion technology, while three companies intend to introduce virtual fashion technology, one company has no intention to introduce it, and one company does not yet know whether it will introduce virtual prototyping technology. On the other hand, the survey found that 71% of European companies have no experience with virtual fashion technologies. 65% of companies intend to introduce virtual fashion technologies, 13% of companies have no intention to introduce them and 22% of companies do not yet know if they will introduce virtual prototyping technology.

The level of digital and other skills of the companies' employees varies depending on the purpose, Figure 2. Both Slovenian companies and all companies at the European level mostly report the level of digital skills in fashion drawing and illustration, technical drawing and computer garment pattern design as medium, while knowledge in other areas such as anatomy of the human body/body measurements, textile materials and garment sewing are rated as high and medium. The results show that knowledge of virtual garment prototyping varies across the European companies surveyed.



(a)



(b)

Figure 2: Level of digital skills for virtual fashion technologies of (a) Slovenian and (b)European companies surveyed

The survey results show that a job profile of 3D designer is needed both in Slovenia and at European level, Figure 3. The expectations of Slovenian and all European companies regarding the age of the job profiles needed are also similar, i.e. between 25 and 30 years.

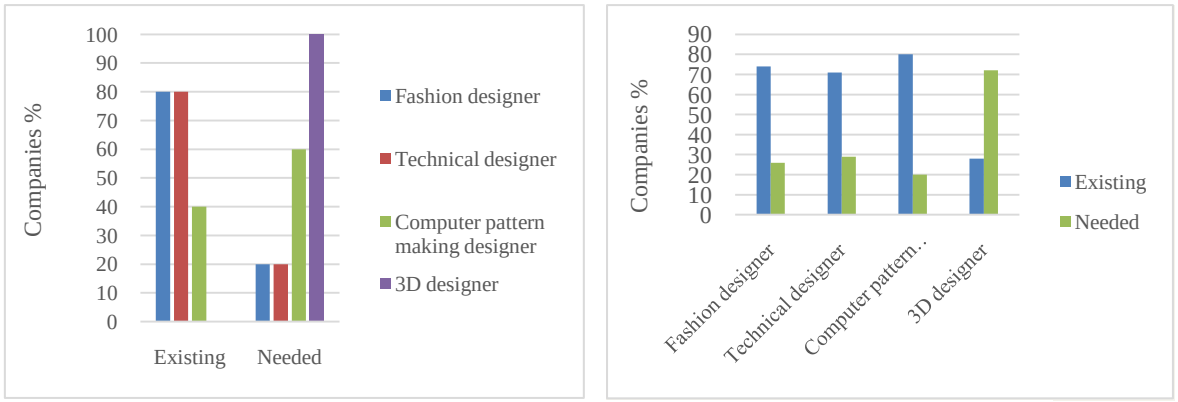


Figure 3: Existing and required occupational profiles in the field of garment design of the (a) Slovenian and (b)European companies surveyed

Analysis of interviews on digital skills and virtual fashion technologies with representatives of Slovenian fashion and clothing companies

The interview with a focus group of fashion and clothing companies aims to identify orientations and needed digital skills for the fashion industry for each partner country, as well as the state of industrial application of virtual fashion technology for each partner country. The interview is based on the identified starting points of the survey analysis for each partner country and provides an in-depth exploration of the required digital capabilities and integration of virtual technology for prototyping personalised clothing in the fashion industry. Interviews were conducted with three fashion or clothing companies per partner.

All the companies interviewed are smaller fashion companies in Slovenia that produce personalised fashion for the adult population, and two of them also have their own clothing collections for women or children (Rudolf et al. (b), 2022). All of the companies use social networks to promote their

activities and clothing, and two of them also offer online sales of clothing. To develop clothes, they use fashion and technical sketches that they draw by hand or with the help of software. Construction of garments is done by hand in all companies, as is the fitting of tailor-made clothes. As far as virtual fashion technologies are concerned, the companies are generally familiar with them, but have no intention of switching to 3D CAD PDS 3D software in the near future. Two companies are familiar with the 2D CAD PDS software for designing garment patterns and only one company has basic knowledge of 3D virtual garment prototyping. However, they use the software to draw patterns for digital printing. One of the companies intends to use 2D CAD software for designing garment patterns in the future, while the other company is on its way to develop garments with personalised embroidery patterns that it wants to offer to the market using virtual fitting technology.

From the interviews with the fashion companies, we can conclude that the companies need new digital skills and knowledge of virtual garment prototyping technologies to develop new products.

Analysis of learning needs of disadvantaged groups at national level in Slovenia

One of the main goals of the DigitalFashion project is to develop new training methods and materials in the digital field that will enable students and professionals to quickly master the key technologies for designing and producing customised products in a virtual environment.

A responsible society must give all groups of the population the opportunity to further their education in a specific field. The goal of the DigitalFashion project is online learning that is accessible to all population groups who can further their education in the field of digital fashion. Therefore, project partners carried out an analysis of learning needs of disadvantaged groups at national levels (Rudolf et al. (c), 2022).

According to the European Institute for Gender Equality (EIGE), disadvantaged groups (EIGE, 2022) are groups of people who:

- Are at higher risk of poverty, social exclusion,
- discrimination and violence,
- the general population, including but not limited to ethnic minorities, migrants,
- people with disabilities,
- isolated older people and children.

These groups have learning difficulties and with online learning in digital fashion, most people in the listed groups who are willing and able to learn in digital fashion can be made accessible. In this way we can include more people in digital fashion education by removing the barrier of language, distance, social exclusion, discrimination and gender.

The COVID -19 pandemic disrupted the education of millions of students around the world. As a result, educational institutions were forced to switch overnight to online teaching software such as Zoom, Google Classroom, Microsoft Teams, Blackboard, Slack, Floop, etc., and online learning became the primary method of teaching during the pandemic. The DigitalFashion project supports the teaching and learning process for fashion design with online teaching methods also for such possible future situations.
It can be shown that the new online fashion design teaching method based on virtual 3D prototyping and training materials can meet different types of students:

- regular students,
- Erasmus students, Ceepus students,
- top athletes,
- recognized artists,
- long-term sick (injured) students.

In addition, online learning of digital fashion can also be addressed to other students, such as:

- pregnant women with problems and
- mothers/fathers who can only learn at home.

Disadvantaged groups include people with disabilities, such as the visually impaired, hearing impaired, mobility impaired, etc., who require special requirements and assistive technologies for online learning and were the focus of analysis at the national levels of the project partners.

Based on the analysis of students with special status at university and faculty level, focusing on visually, hearing and mobility impaired students, as well as students of top athletes, recognised artists, students with long-term injuries or illnesses, mothers/fathers, we can conclude that their number at the University of Maribor and its member, the Faculty of Mechanical Engineering, is not negligible.

Students with special status face special circumstances or challenges that prevent or impede their full and effective inclusion and participation in the academic process. In order for them to acquire the required knowledge and skills and successfully complete their studies, special status students are entitled to certain provisions. This gap can also be closed in the teaching of fashion design through online learning in digital fashion. This is the goal of the DigitalFashion project and enables all regular and special status students considered in this analysis to study digital fashion. Therefore, the teaching methods and preparation of teaching materials need to be considered in the future project outcomes according to the recommendations for online learning for visually, hearing and mobility impaired students.

CONCLUSIONS

This paper presents, on the one hand, research on the required digital skills in the fashion industry and the industrial application of virtual fashion technologies through a survey and an interview with a focus group in companies. On the other hand, it focuses on the analysis of the learning needs of disadvantaged groups with the aim of providing digital fashion education to more people by removing the barrier of language, distance, social exclusion, discrimination and gender. The results of the survey show at Slovenian and European level that there is a need for training in digital fashion and a need for the 3D designer occupational profile. From the interviews with fashion companies it appeared that companies need new digital skills and knowledge of virtual garment prototyping technologies in order to develop new products. At the same time, when offering the new online digital fashion education, we also need to consider the guidelines for educating visually, hearing and mobility impaired students in order to take a step towards a knowledge-based, open and progressive society.

FUNDING

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PRODUCTION CONSUMPTION COMPARISON OF ALKALI-TREATED COTTON FABRIC AND DYED COTTON FABRIC

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ABSTRACT

The concept of sustainability is gaining more and more importance every day. In today's world, where wastes are increasing and the damage to the environment is increasing, every step taken in terms of protecting the world and the environment is very important for the sustainability of our planet. In this study, the alkaline treatment process and the dyeing process which are two of the important processes of cotton finishing were compared under industrial commercial production conditions. This study is important in terms of showing how cotton fabric can be used without coloration processing will offer advantages in terms of production consumption. In here, the production consumption of alkali-treated cotton and dyed cotton fabrics were compared in detail. In conclusion, 92% less chemical, 65% less water, 57% less time and electricity and ultimately 69% less electricity utilizations were required to produce alkali-treated cotton fabric in comparison with the production consumption required to produce dyed cotton fabric.

Key words: Cotton, Cotton finishing, Scouring, Alkali treatment, Hydrophilization, Dyeing, Production consumption, Energy usage, process time

INTRODUCTION

As it is known, sustainability is gaining more importance day by day. In today's world, where wastes are increasing and the damage to the environment is increasing, every step taken in terms of protecting the world and the environment is very important for the sustainability of our planet [1-9]. As known, obtaining successfully dyed cotton fabric requires many pre-treatments such as alkali treatment, bleaching, and many post-washing processes after dyeing [10-13]. In addition to the efforts to increase sustainability, recently using natural fiber fabrics in their natural state or dyeing them with natural dyes has come to the fore. Considering in this context, in this study, it was aimed to compare the production consumption of the hydrophilic cotton, which was obtained only by alkaline treatment without dyeing, with the production consumption of dyed cotton fabric. Here, the hydrophilic structure of the cotton is revealed by alkaline treatment. And this alkali-treated cotton fabric in its natural whitish ecru color can be used in the final textile products such as t-shirts, singlets, etc. So, this kind of cotton fiber in its natural color can be used in many different clothing products. In fact, this study is important in terms of showing how cotton fabric is used without coloration will offer advantages in terms of production consumption and therefore costs. In this study, the alkaline treatment process and the dyeing process which are two of the important processes of cotton finishing were compared under industrial commercial production conditions. Here, the production consumption of alkali-treated cotton and dyed cotton fabrics were compared in detail.

Materials and Methods

100% 30/1 Ne cotton fiber knitted greige fabric is utilized in this study. In this study, the production consumption of alkali-treated cotton fabric and dyed cotton fabric were compared.

Alkali-Treated Cotton Fabric Production Process Steps

To obtain alkaline-treated cotton fabric, greige cotton fabric is first subjected to alkali treatment and then neutralized with acid (Figure 1). Alkali treatment is performed using alkaline and surfactant. Then, alkali-treated cotton fabric is neutralized using acid (Figure 1). Alkali-treatment processes is carried out in Canlar HT dyeing machine. The alkali-treatment process includes 3 baths in total.

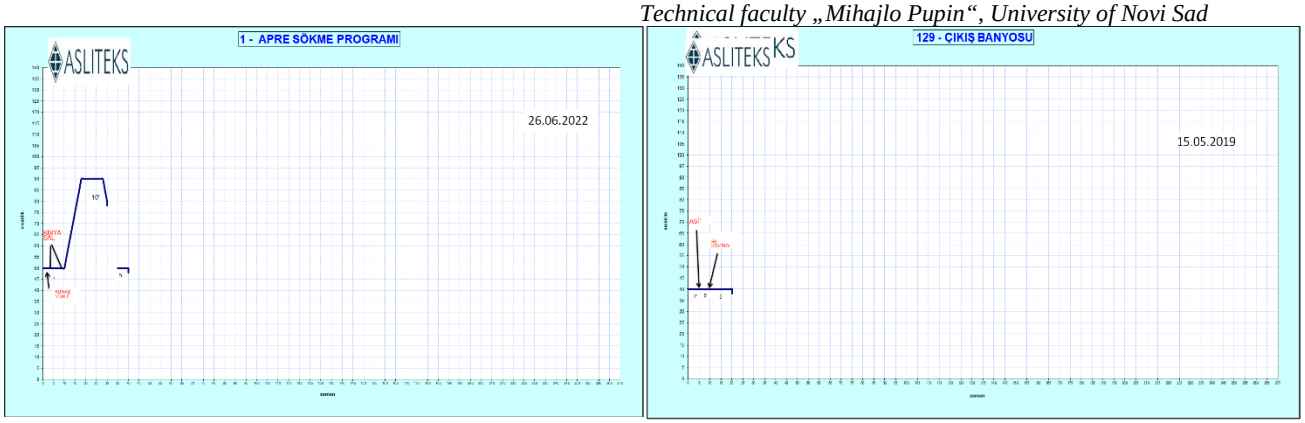

Figure 1. *Alkali-treated cotton fabric production process steps*

Dyed Cotton Fabric Production Process Steps

To obtain dyed cotton fabric, greige cotton fabric is first subjected to bleaching pre-treatment, then reactive dyeing using Levafix reactive dyes and then washing operations (Figure 1). Dyeing process is carried out in Canlar HT dyeing machine. The dyeing process includes 7 baths in total.

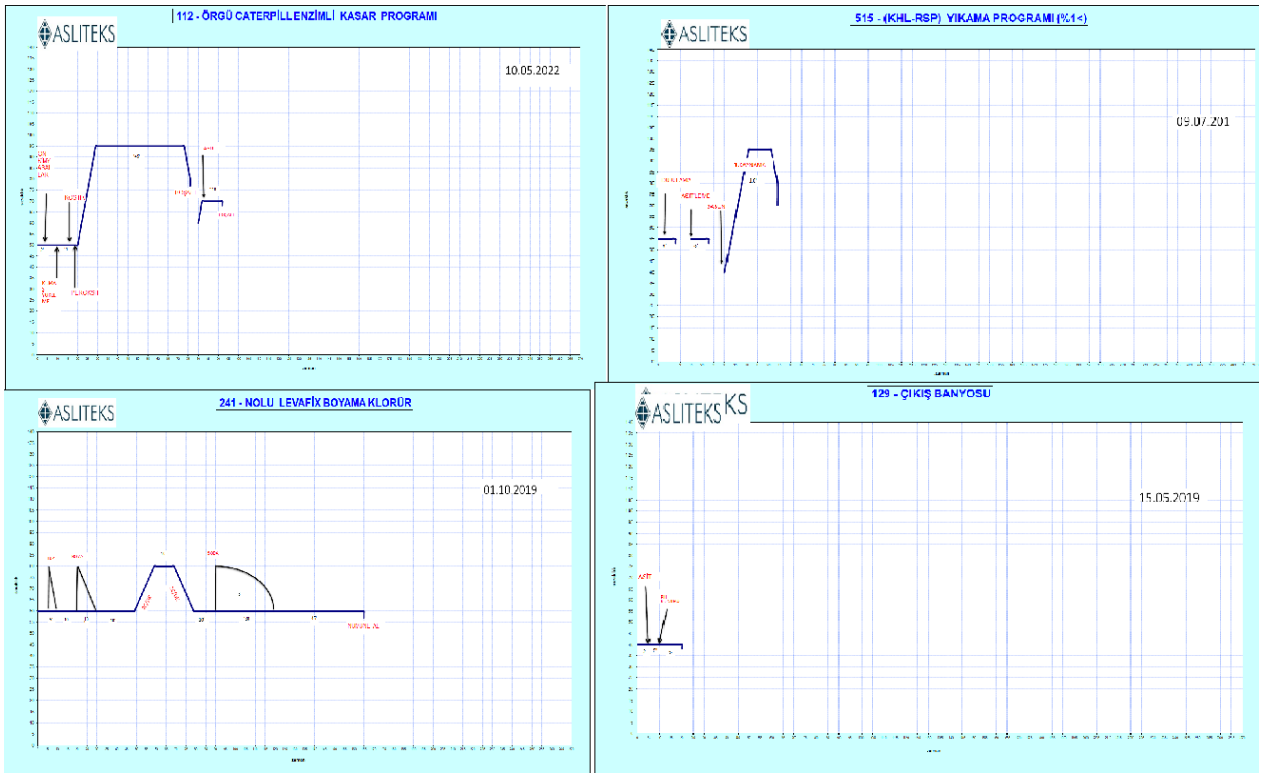

Figure 2. *Dyed cotton fabric production process steps*

Results and Discussions

Production consumption expenditures realized for the dyeing process and for the alkaline process can be seen in Table 1. The chemical usage, water usage, time and electricity usage and energy usage advantages of alkaline treatment over dyeing process for cotton fabrics production consumption of alkali-treated cotton fabric and dyed cotton fabric are exhibited in Table 2.

Table 1. *The production consumption of alkali-treated cotton fabric and dyed cotton fabric*

PROCESSING TYPE	NUMBER OF BATH	WATER RATIO PER FABRIC WEIGHT (KG/LT)	TOTAL CHEMICALS USED (KG)	TOTAL WATER USED (LT)	TIME OF PROCESS	ENERGY SPENT ON HEATING (KJ)
ALKALINE TREATMENT	2	9.5	1.1	1140	02:44:00	165528
DYEING	7	27	13.72	3240	06:24:00	526680

Table 2. *The chemical usage, water usage, time and electricity usage and energy usage advantage of alkaline treatment over dyeing process for cotton fabrics production consumption of alkali-treated cotton fabric and dyed cotton fabric*

CHEMICAL USAGE	WATER USAGE	TIME AND ELECTRICITY USAGE	ENERGY USAGE
92% less	65% less	57% less	69% less

As can be clearly seen from Table 2, 92% less chemical usage, 65% less water usage, 57% less time and electricity usage and finally 69% less electricity usage are required to produce alkali-treated cotton fabric in comparison with the production consumption required to produce dyed cotton fabric. Today, when the trend is towards naturalness, renewability and sustainability, it is very important to reveal the hydrophilic nature of cotton fiber and use it with its natural color, both in terms of cost reduction and in terms of providing great reductions in production consumption.

CONCLUSIONS

In this study, the alkaline treatment process and the dyeing process which are two of the important processes of cotton finishing were compared under industrial commercial production conditions. Here, the production consumption of alkali-treated cotton and dyed cotton fabrics were compared in detail. Overall, 92% less chemical, 65% less water, 57% less time and electricity and ultimately 69% less electricity utilizations were required to produce alkali-treated cotton fabric in comparison with the production consumption required to produce dyed cotton fabric. In here, we have clearly demonstrated the contribution of using cotton in its natural state by hydrophilizing it to sustainability. So, this study is important in terms of showing how cotton fabric can be used without coloration processing will offer advantages in terms of production consumption. Today, when the trend is towards naturalness, renewability, and sustainability, it is very important to reveal the hydrophilic nature of cotton fiber and use it with its natural color, both in terms of cost reduction and in terms of providing great reductions in production consumption.

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MARKETING COMMUNICATION OF SUSTAINABLE TEXTILE CLOTHING FOR ACHIEVING COMPETITIVENESS

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ABSTRACT

The globalization of markets have significantly affected how small and medium-sized enterprises as well as large enterprises conduct their business activities. Challenges in the domain of business are present across all industries. The textile and clothing industry faced challenges even before the current global economic crisis. These previous challenges were in the domain of sustainability and brand image as a large percentage of the textile and clothing industry relied on the exploitation of men, women and children in third world countries. In this paper, marketing communication of sustainable textile and clothing with the goal to achieve competitiveness is analyzed. The paper presents theoretical models regarding marketing communication in the textile and clothing industry. In addition, suggestions and guidelines for improving the domestic textile industry are noted. The study provides a solid basis for future research.

Key words: marketing communication, sustainability, sustainable textile industry, brand loyalty.

INTRODUCTION

The globalization of markets, the aftermath of the COVID-19 pandemic, and the war in Ukraine have significantly affected how enterprises conducted their business. Achieving and maintaining competitiveness presents a big challenges for the majority of enterprises (Bakator et al., 2020b; Tokic, 2020). In such conditions, it is necessary to apply new business methods and approaches. Innovation and sustainability are emerging as crucial aspects of modern business planning (Boar, Bastida, and Marimon, 2020). Innovative actions within enterprises can provide an adequate support for growth in the current economic climate (Brancati et al., 2020). Taking into consideration the challenges of the global economic recession, competitiveness as construct can be affected by various factors and concepts. In the textile industry, which is one of the most versatile and fast growing industry (Bakator et al., 2019a), brand value and brand loyalty are key components of gaining competitiveness (Bakator et al., 2020a). Given that the importance of sustainability is rising, and the awareness of the public regarding sustainable clothing is increasing, it can be argued that communicating sustainable textile clothing could be an adequate approach for increasing market share. Developing brand loyalty basically indicates the development of competitiveness and the textile industry is in a constant race for brand image and brand recognition (Bakator et al., 2019b; Febriyantoro, 2020). The post-COVID-19 period brought tremendous challenges to the domestic market, this includes the domestic textile and clothing industry as well (Álvarez Jaramillo et al., 2019; Bakator et al., 2021).

In this paper marketing communication of sustainability and sustainable textile clothing for obtaining competitiveness is analyzed. The main goal is to provide a concise overview on this subject, to present several theoretical models, and to suggest guidelines regarding the domestic textile and clothing industry. The paper consists of three main sections (excluding the Introduction and Conclusion sections). The first section addresses sustainability and sustainable textile clothing. A theoretical model of the sustainable textile clothing approach and concept is also presented. Next, the importance and role of marketing communication and competitiveness is noted. In addition, a model of marketing communication of sustainable textile clothing is presented. Finally, suggestions and guidelines for improving the domestic textile and clothing industry are discussed.

SUSTAINABILITY AND SUSTAINABLE TEXTILE AND CLOTHING

Sustainability in the context of textile and clothing refers to the social, economic, and environmental impact of enterprises that conduct business in these industries. ICT technologies, as the drivers of globalization, have the potential to increase sustainability in the textile and clothing industry. Implementing and applying new advanced technologies can support transition phases from traditional business strategies to sustainable ones (Avadanei et al., 2020). The challenges of sustainability in the textile and clothing industry are best noted within the concept of circular economy. Namely, a large percentage of used clothing and textile are not recycled nor reused. Therefore, a circular economy model is indeed suitable for the textile and clothing (Koszewska, 2018). Lean production models can also bring effective solutions (Maia, Alves, & Leao, 2019; Majumdar, Garg, and Jain, 2021). However, after the COVID-19 pandemic, it is necessary to address potential weak spots of supply chains that are not resilient. Further, a theoretical model that depicts a sustainable approach to production in the textile and clothing industry is presented on Figure 1.

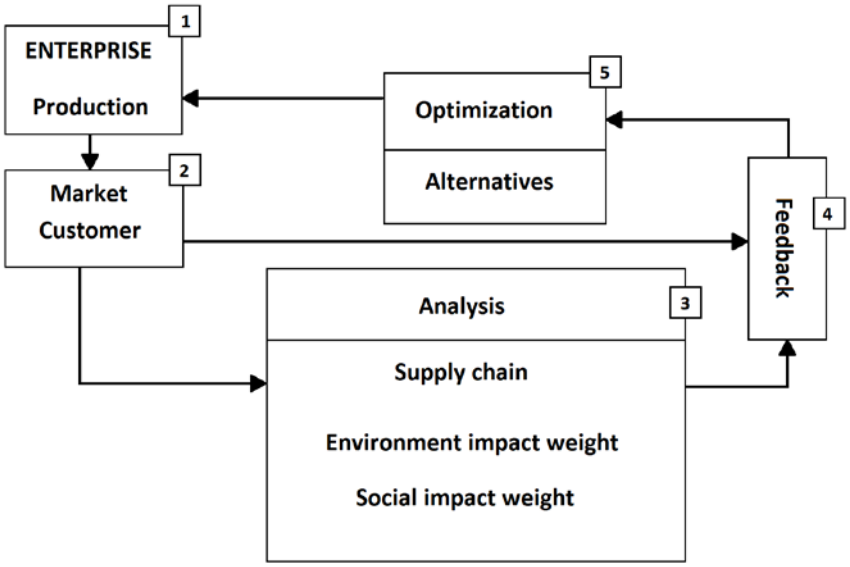

Figure 1: Sustainable approach to production in the textile and clothing industry

Based on Figure 1. it can be seen that production or manufacturing within an enterprise (1) caters to the market/customer (2). The goal of the enterprise is to gain profit. However, sustainability is increasingly gaining on importance when it comes to conducting business in the business paradigm. The enterprise has to analyze (3) its supply chains, its environment impact weight and social impact weight. These factors refer to the sustainability of the business model. Information is collected and through the feedback loop (4) and sent back to the enterprise where optimization occurs and alternative actions (5) are considered (5). This way, the enterprise can control its impact on the environment and on people's lives (social impact). Enterprises in the textile and clothing industry can apply this model for continuous improving and adjusting.

MARKETING COMMUNICATION AND COMPETITIVENESS

Marketing communication presents a powerful tool that every enterprise uses in one form or another. By creating a powerful message, an enterprise can build a strong brand and reflect social responsibility (Alakkas et al., 2022; Czeremski, 2020). Enterprises have to consider modern marketing communication channels and focus on social media and marketing communication as an effective medium of communication (Mohammad Shafiee, Rahmatabadi, and Soleymanzadeh, 2019). On Figure 2., a marketing communication model for competitiveness in the textile and clothing industry, is presented.

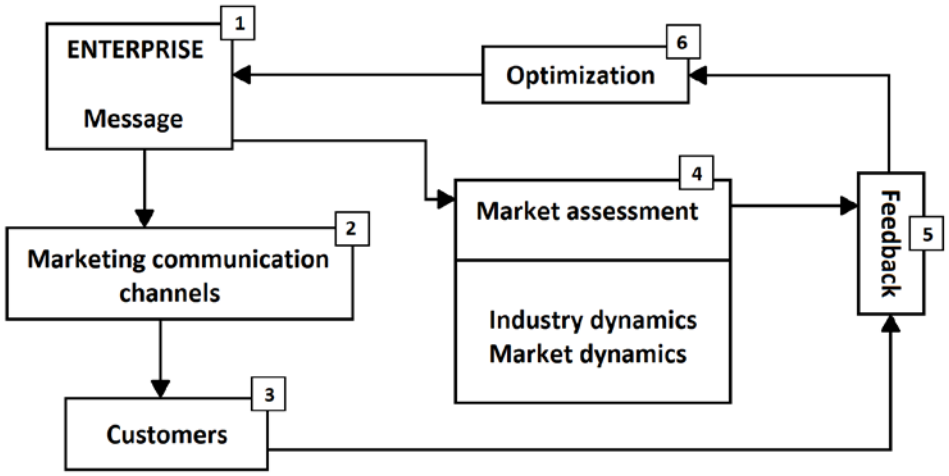

Figure 2: Marketing communication model for competitiveness in the textile and clothing industry

Based on Figure 2., the enterprise (1) develops a message that is sent via marketing communication channels (2). These channels can be in the form of traditional media (TV and radio), or new age digital media outlets (social media networks, forums, web applications). Customers (3) receive the message and based on it a reaction occurs (purchasing, liking, disliking, support, hate, love etc.). The information about the reaction is collected and sent back to the enterprise. Based in the feedback (5), the enterprise can optimize its message. In addition, besides the reaction of the customer, the enterprise has to collect information regarding the market. Hence, market assessment (4) occurs that involves industry and market dynamics in the textile and clothing industry. This approach provides a two-way insight (customers and trends on the market and industry).

SUGGESTIONS AND GUIDELINES

Based on the analyzed literature and the developed theoretical models, the following guidelines for improving the competitiveness of domestic enterprises in the textile and clothing industry are proposed:

- Enterprises should evaluate market dynamics and plan their marketing message accordingly.
- Marketing communication channels should be effective and efficient. For example, advertising on TV is often not suitable for the majority of enterprises. Communication channels should focus on cost-effective solutions such as social media networks (Instagram, Tik-Tok, Youtube etc.)
- The marketing communication message should be clear and it should invite for action from the customer and consumer.
- Marketing communication has to address the current trends on the market and construct messages in accordance with the changes on the market.
- Feedback from customers is an imperative for effective marketing campaigns. Enterprises should take into consideration what customers want, need, and prefer.
- Sustainability and sustainable textile and clothing should be key parts of marketing communication messages.
- Sustainable clothing should be a long-term solution, rather than just a “marketing mirage”.
- Messages of sustainability will positively affect the development of long-term sustainable brand loyalty.
- Brand image and brand loyalty are significant in times of economic distress on the market.
- Cost-to-quality ratios should be rationalized. Sustainability should be the core of how business is conducted, and this has to be promoted to the customer.

In sum, marketing communication is a powerful and necessary tool for developing brand loyalty. In the modern business environment, where the awareness of the public regarding the preservation of the

natural environment is high, communication sustainable textile and clothing can significantly affect competitiveness.

CONCLUSION

Sustainability and sustainable textile and clothing industry practices are going to become the new norm of how business models are developed. The driver of these new approaches is the constantly increasing awareness of public on the impact that unsustainable practices in the textile and clothing industry have. Amidst the dynamic changes on the globalized market and the changes brought by the new business paradigm, enterprises from the textile and clothing industry can significantly improve their brand image and brand loyalty through effective marketing communication of sustainable practices. This can further contribute to the development of brand loyalty. Brand loyalty is one of the final and strongest forms of relationship that can be formed between an enterprise and customer. Developing and nurturing a brand through effective marketing communication is the core of a market share and competitiveness.

The main limitation of this paper is the lack of empirical studies and the lack of studies published in languages other than English and Serbian. However, given the main goal of the paper, these limitations are not severe and can be addressed in the future. Hence, for future studies it is recommended to survey enterprises that conduct business within the textile and clothing industry, and to analyze key parameters that can provide additional insight into this complex matter. Some of these key parameters could be financial performance, marketing strategies, applied technologies, human resource management practices etc.

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ENTREPRENEURIAL BEHAVIOR IN THE TEXTILE INDUSTRY AND ITS IMPORTANCE FOR ECONOMIC GROWTH

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ABSTRACT

The current economic climate brought uncertainty to the globalized market. The dynamics of conducting business changed across industries, bringing economic uncertainty to both small and medium-sized enterprises and large enterprises as well. Entrepreneurship has been shown to positively affect economic growth and it often is characterized with increased standard of living and reduced unemployment rates. Entrepreneurial behavior in the textile industry has the potential to positively affect economic growth. In this paper, entrepreneurship, entrepreneurial activities and behavior in the textile and clothing industry in the context of economic growth, are analyzed. The main goal of the paper is to present how entrepreneurial behavior can translate into competitive advantage in the textile and clothing industry.

Key words: entrepreneurship, entrepreneurial behavior, textile and clothing industry, economic growth.

INTRODUCTION

The development of information communication technologies has increased the rate of globalization. The modern market is globalized and it is affected by global and local factors. Due to the intensification of competitive relations, enterprises face challenges when it comes to achieving a sustainable competitive advantage on the market (Bakator et al., 2019; Grigoryev, and Pavlyushina, 2020). The current war in Ukraine and the aftermath of the COVID-19 pandemic brought a new business paradigm that is characterized by uncertainty and the necessity for resiliency, flexibility, sustainability and value-oriented business models (Bakator et al., 2021; Song & Zhou, 2020). Entrepreneurship has been linked to positively affect economic growth and economic development (Djordjevic et al., 2021a; Djordjevic et al., 2021b; Farinha, Ferreira, and Nunes, 2018). The development of ICTs have opened doors to for enterprises and individuals for entrepreneurial activities. More precisely, technological solutions offer adequate support for value creation and the distribution of products and services (Michelin et al., 2022).
Further, besides the positive effects of entrepreneurship on the economy, it also plays an important role in sustainability on the textile and clothing industry (Su,Wood, & Gargeya, 2022). Therefore, it can be argued that sustainable entrepreneurial behavior in the textile and clothing industry can positively affect economic growth as well as economic development. In this paper, entrepreneurial behavior in the textile and clothing industry for economic growth is analyzed. In addition, theoretical models that provide a graphic and concise overview on the analyzed subject. The paper consists of three main sections (excluding the Introduction and Conclusion sections). The first section analyzes entrepreneurship in the context of economic growth. A theoretical model is presented that encapsulates this relation. Next, entrepreneurial behavior in the textile industry is addressed. In addition, the potential impact of entrepreneurial behavior in the textile industry on economic growth and development is modelled. Finally, suggestions and guidelines for improving the current business models in the textile and clothing industry in the context of entrepreneurship are discussed.

ENTREPRENEURSHIP AND ECONOMIC GROWTH

Entrepreneurship has been noted to positively affect economic growth. Entrepreneurial activities can significantly contribute to reducing unemployment rates, increasing the standard of living, increased innovative actions across industries, and it overall support economic development (Ahlstrom, Chang, and Cheung, 2019; Bosma, Sanders, and Stam, 2018; Sergi et al., 2019). Entrepreneurship as a strong driver of the value economy, and as such it has a pivotal role in creating value. Further, amidst the globalization of markets and the turbulent economic situation, entrepreneurship has to take into consideration the concept of sustainable development and sustainable business. This approach

includes the concept of green entrepreneurship and resilient supply chains (Mangenda et al., 2021). On Figure 1., a theoretical model depicting how entrepreneurship affects economic growth is presented.

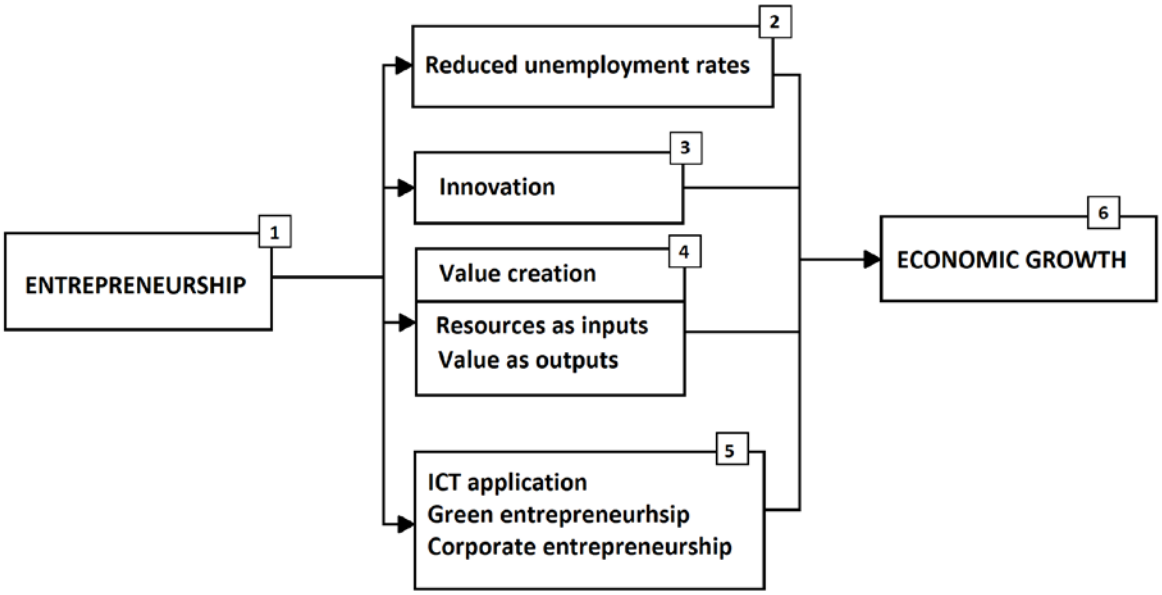

Figure 1: Entrepreneurship affecting economic growth

Based on the model presented on Figure 1., it can be seen that entrepreneurship (1) (including entrepreneurial behavior, entrepreneurial attitudes, intentions and other constructs) affects economic growth (6) through:

- Reduced unemployment rates (2). Entrepreneurship creates new jobs, and self-employment doesn't depend on an employer for job security. Job security is at risk proportionately with market risks.
- Innovation (3) and value creation (4). Innovative actions and new products and services that provide value to the customer can significantly drive economic transactions (production, purchasing, selling etc.). Innovation can create demand at places where there wouldn't be any without innovation and new value.
- ICT application, green entrepreneurship and corporate entrepreneurship (5). The advancement of ICTs can provide the necessary technological support for entrepreneurial activities. Green entrepreneurship refers to the sustainability of conducting business from the aspect of preserving the natural environment. Corporate entrepreneurship refers to entrepreneurship activities in mostly large enterprises.

These noted factors contribute to economic growth by using resources that have little to no value, and create value as outputs.

ENTPREPRENEURIAL BEHAVIOUR IN THE TEXTILE INDUSTRY

Entrepreneurial behavior derives from a complex construct that includes, but is not limited to, entrepreneurial attitudes, entrepreneurial knowledge and skills, and preparedness to take on risks and seize opportunities (Neneh, 2019). Entrepreneurship orientation can be viewed as specific parameters and direction of vectors towards which an entrepreneurial action tends strive (Wahyuni and Sara, 2020). In the textile industry, entrepreneurial behavior is not that different compared to other industries. However, trends in the textile and clothing industry tend to have heavier impact on competitiveness compared to trends present in other industries. The main driver of this impact and change is the fashion industry. Entrepreneurs have to take this factors into consideration when

developing their business model. On Figure 2., a theoretical model depicting entrepreneurship in the textile and clothing industry is presented.

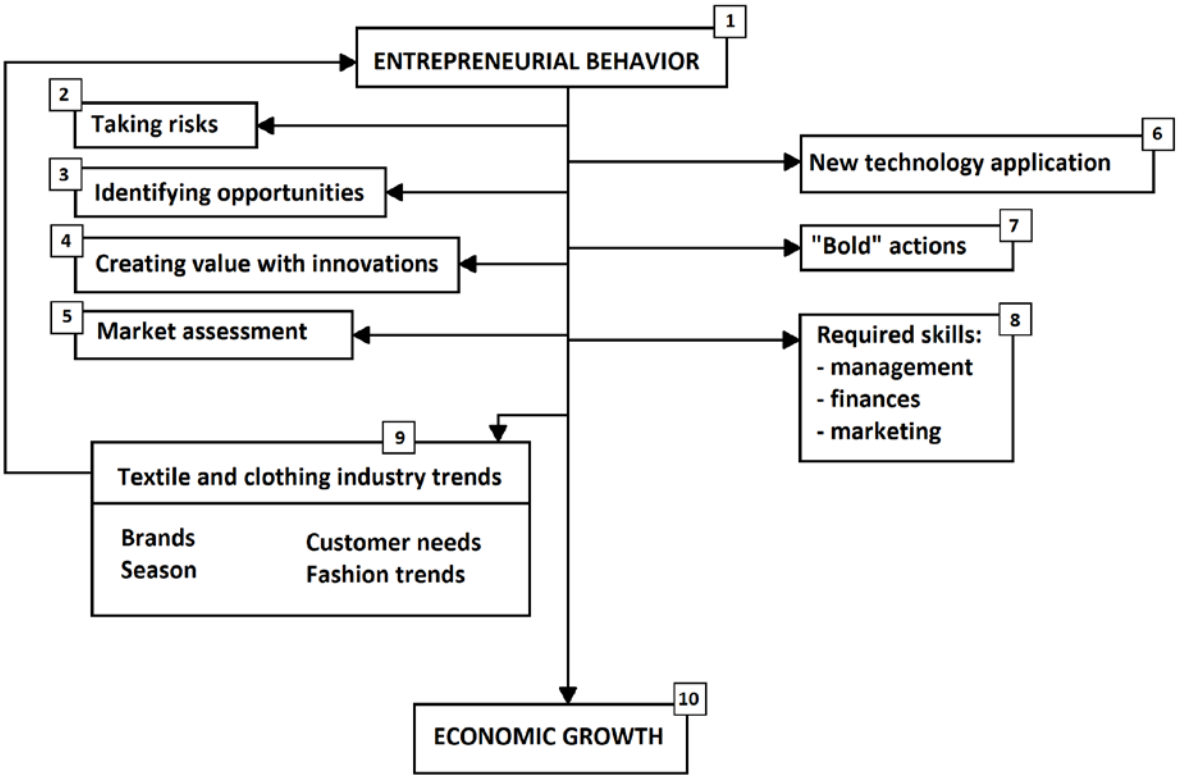

Figure 2: Entrepreneurship in the textile and clothing industry

Entrepreneurial behavior (1) includes a wide array of actions from an individual, group or enterprise. It refers to several key components such as taking risks (2) and identifying opportunities (3). Through the process of seizing opportunities and risk taking, resources are turned into products and services that provide value to the customer. Creating value with innovations (4) has to be in-line with the situation on the market. Therefore, a thorough markets assessment (5) is necessary to accomplish outlined business goals. Entrepreneurial behavior has to take into consideration the current trends in the textile and clothing industry (9). More precisely, brand strength and dominance on the market, time of the year (season), customer needs, trending fashion trends, economic stability and other factors have to be taken into consideration. Information from returns to the entrepreneur who then can apply new technologies (6), take “bold” actions (7) with higher risk-to-return rations, and he can assess which skills (8) are required (management, finances, marketing, logistics etc.). These noted components of the presented model contribute to economic growth (10).

SUGGESTIONS AND GUIDELINES

Based on the literature review and the developed theoretical models, the following suggestions and guidelines for improving economic growth and economic development through entrepreneurship in the textile industry are noted:

- Enterprises should consider entrepreneurship activities based on market dynamics
- Entrepreneurial behavior and activities should be driven by innovation and value creation
- The education systems cater the new business paradigm, and focus on establishing an environment where future entrepreneurs can achieve their potential
- Enterprises should embrace new technologies and implement them in their business processes
- Resources should be effectively used as inputs and the maximization of value as outputs should be prioritized.

- Entrepreneurship should be promoted on a national level across all industries as it can potentially integrate two or more technologies from various industries. For example IT industry and textile and clothing industry can result in smart wear, new materials, smart outfits, etc.
- Entrepreneurial behavior should be rewarded and adequate support should be provided. This support can be in the form of resources (financial, materials, equipment) or intellectual capital (seminars, mentorship, courses etc.).
- Entrepreneurial activities by individuals and also in enterprises should be focused on long-term success and sustainable development. Quick turnaround and short-term activities should be avoided if there is no significant benefit.
- Risk taking should be analyzed and optimized through extensive research and market assessment.

In sum, entrepreneurial behavior and entrepreneurship should be supported on a local and national level. The above noted suggestions and guidelines are in the context of the textile and clothing industry. However, almost every industry can take the positive effects of entrepreneurial endeavors. Individual entrepreneurs can open their business in various sub-fields/occupations of the textile and clothing industry including, but not limited to, tailors, textile manufacturers, atelier owners, fashion designers, textile stores etc. It is evident, that entrepreneurship in this industry can significantly increase economic activity, thus further increasing economic growth.

CONCLUSION

The current economic climate is complex and brings uncertainty across industries and across countries. After analyzing the existing body of literature in the domain of entrepreneurship, economic growth, the textile and clothing industry, it can be concluded, that entrepreneurial behavior and entrepreneurial activities in the textile and clothing industry can positively affect economic growth and the creation of sustainable value. Namely, entrepreneurial activities can create additional value compared to existing business models. This kind of disruption on the market is positive as it can reduce the negative effects of monopolies on the globalized market.

The main limitation of this paper is the lack of survey data obtained from both entrepreneurs and enterprises that conduct their business activities in the textile and clothing industry. These limitations should translate into guidelines for future research. Therefore, it is recommended that future studies address data from multiple entrepreneurs and enterprises. This would allow a systematic comparison and it would provide additional significant insight into the mechanics of entrepreneurial behavior in the textile and clothing industry.

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SLOW FASNION MOVEMENT AS A SIGN OF SUSTAINABLE BUSINESS

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ABSTRACT

With the globalization of the market with rapid changes and demands of the environment for adaptation, the demands of users and consumers of all kinds of products also grow, especially when it comes to the fashion industry. In an effort to meet the needs of the market and consumers and the goals set by the development of marketing, the fashion industry is increasingly turning to the production and sale of clothing that is oriented towards the creation of profit only, which slows down the achievement of sustainability. This paper aims to define the slow fashion movement, its impact on sustainable business and the achievement of corporate social responsibility (CSR).

Key words: slow fashion movement, sustainability, CSR, business.

INTRODUCTION

The mass globalization of the market results in changes at the level of the entire production and service industry. These turbulent changes affect both production and consumer demands, which are becoming increasingly larger and more complex to fulfill. It is important for all companies to achieve a stable market position, competitiveness and profit, and the globalization of the market and the mechanization of production greatly affect the fashion industry. The mentioned changes have become the daily routine of modern society, and a chain has been started that implies greater demand and greater production, while consumption has emerged as a growth trend among consumers. The development of marketing as a whole, digital marketing and marketing strategies focused on target groups of consumers and making money for the company contributed to this chain of modern society. These environmental conditions forced many fashion companies to think „quantity, not quality“ and thus, the so-called fast fashion movement was born, which rules the global market of fashion companies.
Bearing this in mind, companies massively began to see only the profit from this system of rapid industrialization as a factor of faster and more efficient growth, leaving aside the environmental problems that arose with the increase in production and consumption. This has assumed the proportions of global environmetal pollution. For example, the fashion industry represents the industry with the second highest level of participation in global pollution, as well as the consumption of millions of barrels of oil annually to produce polyester, a fiber that takes about 200 years to complete decomposition. In addition to environmental issues, the questions posed by the fast fashion movement concern human and business ethics, such as issues of working conditions where unsafe conditions have been established for the fullfilment of work requirements and mass production with the aim of satisfying the fast-pased market (Silvia Solino L.J. et al., 2020).

The changes that have hit the fashion industry, like all other industries, include mass production, an increase in the number of fashion seasons and modified supply chains. Due to these factors, retailers who cooperate with the fashion industry want flexibility in price and design, quality and speed of delivery to the market. Nowadays, the very concept of fashion is characterized by a large number of marketing factors such as low predictability, high buying impulse, short product life and high marketing demands. In order for the fashion industry to achieve profitability on the market, fashion is capitalized in relation to its competitors. The development of fast fashion is reflected in the transition from a production to a market approach in the clothing industry. This is followed by high demands from consumers, which forces fashion companies to provide the right product at the right moment in

the market. The development of fast fashion represents a dramatic change in the fashion industry and the environment, and what needs to be achieved is consumer awareness of organic clothing, the green market and the development of the slow fashion movement in order to establish sustainability (Bhardwaj, Fairhurst, 2010).

DEFINING SLOW FASNIOH MOVEMENT AND ITS BENEFITS

One of the goals of sustainable development and sustainable business is raising the awareness of companies and consumers, and slow fashion is a concept that deals with these goals in the sphere of the textile and fashion industry. Slow fashion implies high product quality, regional production and proper working conditions for employees. Sustainable business should become a key issue for the clothing industry that will affect their production and marketing strategies, operations and consumer and market research and the slow fashion movement deals with these very issues (Pookulangara, Shephard, 2013). The concept of slow fashion involves the use of green and biodegradable fibers, the development of technologies to minimize waste and pollution, and consideration of the supply chain. Slow fashion movement encourages the development of awareness and education of consumers about their environmental and social impact when shopping fashion industry products.
In order to explain the concept of slow fashion movement in a better way, certain authors have developed a fashion matrix that includes eight key segments that are affected by the development of slow fashion. The aspects highlighted by the matrix are concerned with providing an overview of the areas covered by the development of slow fashion. Sustainability itself is the foundation of the slowfashion movement and this matrix, and that is why it was not mentioned as one of the factors. The elements that the matrix includes are (Štefko, Steffek, 2018):

- Price – consumers of slow fashion guided by ethical principles buy products created in the so-called “production without sweat” and various studies have shown that such consumers are ready to accept a higher price for brands. During the research, it was found that every third consumer is aware of the slow fashion movement and is ready for a 30-40% higher price compared to fast fashion products.
- Quality – a condition for creating a successful slow fashion brand is the implementation of top quality materials and fabrics in production. This encourages consumers to be interested not only in the design, but also in the origin of the fabric they buy.
- Cost of production – slow fashion products are characterized by the long-lasting value, while fast fashion employs cheap labor in a poorly developed economy. Therefore, slow fashion products create more value for the company and reduce resource waste.
- Style – fast fashion products have lost the characteristics of individualized and authentic pieces due to mass commercialization. Slow fashion movement encourages individuality and creativity.
- Service – the lack of local suppliers to produce small quantities of products at a reasonable price needs to be addressed. The difference between slow fashion and fast fashion is reflected in customized service and authentic experience.
- Quantity – nowadays, quantity is often compared and even equated with the term of quality, and slow fashion emphasizes this difference and the importance of quality and endurance. The longer product life reduces the amount of waste in landfills.
- Customers – empirical studies have shown that consumers of slow fashion are mostly highly educated women who support the local economy, fair trade and good working conditions. It is necessary to develop this awareness to a larger target market.
- Response to trends – what stands out as a disadvantage of slow fashion is the inability to respond to rapid market changes and trends unlike fast fashion. Slow fashion emphasizes quality and durability and it is necessary to develop systems for market adaptation.

Companies that emphasize sustainable practices and strategies encourage effective management and quality products. Such companies naturally promote sustainability by following ethical principles and production techniques, as well as by using organic and recycled materials. The labor force engaged in the production of such products has better earnings as well as the protection of their superiors when it

comes to the supply chain. Clothing pieces produced according to the principles of the slow fashion movement cost more, but its advantage is developed style, durability and quality. By emphasizing the creation of connections between raw materials, designers, retailers and consumers, slow fashion companies promote sustainability in sourcing, production and consumption. However, the challenges for these companies are facing and competing with low-cost designs of solid position and mass sales. In order to make the conditions of competition equal between fast and slow fashion, it is necessary to reorient supply chains to degradable, organic raw materials, educate the larger target market of consumers and adapt goverment policies (Brewer, 2019).

Viewed from a practical side, sustainable design in fashion focuses primarily on the selection of materials for production. Therefore, it is important where the product comes from and how it is consumed. An increasing number of fashion companies and non-govermental organizations cooperate in promoting sustainable development in business. Many activities and gatherings were organized with the purpose of developing sustainable consumption habits and increasing environmental awareness among consumers. Such organizations also promote collectivity and sharing instead of infividual ownership, which is important for reducing the demand for fast fashion products. From the point of view of consumers, their participation in promoting the slow fashion movement can have an environmental or financial aspect, as well as simply spreading positive experiences to the environment (Ozdamar Ertekin, Atik, 2015).

The stages of the life cycle of fast fashion products have a particulary harmful effects on the environment, because they require the consumption of energy, chemicals and water. For example, cotton production requires 10% of the world’s annual use of synthetic pesticides. In addition, dyeing textiles consumes thousands of liters of water. These and many other examples show that this kind of toxicity permanently affects the environment and leads to the poisoning of agricultural products as well as the degradation of natural resources. Therefore, slow fashion could be the solution for environmental sustainability in the sphere of fashion industry. What needs to be further researched are the systems for implementing slow fashion in achieving sustainability in the industry (Jung, Jin, 2014). The slow fashion movement represents a direction that can provide many solutions, but it also represents a coherent set of fashion activities and promotes the diversity of fashion production and consumption. Slow fashion has a cultural aspect within biophysical boundaries (Fletcher, 2010).

DEFINING SUSTAINABLE BUSINESS, CSR AND ITS IMPORTANCE

In modern organizations, it is important to develop the ability of quick and successful transition to new business models, which represent an important source of competitive advantage and improvement of the company’s sustainable performance. A sustainable economic system is increasingly desirable and for its realization it is necessary to innovate business models by adopting sustainable solutions. As the level of productivity of a country determines the sustainable level of prosperity that an economy can reach and mantain over a longer period of time, the development of the competitiveness od the market economy implies the improvement of general factors of competitiveness in accordance with the principles of sustainable development. Therefore, sustainable development as a long-term process is important for survival, and it is considered the only concept of balanced development in the future (Geissdoerfer et al., 2018).

Corporate sustainability is defined as a business approach focused on creating long-term value for the company, through consideration of all dimensions of the relationship to its economic, social and natural environment. Creating an ecological, „green strategy“ focused on the environment and including all aspects of environmental responsibility is considered as an very important step towards sustainable development (Ivanović, 2017).

The concept of business sustainability can be in a relatioship with the concept of environmental ethics, which comes into conflict with our moral principles when it does not apply with other people. Namely, the first form of ecological ethics is conditioned by human activities in the use of resources

in order to preserve human health. Ecological ethics is realized through the preservation and prevention of natural values (Pavlović, 2011). The essence of the sustainability of the company is in the economical and rational use of resources, and sustainable development enables an increase in the quality of life according to ecological possibilities. The concept of sustainable business represents a combination of scientific principles and human values. It implies a redetermination of rules in order to replace wasteful consumption with savings and conservation (Čnjar, 2009). The concept of sustainability lies in the development of society in an economic and social sense, while at the same time preserving the environment. All three factors, economic, social and environmental are equally important and must be established and operate in such a way that they improve each other, which is related to corporate social responsibility (Knežević, 2009).
In order to a certain company to achieve sustainable business, it is necessary to apply the principles of corporate social responsibility (CSR). As a concept, CSR implies responsible business according to ethical, ecological and social principles. CSR refers to a company's obligations to society, especially those stakeholders affected by corporate policies and practises. CSR implies the achivement of the common good and value for the entire society , therefore, this concept is directly related to the business of the fashion industry and implementation of the slow fashion movement. Socially responsible business is a part of management that strives to achieve a balance between profit and long-term benefit for the social community (Smith, 2003).

CSR in many companies is moving from ideology to reality, because it is a concept that involves the improvement of the entire business and adoption of „not only is doing good the right thing to do, but it also leads to to doing better“. Many organizations consider this concept necessary in defining their roles in society and apply social and ethical standards to their businesses (Lindgreen, Swaen, 2010). On the basis of the above, it can be pointed out the direct connection between CSRand sustainable business that the fashion industry should implement in its business activities, because it represents a long-term solution for the preservation of the ecosystem and the social community as a whole.

CONCLUSION

Sustainable development and economic progress requires the need to develop a competitive economy based on knowledge, new technologies and innovation. Managers of fashion companies must be effective together with all employees of the company. In an organization based on knowledge, quality, innovation and CSR, the productivity of each individual employee makes the entire system productive and sustainable. Sustainable development, with its goals and vision, is established again and again in specific situations between different groups. That is why education od managers, employees and society and the creation of their environmental awareness is a very important factor in establishing sustainability. There are many challenges for the fashion industry in terms of sustainability and CSR and finacial and public support in this movement needs to be achieved. Increase of the awareness about slow fashion movement among consumers is important because it will affect their purchase desicions. Implementation of slow fashion movement depends on knowledge and understanding of the issue. Slow fashion companies for sure provide a template for the future generations of the global fasnion industry.

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REVOLUTION IN TEXTILE INDUSTRY – INDUSTRY 4.0

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ABSTRACT:

The fourth industrial revolution, or as it is now generally called industry 4.0, was not triggered by any special invention like the previous three. Industry 4.0 implies complete digitalization of all production processes and the application of digital technologies when creating an idea for a product, organization and realization of production, process control and provision of industrial services. Its initiation by Germany in 2011 gave impetus to the development of industry and the automation of the production process using all modern means of production, which are united under the name cyber-physical systems (CPS – Cyber – Physical System). They integrate computer technology, data transmission and processing, and modern mechanical systems. The modern factory is not isolated from social changes in the development of the economy, the development of science and education, which is shown by the Triple Helix Model. This trend is also present in the production of textiles and clothing and we can talk about the textile industry 4.0. Some trends in the development of the automation of clothing production have been highlighted, which justify that name.

Key words: *4.0 industry, automatic, modern, textile industry*

INTRODUCTION

Great scientific discoveries triggered industrial revolutions, fundamentally changing the way of production and living. The first Industrial Revolution was marked by the steam engine at the end of the 18th century. The second one came a hundred years later, using electricity in mass production.
One hundred years later, in the second half of the 20th century, the digital revolution marked the Third Industrial Revolution, using electronics and information technologies in the automation of production. The Fourth Industrial Revolution, of which we are contemporaries, came very quickly as a continuation and improvement of the way of production in Industry 3. This step is characterized by autonomous cyber-physical systems that communicate with each other using Internet of Things, Internet systems, artificial intelligence and large amounts of data stored in the so-called clouds. The fourth industrial revolution initiated major changes not only in the way of production but also in the way of working, which changed business models. Technological progress is increasingly shifting the boundaries between jobs performed by humans and those performed by machines and algorithms, requiring new types of knowledge and skills from humans. Under the heading Industry 4.0, many physical and digital technologies are converging through analytics, robotics, artificial intelligence, digitalization, and the internet of things, such as Textile Industry 4.0. These technologies are creating digital companies that can communicate, collect and analyze data on machines enabling faster, more flexible, and more efficient processes, which will help produce high-quality goods at reduced costs. This revolution will end up strategically contributing to increased productivity, considerably improving the economy of all segments of the industry, but especially fashion and food and service goods, resulting in real and progressive growth and a total change in the competitiveness of organizations worldwide.

THE FOURTH INDUSTRIAL REVOLUTION

The Fourth Industrial Revolution, 4IR or Industry 4.0, conceptualizes rapid change to technology, industries, and societal patterns and processes in the 21st century due to increasing interconnectivity and smart automation.[18] The term has been used widely in scientific literature. Industry 4.0 is characterized, above all, by the development of digital technologies, physics and biology. The

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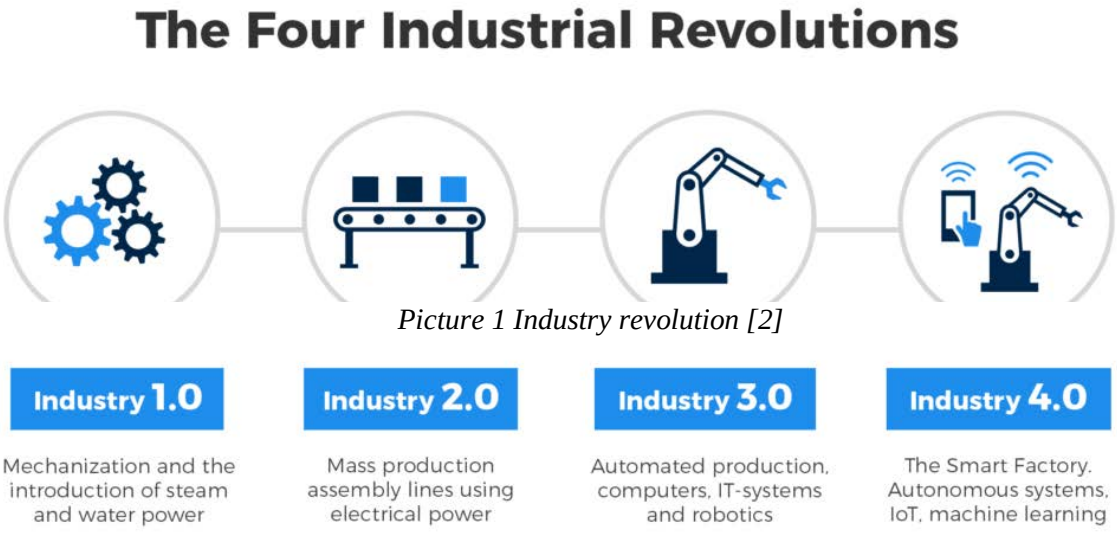
boundaries between the real and the virtual world are becoming less pronounced. Experts believe that Industry 4.0 will bring serious changes in the fields of nanotechnology, artificial intelligence, biotechnology, transportation, energy storage, 3D printers, and others. [1]

Industry 4.0, viewed as a logical continuation of the previous three industrial revolutions, refers to: rapid digital transformation of processes within the processing and manufacturing (but also other related) industries. The transformation is based on the intelligent networking of machines (and other devices) using advanced information and communication technologies, with the aim of enabling autonomous communication between devices, analyzing and collecting large amounts of data, autonomous decision-making, real-time monitoring of assets and processes, creation of added values and vertical and horizontal integration. The basis is the integration of information technologies with operational activities, which leads to a stronger production organization. The humankind has already seen three major revolutions in manufacturing industries: [1-2]

- 1st was when mechanization and steam power changed the whole concept of manufacturing.
- 2nd revolution happened when mass-production assembly lines and electrical energy took place and enabled a giant step in production efficiency.
- 3rd revolution brought automation, computers, and robots to production.

Industry 4.0 depends on a number of new and innovative technologies, which essentially include the following: [2-3]

1. **Industrial Internet of Things (Internet of Things, IoT) -** Perhaps the most important element of Industry 4.0. It is characterized by connected devices that communicate with each other and with a central base (people) via an Internet connection. Devices usually have built-in sensors. Data received from each device is stored in the cloud and used for real-time analysis and decision-making.
2. **Advanced robotics – autonomous robots -** Robots are becoming more and more autonomous, flexible and cooperative. They are expected to communicate with each other and exchange information. They are used for various activities – from picking products in warehouses to preparing products for shipping.
3. **Additive manufacturing (3D printers) -** It is currently used for the development of prototypes and individual components necessary for a particular product. In the future,



Picture 1 Industry revolution [2]

additive manufacturing is expected to be widely used to produce small quantities of unique products that meet specific customer needs/desires.

4. **Augmented reality** - Systems based on augmented reality can be used for various services, e.g. to select parts in the warehouse or to send instructions for repairing a device via mobile phone.
5. **Simulations** - Currently, 3D product simulations are used to display products, materials, and production processes, but an even stronger use is expected in the plants themselves.
6. **Work in the cloud (cloud computing)** - An increased use of software located in the cloud related to production itself (not only general processes within the company) is expected, also encouraged by the implementation of other 4.0 technologies, which will lead to greater dissemination of data within the company and beyond.
7. **Cyber security** - The increase in connectivity will also increase the need for adequate protection of industrial systems and production lines.
8. **Big Data and analytics** - Collection and analysis of data from various sources: production equipment and production system, the entire company system, customer and supplier systems. An opportunity to recognize certain patterns of behavior, which enables optimization of production quality, energy saving, etc.
9. **Horizontal/vertical system integration**

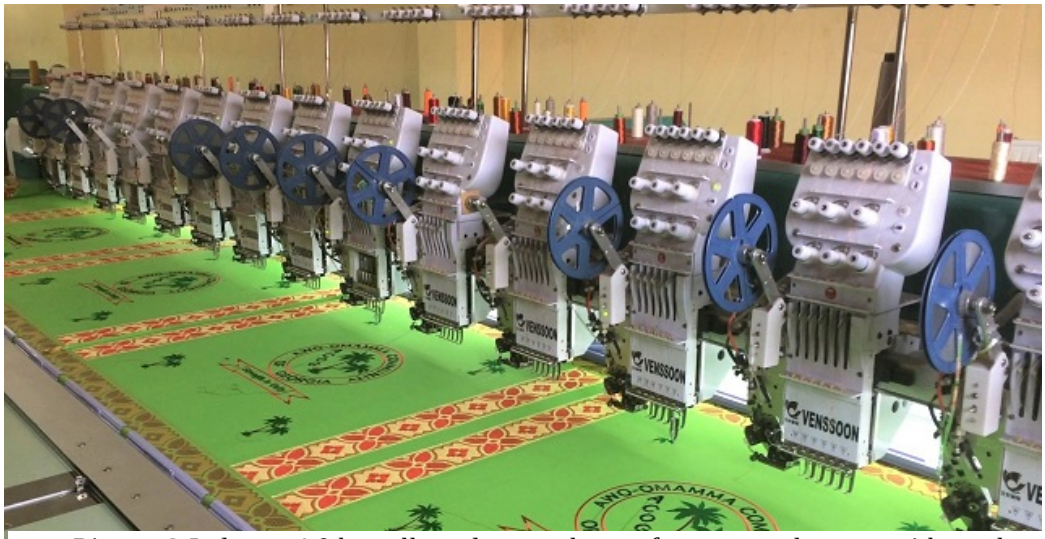
- Horizontal: digitization in the entire value chain through the exchange of information and the connection of information systems (from customers to suppliers)
- Vertical: IT system integration through all levels of hierarchy in the company (production, control, operational level)

TEXTILE INDUSTRY 4.0

Figure 2 Industry 4.0 [3]

Modern technology is changing the state of manufacturing, with most of it happening as a result of Industry 4.0's rise. Like any other manufacturing segment, the textile industry is seeing the rise of more advanced and smarter technologies such as artificial intelligence, machine learning, big data, automation systems, 3D printing and more. The technology has created a perpetual state of change, and it's something that will likely stick around for quite some time. The trend is mainly positive, offering considerable improvements across the board. In reality, while many of the related technologies already provide incredible features and functionality, there is still a lot of experimentation going on. This revolution will end up strategically contributing to increased productivity, considerably improving the economy of all segments of the industry, but especially fashion and food and service goods, resulting in real and progressive growth and a total change in the competitiveness of organizations worldwide. Strictly speaking, with regard to the Textile and Apparel and Textile Industry 4.0. Due to the intensive use of labor, lack of technology, and rising costs, the competitiveness of the textile industry is weakening in many countries. The result of these constraints, ranging from the level of productivity and efficiency to quality, is always affected in most cases. We also have a new trend is to have product customization with more variations, requiring an adjustment to market needs in the shortest time possible. [4-5]

Textile 4.0 is an interpretation and application of Industry Revolution 4.0 in the Textiles Technology and Textile Manufacturing sectors across the supply chain in Spinning, Weaving, Finishing and Garmenting. Due to the rising cost, high-end consumer, and the complex value chain, competitiveness



Picture 3 Industry 4.0 has allowed apparel manufacturers to keep up with market changes and consumer demand [4]

of global manufacturing industry weakens and makes it imminent to upgrade. [6]

The world is at the threshold of a new industrial revolution characterized by Artificial Intelligence, Internet of Things, next-generation robotics, 3D printing, wearable's, gentle engineering, nanotechnology, advanced materials, biotechnology and others. Industry 4.0 is the future of manufacturing technologies and is increasingly important trend in automation and data exchange. This enhanced technology, digital systems and automated processes will make it optimum for manufacturing of quality products. Industry 4.0 includes cyber-physical systems, the Internet of things, cloud computing and cognitive computing which creates what is being defined as a "Smart Factory". [5-6]

- **Smart manufacturing:** It covers many different technologies. Some of the key technologies in the smart manufacturing movement include big data processing capabilities, industrial connectivity devices & services and advanced robotics. [6]

- **Optimize logistics and supply chains:** A connected supply chain can adjust and accommodate when new information is presented. If a weather delay ties up a shipment, a connected system can proactively adjust to that reality and modify manufacturing priorities. [6]
- **Autonomous equipment and vehicles:** There are shipping yards that are leveraging autonomous cranes and trucks to streamline operations as they accept shipping containers from the ships. [6]
- **Robots:** From picking products at a warehouse to getting them ready to ship, autonomous robots can quickly and safely support manufacturers. [6]
- **3D printing:** This technology has progressed from primarily being used for prototyping to actual production. Advancement in the use of metal additive manufacturing have opened up a lot of possibilities for production. [6]
- **Internet of Things and the cloud:** Not only does this help internal operations, but, through the use of the cloud environment where data is stored, equipment and operations can be optimized by leveraging the insights of others using the same equipment or to allow smaller enterprises access to technology they wouldn't be able to on their own. [6]
- **Artificial Intelligence:** It is used by the textile companies for trend predictions and machine diagnosis and analyzing large chunk of data collected from manufacturing, purchase, marketing and logistics, etc. [6]
- **Cyber-physical systems:** From raw materials to product sales, digital tracking device is connected to each other according to standard protocols for data analysis, error forecast and self-configuring. [6]

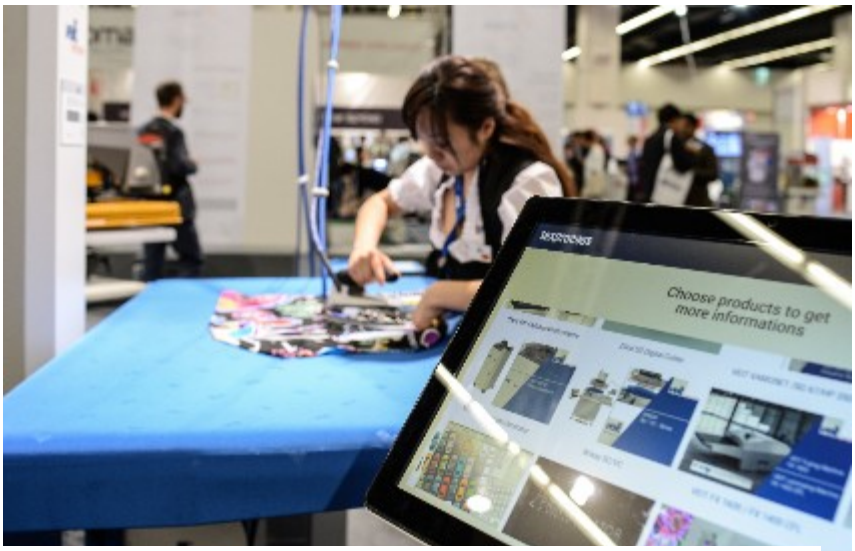


Figure 4 Textiles and the digital revolution [7]

THE FUTURE OF THE TEXTILE INDUSTRY 4.0

Industry 4.0 has brought the ‘smart factory’ into existence in which smart digital services are networked and they communicate with raw materials, semi-finished products, machines, tools,etc. This industry is characterized by flexibility, efficient use of resources and integration of customers and business partners in the business process. In this networked factory, machines and men have become equal partners, having a higher degree of AI in relation to the previous generation of robots. Highly active sensors incorporated in the looms enable cooperation between the machines and the workers. The factories are characterized by connected production, resilient nature, intelligent maintenance and self-organizing logistics. The systems are cognitive and enable workers to achieve and maintain quality production standards and implement predictive maintenance. [8]

The future of truly smart textiles lies in the potential of technology convergence, where the processing of electroactive polymers and molecular electronics into fibres and fabrics. The polymers on being transferred to the textile industry, will be able to produce soft intelligent textile products that will permit a broad spectrum of functions and capabilities. The use of electroactive polymers in textiles will give clothes light-emitting capabilities. Nanotechnology and plasma technology will be used more widely in textiles of the future for specific applications. The variable properties of fibers and filaments can give textiles multifunctional capabilities. Mainly it will go into haute couture textile products. Integrating electronic functionality into textiles will open up a new world for your applications. Conductive fabrics with the possibility of using thermochromic ink (which undergoes a reversible change of color when heated or cooled) for printing give the fabric very special functional capabilities. [8-9]

The installation of textile mechanical sensors which can sense and measure gestures and movements, Textile systems that can sense the physiological signals of the wearer to recognize how the wearer s feeling and respond accordingly, Effective bulk use of conductive fabric on which thermochromic ink can be printed and the use of electroactive polymers like light emitting polymers, power polymers and actuators as well as electronic ink can be extensively carried out with the progress of Industry 4.0. [8-9]

Nanotechnology has now emerged as the future of fabrication. Multi functional, responsive and adaptive fibers can be produced by modifying the surfaces of fibers and using grafting materials. The information and communication technology unit’s collaboration with the community of design and human sciences gives a whole new dimension to the fabric production process. Integration of electronic functionality into textiles ensure versatility and quality in the nature of the commodities.[8-9]

An example of this technology is Bella Hadid and the French fashion house Copernicus which are took care of a real show at Paris Fashion Week. Bella walked the catwalk naked, only in white panties, in an instant she was surrounded by designers with bottles full of white spray and meticulously sprayed her body, from shoulders to knees and formed the look of a dress, when the paint soon dried, it turned into real fabric and formed a white dress. This revolutionary technique was designed by the Spanish company Fabrican, and it is a special polymer that, when combined with the body, becomes a solid fabric. [10]

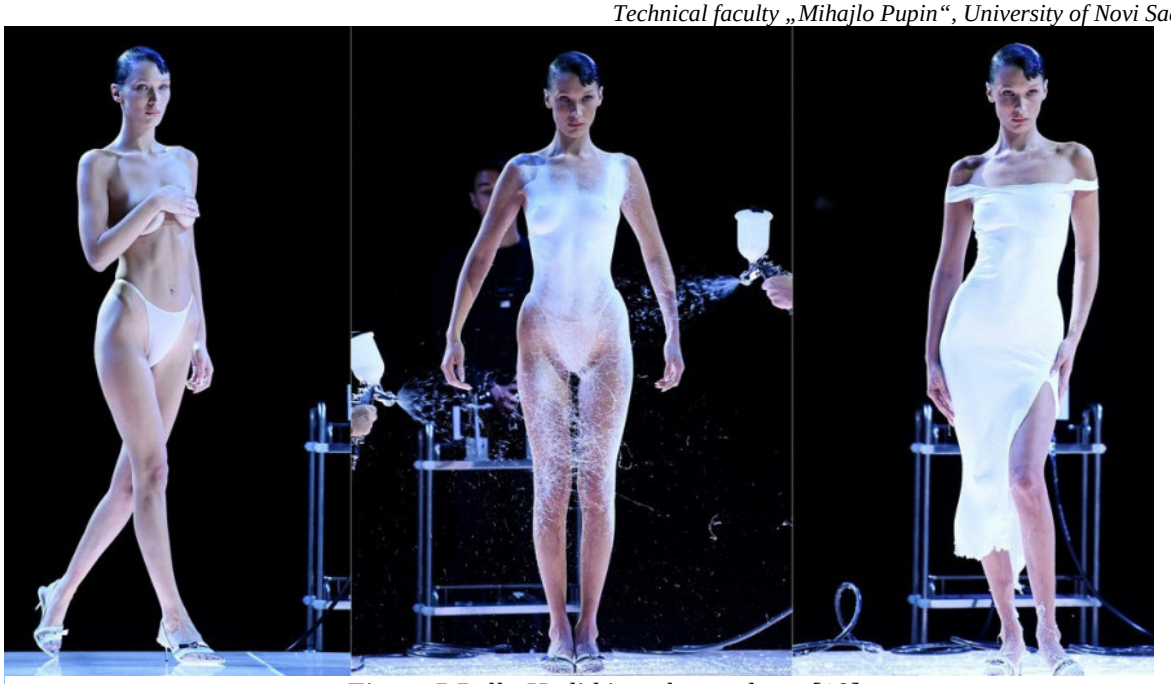


Figure 5 Bella Hadid in polymer dress [10]

Globalization, demographic changes and adoption of Industry 4.0 are the three giant factors that will determine the future of jobs in the textile sector. The Industry 4.0 has created a major impact in the service sectors as well as retail marketing. However, the extent of its impact depends on the extent to which the industry adopts the new technologies including Robotic Process Automation, Artificial Intelligence, Machine Learning and Internet of Things. [11]

The impact of Industry 4.0 will result in different possibilities. Some new jobs would be created, some existing ones would need additional skill requirements, some would continue to exist without any change while some would disappear. The jobs that would disappear are the ones that would require Routine Manual and Routine Cognitive skills. All such jobs would be automated. Among the two sectors, textiles and apparels, the latter is more likely to adopt the new technologies because high labour intensive operations are required in stitching, packing and inspection. Job roles such as fabric checker, packer helper etc will most probably cease to exist. [11]

Even before the introduction of Industry 4.0, the spinning sector had long gone replaced some of the job roles which required RM and RC skills with robotics. For example, auto doffers on ring frame, chute feed cards, etc. [11]

The Textile Industry is all set to employ specialists in resource and process management rather than technology change in the manufacturing of textiles. The replacement of mechanical gadgets with electronic components in almost all types of machines has also given opportunities for specialists in PLC maintenance. The current trend of appointing these specialists shows that they will be working as freelance specialists rather than working as full time employees. [11]

CONCLUCION

The Fourth Industrial Revolution, 4IR or Industry 4.0, conceptualizes rapid change to technology, industries, and societal patterns and processes in the 21st century due to increasing interconnectivity and smart automation. Textile 4.0 is an interpretation and application of Industry Revolution 4.0 in the Textiles Technology and Textile Manufacturing sectors across the supply chain in Spinning, Weaving, Finishing and Garmenting. Due to the rising cost, high-end consumer, and the complex value chain, competitiveness of global manufacturing industry weakens and makes it imminent to upgrade. Industry is rebooting new digital age by adopting smart factory. The boom of global re-industrialization would make manufacturing more intense, competitive and the traditional model will be substituted for emerging model, which could be called integration of industrial chain better than an industrial revolution, and all participants in the production process will collaborate production in a new way. This manufacturing revolution will ultimately help in increasing productivity, improving economics resulting in fostering growth and changing the competitiveness of organizations. It’s nearly impossible to predict what the future of the textile industry will look like years down the line, at least with any degree of certainty. One thing is apparent, however, and it’s that modern technology will pave the way for more unique, cost-effective and high-quality goods. When coupled with more customization opportunities and faster time to market, all the benefits will contribute to a higher customer satisfaction rating.

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