ANNALS
OF THE
UNIVERSITY OF ORADEA

FASCICLE OF TEXTILES, LEATHERWORK

VOLUME 21

No. 1

2020

ISSN 1843 – 813X

ANNALS OF THE UNIVERSITY OF ORADEA

FASCICLE OF TEXTILES, LEATHERWORK

VOLUME 21
No. 1

2020

Contact and Editors' Address:
Liliana INDRIE
UNIVERSITATEA DIN ORADEA,
FACULTATEA DE INGINERIE ENERGETICĂ ŞI MANAGEMENT INDUSTRIAL
DEPARTAMENTUL: TEXTILE- PIELĂRIE ŞI MANAGEMENT INDUSTRIAL
Str. B.St.Delavrancea nr. 4,
Oradea, 410058, Romania,
Tel.: 00-40-259-408448
E-mail : lindrie@uoradea.ro

Published by
Editura Universităţii din Oradea
Universitatea din Oradea, Str. Universităţii Nr. 1, 410087, Oradea, Bihor, Romania
P- ISSN 1843 – 813X
E - ISSN 2457-4880
CD- ISSN 2068 – 1070

Indexed in:

EBSCO-Textile Technology Complete
Index Copernicus (ICV 2018: 97,58)
Directory of Open Access Journals (DOAJ)
Ulrich's Update - Periodicals Directory

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

STUDY OF BENDING AND RESISTANCE TO SHARP OBJECT PENETRATION IN METAL-REINFORCED FABRICS

AMIRSHIRZAD Forough[1], EZAZSHAHABI Nazanin[2], MOUSAZADEGAN Fatemeh[3]

[1,2,3] Amirkabir University of Technology, Textile Engineering Faculty, 424 Hafez Ave, 15875-4413, Tehran, Iran
E-Mail: amirshirzad@aut.ac.ir, ezazshahabi@aut.ac.ir, F_mousazadegan@aut.ac.ir

Corresponding author: Amirshirzad, Forough, E-mail: amirshirzad@aut.ac.ir

Abstract: *In various working conditions and some hazardous situations, people may be subjected to assaults by sharp objects. Therefore, protective clothing is utilized to defend the human body against dangers and damages caused by these threats. In this study several metal-reinforced fabrics were designed and prepared through a weft-backed weaving system and their protection performance was assessed. To prepare the fabric samples, different metal threads having various diameters and weave ratios were used. The designed fabric's resistance to bending and penetration of sharp objects was measured and the outcomes showed that using metal threads in fabric structure increased the fabric resistance against bending and penetration of sharp objects in general. The impact of metal threads diameter and weave ratio was also investigated. Thicker metal threads resulted in further increasing of the fabric resistance to penetration and bending. In fabrics reinforced with metal thread that have similar diameters, the samples with lower weave ratio need considerably greater force and energy for penetration. It was also observed that the impact of weave ratio is more significant than the impact of diameter of metal threads on fabric resistance to penetration. However, in terms of fabric resistance to bending, the impact of diameter of metal threads was higher compared to number of metal threads.*

Key words: *Bending Resistance, Penetration Force, Weave Structure, Metallic Thread, Protective Clothing*

1. INTRODUCTION

There are many occupations that may be at the risk of sharp object assaults. Protective clothing is used to protect the human body against various threats such as damages caused by sharp objects. Aramid multi-layer fabrics are widely used in the production of bullet-proof and stab resistant vests [1]. In addition to high strength multi-layer fabrics, using ceramic or metallic components can improve protection performance of protective clothing [2]. Tien et al. (2011) found that the stab resistance of the woven fabrics changed considerably with the variation of fabric's density [3]. Reiner et al. (2015) studied the effect of inserting wool layers instead of aramid fabrics as top and bottom layers in a multilayer panel, on stab resistance of panel. It was pointed out that application of wool fabrics provides acceptable penetration depth value with fewer layers, as well as reducing weight and improving comfort for the wearer [4]. Hejazi et al. (2016) investigated the effect of coating a woven textile with a series of metallic particles on the stab resistance of the textile. According to their findings, adding metallic particles to the surface of the fabric increased fabric's elastic modulus, and reduced the depth of knife penetration [5]. Aliverdipur et al. (2020) analyzed the relation between the tensile modulus and the penetration depth of woven fabrics. In this

research it was observed that when the tensile modulus of the fabric is small, it extends more before the penetration, and due to this reason, the passage of sharp object through the fabric is delayed. Besides, it was declared that there was a direct relation between the sharp object's geometry and fabrics' destruction [6].

2. EXPERIMENTS

2.1 Materials

The metal-reinforced fabric was woven through a weft-backed system with the Twill $\frac{2}{2}$ Z weave pattern using a handloom weaving machine. The acrylic yarn with the count of $33/2$ Nm was used as both warp and weft yarns for weaving the samples. In order to raise the fabric's resistance against penetration of sharp object, stainless steel metal threads were used as the backing weft yarns, which only appear on the back of the fabric. This provides no contact of metals with the skin surface. To avoid fabrics heaviness and improvement of the flexibility, a combination of acrylic and metal threads with a woven ratio of 5: 1 and 3:1 was applied as weft threads in weaving process. In other words, as it is shown in Figure 1, after each five or three acrylic yarns, one metal thread is inserted as weft yarn in the fabric structure. Three metal thread diameters including 0.2, 0.3, and 0.4 mm were used to prepare different samples. To examine the influence of metal thread's presence on the fabric's resistance against penetration of sharp object, fabrics were also woven without metal threads to be used as the control specimens. The warp and weft density of samples were 12 and 11 (cm^{-1}), respectively. Physical properties of woven fabrics are reported in Table 1.

Table 1: *Physical properties of woven fabrics*

Sample Code	Metal Diameter (mm)	Weave Ratio	Thickness (mm)	Mass per unit area (g/m^2)
S0W5	- (control sample)	5:1	1.29	201.76
S2W5	0.2	5:1	1.33	268.24
S3W5	0.3	5:1	1.36	294.39
S4W5	0.4	5:1	1.45	381.29
S3W3	0.3	3:1	1.42	299.98

Fig. 1 *The weave pattern and front and back images of sample S3W3*

According to Table 1, there is no significant difference between thickness of S2W5 and S0W5; however, application of metal threads has increased mass of S2W5 sample. S4W5 and S3W3 have the most thickness and mass. In other words, using thicker metal threads or more number of them has increased thickness and mass of fabric samples. Characteristic of the applied knife is also presented in Table 2.

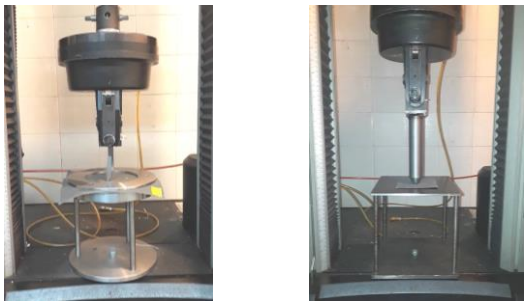
Table 2: *Characteristic of the applied knife*

Knife's Shape	Length (mm)	Thickness (mm)	Tip Angle ($^\circ$)	Application
	78	1.96	127	Toggle Knife

2.1 Test Method

Evaluating the fabric stiffness was carried out on Instron 5566 universal testing machine based on the standard test method for stiffness of fabric by the circular bend procedure (ASTM D 4032). In this test method, a plunger forces the fabric through an orifice in a platform. The maximum force required to push the fabric through the orifice is an indication of the fabric stiffness (resistance to bending). The test was carried out; using 24×24 cm^2 samples and the speed of the test was set on 100 mm/min.

Penetration test was also performed on Instron machine, according to the method presented by San et al (2011) [7]. The fabric holding system was substituted with the bottom jaw of the testing machine, and the knife was positioned in the machine's upper jaw. At the initiation of the test, the knife tip is in contact with the surface of the fabric. As the test starts, the knife moves down and penetrates the fabric sample. The penetration speed of knife was 100 mm/min and the penetration process was executed to the depth of 50 mm. For each fabric, three specimens were tested, and the average of the obtained outcomes was reported. Setup of penetration and stiffness tests on Instron machine are illustrated in Figure 2. To investigate the effect of inserting metal threads in fabric structure on fabric resistance, penetration test was conducted in the weft direction.



a ***b***

Fig. 2*: Setup of a) penetration, and b) stiffness tests*

3. RESULT AND DISCUSSION

3.1. Resistance to bending

The bending force-displacement diagram obtained from stiffness tests are illustrated in Figure 3. As the test starts, the plunger tries to push the fabric sample out of the orifice. In respect to the fabric stiffness, the force reaches its maximum value and then decreases to zero, which means that the fabric is fully passed through the orifice. The maximum bending force (maximum force in the chart) and bending energy (area under the chart) of each fabric sample are reported in Table 3.

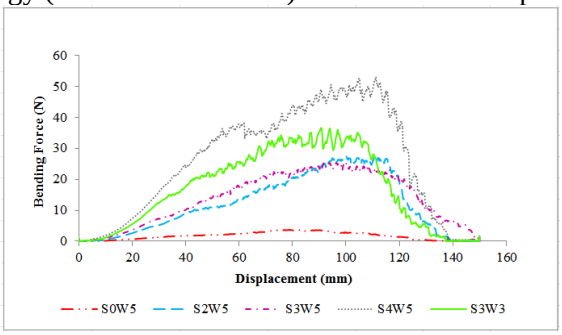


Fig. 3*: Bending force by displacement diagram of fabric samples*

Table 3: *Bending force and energy of fabric samples*

Sample Code	S0W5	S2W5	S3W5	S4W5	S3W3
Bending Force (N)	3.79	27.65	25.66	53.03	36.69
Bending Energy (J)	0.258	1.800	2.050	3.890	2.566

As it was expected, the control sample without metal (S0W5) has the lowest bending force and energy, and adding metals to fabric structure has increased the fabric stiffness. In samples woven with the same weave ratio and different metal thread diameters of 0.2 and 0.3 mm (S2W5 and S3W5), there was not much difference between the bending forces. Whereas, the use of metal threads with a diameter of 0.4 mm (S4W5) considerably increased the bending force and reduced the flexibility of the fabric, due to the higher bending rigidity of coarser metallic threads. Both S3W5 and S3W3 specimens were woven with a metal thread diameter of 0.3 mm and different weave ratios of 5:1 and 3:1, respectively. According to Table 3, the bending force of S3W3 sample is higher than the S3W5, and this means that increment in the number of metals in fabric structure has increased the fabric stiffness.

3.2. Resistance against penetration of sharp object

The diagram of the penetration force versus knife displacement is illustrated in Figure 4. As displayed in Figure 4, at the beginning of the diagrams, a slight increase in force is observed by increasing displacement. Initially, the knife blade is not able to penetrate the fabric and displace the yarns; in fact, this part is the knife indentation step into the fabric. As the knife displacement continues, the slope of the diagram increases; this part of the diagram can be attributed to the knife's involvement with the yarns and metals. The blade encounters threads and metals over its path of movement and tries to push them apart and pass through them. The rise of force by increasing the knife's displacement, eventually results in the fabric being extended, destructed, and abraded by the knife blade, resulting in the cutting of threads. As a result, the force reaches the maximum value, and then diminishes as seen in the chart. In Figure 5, the penetration force and energy of various fabric samples are compared.

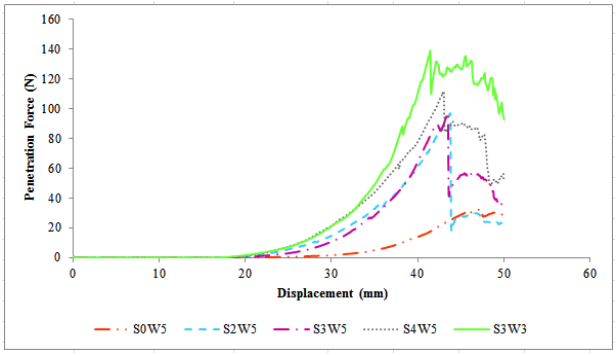


Fig. 4*: Penetration force by knife displacement of fabric samples*

As can be seen in Figure 5, the greatest penetration force and energy was related to the S3W3, S4W5, S3W5, S2W5, and S0W5 samples, respectively. S0W5 fabric which is the control specimen and is woven without metal threads has the lowest penetration force, while using metal threads in fabric structure has considerably increased the penetration force and energy. S3W3 sample which is woven by application of metal threads with the diameter of 0.3 mm and weave ratio of 3:1 has the greatest penetration force and energy. S2W5 and S3W5 samples have similar penetration force, and then S4W5 fabric has more penetration force compared to S2W5 and S3W5 samples. When using thicker metal threads, the knife blade needs further force to push the metals

aside and penetrate through the fabric, which causes the higher penetration force and energy of S4W5 fabric compared to S2W5 and S3W5 samples. S3W3 sample has more penetration force and energy than S3W3 one. In weave ratio of 3:1, after insertion of three acrylic yarns, a metal thread is inserted as the weft yarn in the fabric; consequently, the number of metal threads in the fabric structure is more than weave ratio of 5:1. In this regard, higher number of metal threads resulted in greater penetration force and energy in S3W3 fabric. From Figure 4, it is visible that after the 20-30 mm displacement of the knife, the differences between the sample's penetration forces became more distinct. In the process of penetration into the fabric, the knife tries to push yarns aside in the fabric structure and pass through them. When the knife moves further into the fabric, it pushes more yarns sideways and a concentration of acrylic and metal threads are formed around the knife. When using a higher number of metal threads, the role of mentioned concentration is more critical, and this results in greater penetration force and energy. The mentioned phenomenon and the deformation of the fabric in the penetration region are shown in Figure 6.

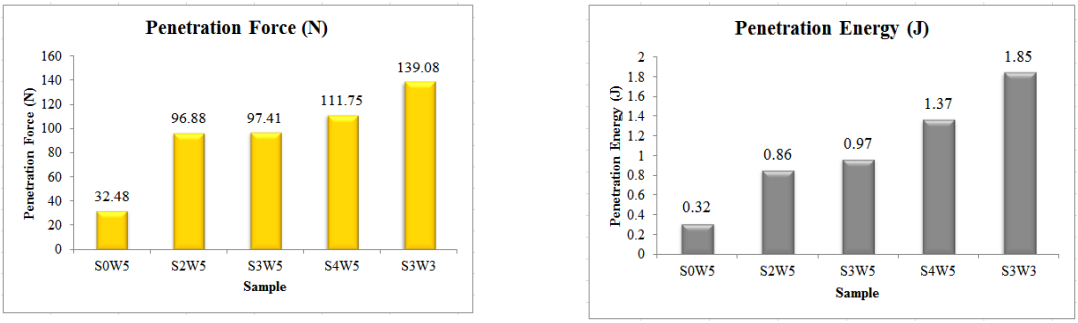


***Fig. 5**: Penetration force and energy of fabric samples*

According to the obtained data for stiffness and penetration tests, it was observed that generally the samples with more bending force also have more penetration force. During the knife penetration into the fabric, because of fabric's extension, fabric is pulled down with the downward movement of the knife in the penetration zone. It seems that, this phenomenon can be affected by the fabric flexibility or in other words the fabric's bending behavior.

***Fig. 6**: Deformation of fabric structure during knife penetration into the fabric*

As discussed earlier, S4W5 and S3W3 samples had the highest penetration force and energy among the tested samples. However, the increment in penetration force and energy of the S3W3 sample is much more considerable than the S4W5 sample. Besides to the greater protective performance of the S3W3 sample, it also has lower weight and stiffness. Hence, S3W3 seems to be the most suitable sample to use in protective clothing.

4. CONCLUSIONS

Fabrics in either soft or rigid forms are used for personal protection against sharp objects' threats. In this study, a metal-reinforced fabric is designed and prepared through a weft-backed system. Different diameters of metal threads including 0.2, 0.3, and 0.4 mm, with weave ratio of 5:1 and 3:1 were used to weave the fabric samples. Bending resistance and resistance against penetration of sharp object were measured for each fabric sample. Test results revealed that adding metals to fabric structure increased the fabric stiffness. Samples constituted of the thickest metal threads had the highest bending force and energy among the tested samples. Furthermore, with the same metal thread diameter, fabric samples with lower weave ratio and higher number of metal threads in a specified area of the fabric had greater bending force and energy.

Using metal threads in fabric structure had significantly increased the penetration force and energy of the fabric samples. Using thicker metals or a higher number of metal threads had resulted in greater resistance against penetration of sharp object. It has to be considered that the impact of the number of metal threads was considerably greater than the influence of metal threads' diameter. However, the impact of metal threads diameter on the fabric resistance against bending was higher than the number of metal threads. In general, the same trend is perceived in bending resistance and resistance against penetration of sharp object. Fabrics with more bending force also had more penetration force.

Based on the obtained results, in addition to providing better protective performance, achieving lower weight and lower stiffness of fabric is also desired by incorporating higher number of metal threads, instead of using coarser metal threads.

REFERENCES

[1] G. Nolan, S.V. Hainsworth, G.N. Rutty, *"Forces Generated in Stabbing Attacks: An Evaluation of the Utility of the Mild, Moderate and Severe Scale,"* International Journal of Legal Medicine, vol. 132(1), p.p. 229–236, 2018.

[2] R. Nayek, I. Crouch, S. Kanesalingam, J. Ding, P. Tan, B. Lee, M. Miao, D. Ganga, L. Wang, *"Body Armor for Stab and Spike Protection, Part 1: Scientific Literature Review,"* Textile Research Journal, vol. 88(7), p.p. 812-832, 2018.

[3] D.T. Tien, J.S. Kim, Y. Huh, *"Stab-Resistant Property of the Fabrics Woven with the Aramid/Cotton Core-Spun Yarns,"* Fibers and Polymers, vol.11(3), p.p. 500-506, 2010.

[4] P. Reiners, Y. Kyosev, L. Schacher, D. Adolphe, K. Ku¨ster, *"Experimental Investigation of the Influence of Wool Structures on the Stab Resistance of Woven Body Armor Panels,"* Textile Research Journal, vol. 86(7), p.p. 685-695, 2015.

[5] S.M. Hejazi, N. Kadivar, A. Sajjadi, *"Analytical Assessment of woven fabrics under vertical stabbing – The role of protective clothing,"* Forensic Science International, vol. 259, p.p. 224-233, 2016.

[6] N. Aliverdipour, N. Ezazshahabi, F. Mousazadegan, *"Characterization of the effect of fabric's tensile behavior and sharp object properties on the resistance against penetration,"* Forensic science international, vol. 306, 2020.

[7] B. Sun, Y. Wang, P. Wang, H. Hu, B. Gu, *"Investigation of Puncture Behaviors of Woven Fabrics from Finite Element Analyses and Experimental Tests",* Textile Research Journal, vol. 81(10), p.p. 992-1007, 2011.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

STUDY ON MAKING SOME PROTECTIVE MASKS BY KNITTING PROCEDURES

BOHM Gabriella[1], DOBLE Liliana[1] , SUTEU Marius Darius[1], SERFEZI Adrian[2]

[1]University of Oradea, Faculty of Energy Engineering and Industrial Management, Department Textiles, Leather and Industrial Management, 410058, Oradea, România, E-Mail: bohmgaby@gmail.com

[2]S.C.Astrico Nord Est S.R.L., Piatra Neamt, România

Corresponding author: Gabriella BOHM, E-mail: bohmgaby@gmail.com

Abstract: *In the midst of the health crisis, we are all trapped in a story that, some time ago, we could not have imagined. Our desire is not to be the witnesses of a history, but the protagonists of a change. This is why we joined the initiative of our colleagues from S.C. Astrico Nord Est S.R.L. Piatra Neamt, and we made a protective mask prototype of 100% cotton which can meet the current needs. This is intended to be a reusable protective mask, as disinfection of the mask can be washed and dried at 700 C, without damaging its properties and shape. This mask was made on the rectilinear knitting machine SIR 123 finness 14, produced by Shima Seiki from Japan. These knitting machines use, for product design, the SDS-One graphics station or the APEX graphic station - the latest generation variant. Using the technological possibilities offered by both the machine and its graphical assistance program, we aimed to attain a production efficiency, which can be achieved by finding methods to reduce the execution time as well as to increase the comfort and quality of the products made. The authors intend to create a product that can cover the needs of ordinary citizens, but also those of the interior of the medical system by giving them these masks that can be disinfected in the hospital autoclave, without the need for such high consumption of raw material, but also once fulfilling the safety conditions of the bearer.*

Key words: *Mask prototype, knitting, SDS-One graphics station, APEX graphic station.*

1. INTRODUCTION

In a world with finite resources, creativity, generating scientific and technical progress is the key to solving any problem [1]. Innovation, as a factor of technical progress materialization is, above all, a social phenomenon [2].
Knits, which have had great popularity in recent years, are among the favorite textile materials for making everyday clothes. Clothing comfort is an important factor because people make their own clothing selections [3].

2. EXPERIMENTAL PART

The mask is a tool used to prevent the transmission of infections by limiting the spread of germs. When a person speaks, sneezes or coughs, small drops of pathogens are released into the air that can infect the surrounding people. It should be noted that these masks can be used to prevent dust inhalation or touching the area around the mouth with hands, but do not provide protection

against Covid 19. The experimental part was done inside S.C. Astrico Nord Est S.R.L.Piatra Neamt. In order to make the product, the rectilinear knitting machine SIR 123 finesse 14 [4] was used, produced by Shima Seiki from Japan, This is a machine with electronic control and selection, with two knitting systems. The machine is equipped with a carriage, with two integrated cam systems. The DSCS device (patented by Shima Seiki) represents the most important improvement in the technology of knitting on rectilinear machines. The device controls and adjusts the length of the used yarn, digitally, aiming to keep it constant, with a tolerance of ± 2%. This device is essential for contour knitting and full knitting, as it allows the constant size of knits to be maintained. The first step in making the mask was the selection of the yard out of which the product was going to be made [5]. This yarn will have to fulfill both the safety conditions of the wearer ensuring a physical barrier around his nasal-buccal area, as well as the conditions of comfort, permeability of the air and vapours of the wearer. The chosen yarn was a 100% cotton yarn, 50/2 finesse to which it was fed, in parallel a Lycra yarn to ensure the firmness of the shape and the necessary rigid aspect. In order to make the knitted product, the dimensions of the product are determined, the knitted structure from which it will be made and the values of knit texture [6]. After establishing them, the product design program was drawn up (Figure 1, Figure 2.) [6]. This was done on the support software of the APEX graphical station, the graphical support stations of the SHIMA SEIKI knitting machines.

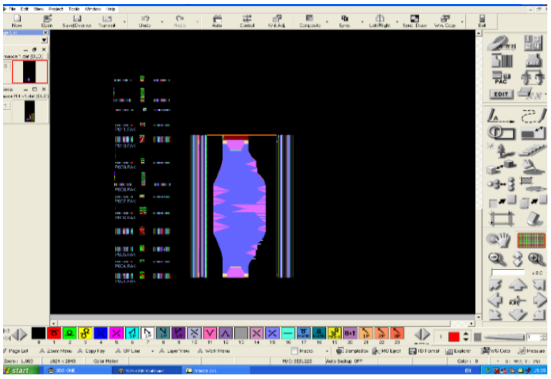


Fig. 1. *The program in which the mask was made - sketch and work packages*

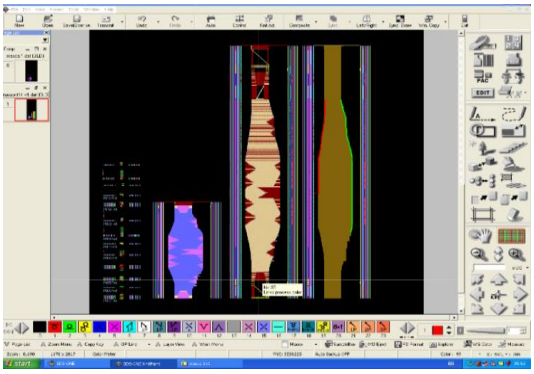


Fig. 2. *The program for working with the mask product*

After completing the design programs for producing the mask, the next phase was processing of these programs. This consists in the translation of the codes from the design program into the actual language of knitting machines, in order to make the products Figure 3.

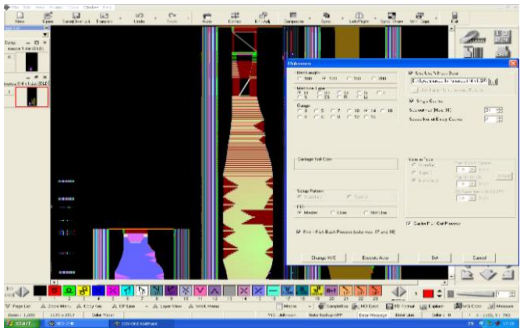


Fig. 3. *The program processing phase for the knitted protective mask product*

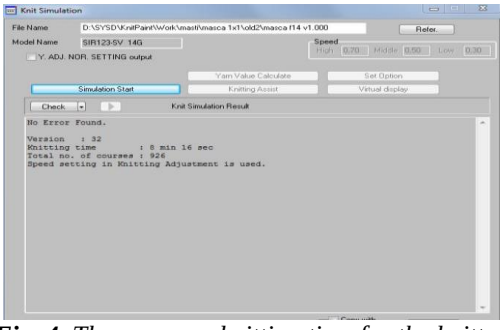


Fig. 4. *The program knitting time for the knitted protective mask product*

The product was made on the Shima Seiki rectilinear knitting machine, model SIR 123, fineness 14, Figure 5, having an execution time of 8 min and 16 seconds/piece, Figure 4.

Fig. 5. *The rectilinear knitting machine SHIMA SEIKI SIR 123 finness 14*

In Figures 6, 7 and 8 you can see the image of the product, the knitted protective mask, made of 100% cotton yarn and lycra.

Fig. 6. *Knitted protective mask - front view*

Fig. 7. *Knitted protective mask - profile view*

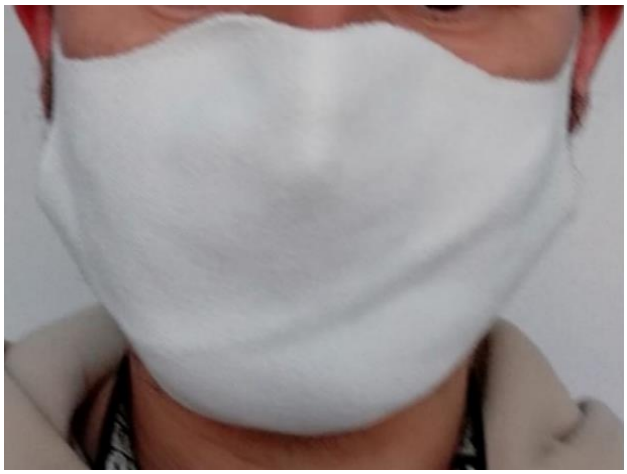


Fig. 8. *Protective mask made by knitting process*

5. CONCLUSIONS

We want to create a product that can meet the needs of ordinary citizens, but also those of the medical system by giving them these masks that can be disinfected in the hospital autoclave, without the need for such high raw material consumption, but at the same time fulfilling the safety conditions of the bearer regarding the assurance of a physical barrier in its nasal-buccal area, as well as the conditions of comfort, permeability of the air and vapors of the carrier.

The authors intend to carry out comparative research regarding these properties related to the permeability of the air flow, respectively vapors from the outside to the inside but also vice versa to ensure the comfort of the user.

REFERENCES

[1] Platon, V., Sisteme avansate de producţie, Editura Tehnică,Bucureşti, 1990.

[2] Moisescu, E., Control tehnic de calitate – Tricotaje, Editura,,Gh. Asachi" Iaşi, 2000.

[3] Utkun E. Comfort-related properties of woven fabrics produced from Dri-release® yarns. In: Industria Textila, 2014, vol. 65, issue 5, pp. 241-246.

[4] http://www.shimaseiki.co

[5] BOHM Gabriella, DOBLE Liliana, - "Streamline of producing knitted products for children", Annals of the University of Oradea, "Fascicle of Textiles, Leatherwork", volume XX, 2018, ISSN 1843 – 813X, Editura Universităţii din Oradea, 2019, pg.19-22.

[6] Bohm G., Șuteu, M.D., Doble, L., Albu A. - "Improving the aesthetic aspect of a knitted product for women" Annals of the University of Oradea, Fascicle of Textiles, Leatherwork, issn 1843-813x, Oradea, volume XIX, 2018, no. 1, pp. 25-30.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

DESIGN OF ADAPTED FUNCTIONAL PRODUCTS BASED ON THE ANTHROPOMORPHOLOGICAL PARTICULARITIES OF PREMATURE CHILDREN

DANILA Victoria[1], CURTEZA Antonela[2], BALAN Stela[3]

[1, 2]„Gheorghe Asachi" Technical University of Iasi-Romania, Faculty of Industrial Design and Business Management, Blvd. Mangeron, No. 59A, 700050, Iasi, Romania
victoria.danila@mctt.utm.md, antonela.cuteza@tex.tuiasi.ro

[3]Technical University of Moldova, Faculty of Textile and Poligraphy, Stefan cel Mare 168, 2004-MD, Chisinau, Republic of Moldova, Email: stela.balan@adm.utm.md

Corresponding author: Victoria Danila, victoria.danila@mctt.utm.md

Abstract: *The article presents the results of studies on the analysis of anthropomorphological features of premature babies and aspects related to the design of clothing for premature babies in the intensive care unit. The aim of this research lies in the development of the following elements: the definition of prematurity groups and describing the data necessary initial design (anthropomorphological characteristics of the group of carriers). The anthroporphological indicators taken by the medical professionals were identified and analysed. Finally, the aspects related to the elaboration of functional clothing products targeted for premature babies in medical incubators were presented, combining the comfort for the child and the support of the necessary medical procedures. The theoretical significance of the work performed resides in a study based on the research of the user's categories, of their degree of development. In order to solve the problems in the design of functional clothing adapted for premature infants, the study results will serve to develop the range of clothing for premature babies in the light of their characteristics morphofunctional development. This product will help reduce discomfort; to improve motor and cognitive activity; to improve the quality of life for a premature baby and his parents. The design of functional products adapted for premature babies based on initial scientifically substantiated data will have an ergonomic, economic and socio-human impact on this category of carriers.*

Key words: *prematurity, gestational age, functional clothing.*

1. INTRODUCTION

Designing clothing for premature babies compared to that for children born on term requires specialised knowledge, which includes studying the peculiarities of conformation, proportions and the degree of development in each period.

The World Health Organization (WHO) defines a premature birth as any birth before 37 weeks of gestation completed or less than 259 days from the first day of a woman's last period. That is further divided based on gestational age (GV) [1].

According to the International Classification, the lower limit for declaring a live birth is considered 500 g in weight or/and 22 weeks gestational age. This classification uses the weighted criteria to categorise new-borns: "low birth weight" (LBW - less than 2500 g), "very low birth

weight" (VLBW - up to 1500 g and 1000 g) and "extremely low birth weight" (ELBW - less than 1000 g).

2. DETERMINATION OF THE INITIAL DATA REQUIRED FOR THE DESIGNING OF FUNCTIONAL CLOTHING PRODUCTS FOR PREMATURE BABIES

Initial data required for the design of children's clothing products:

- ✓ information about the wearer - the anthropomorphological characteristic and the particularities of the physical development according to the prematurity group;
- ✓ information about the product - properties, functions and specific requirements imposed, the type of medical manipulation, equipment to which children are involved;
- ✓ information about the materials used.

Anthropomorphological characteristic of the carrier group

The assessment of neonatal maturity is a theoretical notion that relates the process of growth and differentiation to the temporal chronological criterion. The idea of maturity for gestational age is meant to achieve a certain somatic and functional development in relation to the accepted standards for that gestational age.

When are compared the somatic development of the children being assessed by the anthropometrical data (weight, waist, skull perimeter) and the chronological data, it was established that there is a correlation expressed through the intrauterine growth curves (fig. 2). On these graphs, the new-borns who developed according to the gestational age are placed between the 10th and 90th percentiles (± 2 standard deviations). Older children for gestational age are above the 90th percentile, and below the 10th percentile are young babies for gestational age (with intrauterine growth retardation). Older babies for gestational age are above the 90’th percentile, but below the 10’th percentile are young babies for gestational age (with intrauterine growth retardation).

Each clinical examination will mandatory include the growth monitoring by dynamic tracking of the cranial perimeter, weight and waist. The corresponding creation curves target the evaluation parameters. In the first two years of life, there are different patterns of growth between the full-term and premature new born; thus, at birth, we evaluate anthropometric data using Lubchenco curves and then use growth curves specific to preterm babies [2].

The Intergrowth-21 study proposes the use of growth curves for premature up to 64 weeks VPM, after which the WHO growth curves can be consulted [3]. Intrauterine growth curves (Fig. 1) [2] provide idealised guidelines for monitoring the growth of preterm babies. Premature birth has many variables that can affect growth. However, However, using the WHO International Growth Standard, it is suggested to adjust that postnatal growth to gestational age at birth, and all children assessed.

Each of these new-borns may have gestational age (AGA), small gestational age (SGA) or large gestational age (LGA) weight. For a correct assessment, respectively, the classification of the new born in the mentioned categories, the weight index (WI) will be calculated using the formula presented in table 1.

Table 1: *Weight index in premature babies*

$WI = \frac{\text{The weight (g)}}{\text{Talia}^3\text{ (cm)}} \times 100$	AGA, IP =2,3-3 SGA, IP< 2 LGA, IP>2,3 **Premature new born**

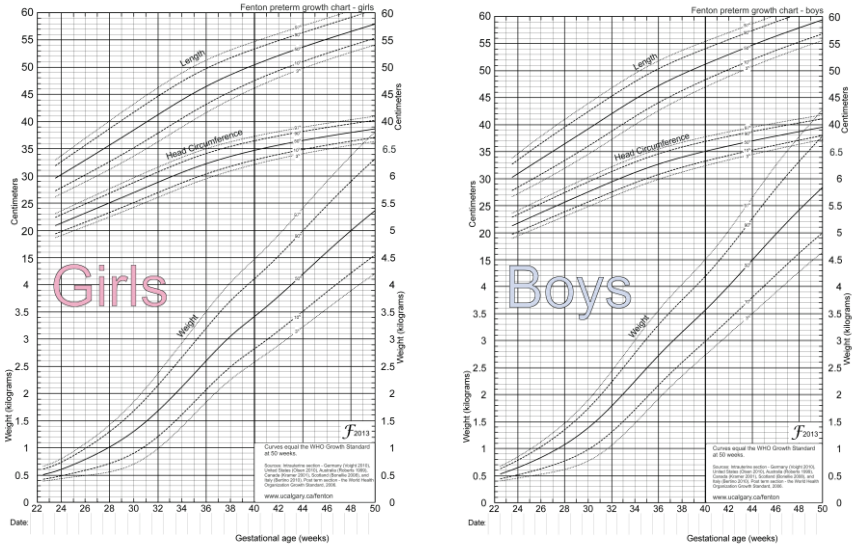


Fig. 1: *Infant fetal growth curves for preterm infants*
Source: https://bmcpediatr.biomedcentral.com/articles/10.1186/1471-2431-3-13

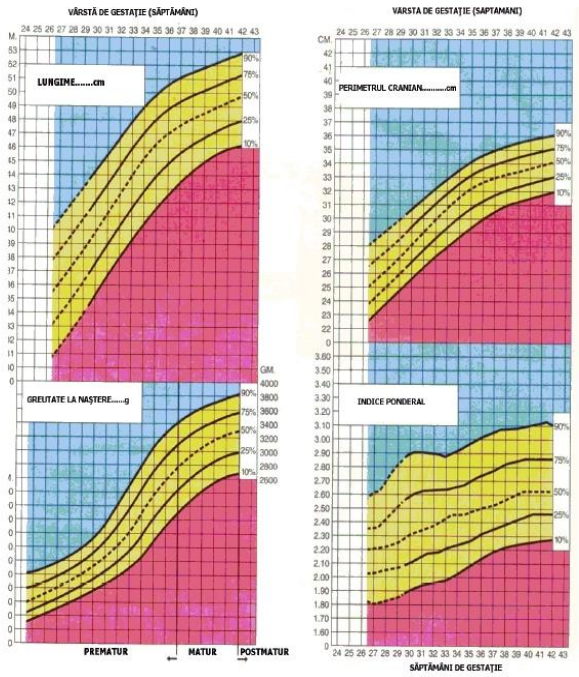


Fig. 2: *Intrauterine growth curves (after Lubchenco)*
Source: http://legislatie.just.ro/Public/DetaliiDocumentAfis/132250

3. RESEARCH METHODS USED

The research methodology focused on the analysis and examination of medical records and descriptions made by medical personnel, of the morphometric and physiological particularities of 500 premature babies. The importance of the collected data will serve for the design of ergonomic products adequate dimensionally to the user group.

4. EXPERIMENTAL RESEARCH

The body of the baby is subject to the effort of adaptation to a new living environment, with numerous transient phenomena. This involves a series of rapid changes, most of them predictable [4]. As indicators that characterise the physical development of the premature baby are the global morphological indicators: the waist, the perimeter of the chest and the body mass, which are supplemented by the indicator that establishes the cranial perimeter [5].

In case of a rapid postnatal (in urgent situations) estimation of gestational age is required, it is highly recommended that the neonatologist estimate VG using a fast score to assess the maturation of morphological features (Table 3) [6].

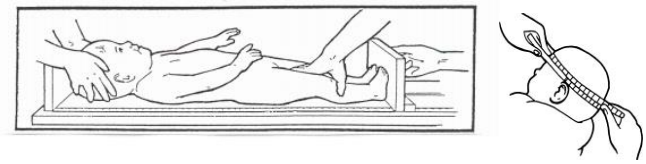
Table 3: *Rapid determination of gestational age using morphological features (adapted from Gomella TL: Neonatology On-call problems)*

Gestational age	Plantar growth	Mammary gland areola dimensions)
GA < 36 weeks	One or two transverse plantar ridges, ¾ posterior leg without crests.	2 mm
GA 37-38 weeks	Create multiple on the previous 2/3 of the plant, heel without ridges.	3-4 mm
GA > 39 weeks	The whole plant covered with ridges.	7 mm much more

Below is attached the anthropometric data presented by the medical institution „Spitalul Municipal Materinitatea Nr. 1" from Chisinau for the period 2015-2018. Their values were analysed and grouped according to the degree of prematurity.

Weight, length, head circumference and chest circumference were measured within 12 hours of birth. Anthropometric data were taken using methods and equipment recommended for this category of new-borns [7].

The measurements were recorded after being taken three times (with the error range for weight - 0.5g; length - 0.4cm; perimeter of the head - 0.4cm ; perimeter of the chest – 0.4cm) by two anthropometrists. The perimeter of the rib cage and the cranial perimeter are measured with the centimetre ribbon (fig. 3), having as reference points the axillary points and the nipples. The cranial perimeter is passed around the head at the level of the external occipital protuberance and the glabella. Values vary depending on the degree of prematurity.



a b

Fig. 3: *How to take over the main anthropometric indicators: a – perimeter of the chest, b – cranial perimeter*

Body mass is determined using a children's scale (fig. 4). It is mentioned that during the follow-up period, it is recommended to weigh the child at the same time of day and in the same physiological state (preferably in the morning on an empty stomach). Before performing the measurements, the scale is balanced, a clean diaper is weighed, and the child is placed entirely naked on the scale, lying on his back.

Fig. 4: *How to correctly to check the weight of the body*

According to the analysis carried out for the period 2015 - 2018, the majority of the children born prematurely who have the birth weight between 2080-2660 g, with the body length of 42.8 - 50.6cm, with the perimeter of the head of 30.8 - 34.4cm and the chest perimeter of 31.8 - 35.4cm, which represents the gestational age category at week 32 - 37.

The main objective was achieved by identifying the anthropometric parameters, which are 4 in number: body weight(birth weight), body length, head perimeter and chest perimeter. The premature children with the highest birth weight are from the first group of prematurity according to the value weight of the dimensional characteristics for the analysed sample.

Premature babies with very low birth weight and extremely low birth weight especially new-borns less than 37 weeks gestational age. Those are characterized by a slower rate of body weight gain in the first two months of life, and the average rate is significantly lower compared to children aged gestational age 37 and older (Table 4).

Table 4: *Dynamics of anthropometric indicators - body mass and body length in the first year of life in children born at different gestation levels*

Age, months	**GA > de 37 weeks**		**GA < 37 weeks**	
	The length, cm	**Body mass, gr.**	**The length, cm**	**Body mass, gr.**
3	57,6±0,4	5320±90	51,2±1,3	3980±230
6	65,0±0,2	7350±90	58,5±1,3	6250±230
9	70,0±0,4	8820±100	67,0±1,4	7670±270
12	74,8±0,5	9710±100	71,5±1,8	9120±290

The change of body proportions in the process of raising the child occurs unevenly, so for premature babies are characterized by the following features of conformation and proportions: 1) physically disproportionate (relatively short neck and limbs, relatively large head); 2) predominance of the brain skull over the face; 3) the bones of the skull are soft, supple, the sutures and fountains

are open; 4) auricle underdevelopment; 5) lanugo abundant throughout the body, pronounced lubricant such as cottage cheese; 6) the umbilical ring is moved to the chest; 7) The external genitalia of girls and boys are not well-formed.

The analysis of the morphological features of premature babies served as a theoretical basis for the development of appropriate products for the analysed segment. Regarding the presented results, we conclude that there is a need for a new approach in the design of children's clothing with a flexible structure. Those will fit the following design principles: the principle of interchangeability of functional elements; the principle of universality of functional elements; the principle of multifunctionality of the elements; the principle of morphological transformation.

Thus, for the elaboration of functional products for premature children, the following aspects were taken into account: the dynamic modification by categories and degrees of prematurity of the anthropometric indicators; modification of the constructive parameters of the basic patterns for baby's clothing products depending on the dynamics of changes in dimensional indicators by gestational age; the compositional-constructive means of prolonging the life cycle of baby's clothing products.

5. CONCLUSION

The analysis of anthropometric data of premature babies is the primary source for the elaboration and development of standard constructions adapted to their needs. The clothing products are adapted to the needs of the wearer group, depending on the degree of prematurity. The primary purpose is to meet the requirements of safety, comfort, performance and easy access to the baby's body. Proper care through the easy use of medical devices, without disturbance and discomfort for premature babies, will be possible only through the use of these clothing units.

REFERENCES

[1.] Howson CP, Kinney MV, Lawn J., „*Born Too Soon: the global action report on preterm birth*", March of Dimes, PMNCH, Save the Children, WHO; 2012.

[2.] Fenton preterm growth chart. Editor: BMC Pediatrics, [Online]. Available: https://live-ucalgary.ucalgary.ca/resource/preterm-growth-chart/preterm-growth-chart

[3.] José Villar, Francesca Giuliani, Zulfi qar A Bhutta, „*Postnatal Growth Standards for Preterm Infants: The Preterm Postnatal Follow-up Study*" of the INTERGROWTH-21st Project, Lancet Glob Health2015; 3: e681–91.

[4.] Als H, Lawhon G, Duffy FH, McAnulty GB, Gibes-Grossman R, Blickman JG., „*Individualized developmental care for the very low-birth-weight preterm infant. Medical and neurofunctional effects*". JAMA. 1994, Sep 21; 272(11):853–8. Als H. A new era of newborn intensive care. In: The Psychological Development of Low Birthweight Children Advances in Applied Development Psychology. (Advances in Applied Development Psychology). p. 341-388.

[5.] Постановление Главного государственного санитарного врача РФ от 17 апреля 2003 г. № 51 «*О введении в действие санитарно-эпидемиологических правил и нормативов СанПиН 2.4.7./1.1.1286-03*». (Decretul medicului șef sanitar de stat al Federației Ruse din 17 aprilie 2003 nr. 51 „Cu privire la aplicarea regulilor și normelor sanitare și epidemiologice din SanPiN 2.4.7./1.1.1286-03"). [Online]. Available: http://base.garant.ru/4179177/#ixzz3L0iZM15O

[6.] Gomella TL. „*Neonatology – Assessment of Gestational Age*" in Management, Procedures, OnCall Problems, Diseases, and Drugs, 6th ed, 2009, p. 23-31.

[7.] Athropometry guideline. Paediatrics, [Online]. Available: http://www.adsa.org.za/Portals/14/Documents/Clinical20Guideline20Anthropometry.pdf

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

STUDY OF THE EXPERIMENTAL CONDITIONS IN BIOSCOURING TREATMENT OF COTTON-HEMP BLENDED FABRICS

DOCHIA Mihaela[1], GAVRILAŞ Simona[2], SZABO Monica[3]

[1] "Aurel Vlaicu" University of Arad, Research Development Innovation in Technical and Natural Science Institute, Postal address, 310330, 2-4 Elena Dragoi Street, Arad, Romania, E-Mail: dochiamihaela@yahoo.com

[2] "Aurel Vlaicu" University of Arad, Faculty of Food Engineering, Tourism and Environmental Protection, Department of Technical and Natural Sciences,
Postal address, 310330, 2-4 Elena Dragoi Street, Arad, Romania, E-Mail: simona2213@yahoo.com

[3] "Aurel Vlaicu" University of Arad, Faculty of Engineering, Department of Automation, Industrial, Textile and Transportation Engineering, Postal address, 310330, 2-4 Elena Dragoi Street, Arad, Romania,
E-Mail: szabomonica@yahoo.com

Corresponding author: Gavrilaș Simona, E-mail: simona2213@yahoo.com

Abstract: *The main objective of the pretreatments applied in textile industry is to remove all native impurities present in the natural fibers. The nature and quantity of noncellulosic compounds present in hemp and cotton fibers is variable. These have hydrophobic characteristics which negatively influence the fabrics hydrophilicity. Depending on their nature these can be eliminate by a simple wash procedure or if we think at those of chemical nature more advance methods need to be performed.*
In the study, the result obtained after applying a bioscouring treatment on 50 % of hemp-50 % of cotton blended fabrics are presented. The aim of the procedure was the elimination of physical and chemical compounds presented in the fabric for the improving of its technological characteristics.
A pectinolytic commercial product (Beisol PRO) was used, varying its concentration. The reaction bath contained phosfate buffer solution of 0.1 M and pH 8, 2 g/L complexing agent (EDTA) and 0.5 % surfactant (Denimcol Wash RGN). The bioscouring treatments were performed using a central, rotatable second order compound program with two independent variables: Beisol PRO concentration (between 1-3 % o.w.f) and exposure time (15-55 minutes) at 55°C. The liquid to faric ratio was 20:1. The following parameters were determined: weight loss, hydrophilicity, calcium content, whiteness and yellowness index.
The obtained results underline the efficiency of the considered method. The pectinolytic procedure applied on the hemp-cotton materials has contributed to pectin hydrolysis and optimum removal of undesired impurities with minimum fabrics degradation.

Key words: *cotton-hemp material, enzymatic treatment, pectinolytic commercial product, calcium quantity*

1. INTRODUCTION

The main objective of the pretreatments applied in textile industry is to remove all native impurities present in the natural fibers to improve their technological properties. The nature and quantity of noncellulosic compounds present in hemp and cotton fibers is variable. These have hydrophobic characteristics which negatively influence the fabrics hydrophilicity. Depending on

their nature, these can be eliminated by a simple wash procedure or if we think at those of chemical nature more advance methods need to be performed.

Classical scouring presents a series of advantages but also some important disadvantages. The alkaline treated fabrics show improved characteristics as wettability or chromatic indexes [1], but also a mass loss increase which is determined by advanced fiber degradation. This last aspect influences the materials behaviour in future processes by affecting their chemical and thermal stability [2]. Another aspect which should not be neglected is the environmental one. The scouring treatment implies utilisation of large quantities of harmful chemicals and hight costs.

A viable alternative is represented by the bioscouring. The procedure consists in application of specific mixture of enzymes in order to hydrolase principally the pectins and the lignin presented in the bast fibers [3, 4]. Using modern scanning technologies, it has been proved that the ecofriendly methods improve fibers surface smoothness degree by advanced impurities elimination with less or non fiber degradation [5].

2. EXPERIMANTAL PART

For the pretreatmens were used 13 models, varying the enzyme quantity and treatment time. The determined parameters value also included the raw blended fabric and water washed one (the control).

The hemp-coton blended fabric has the following characteristics: width (120 ± 3 cm), weight (220 ± 10 g/m^2), warp density (10 fibers/cm), weft density B (10 fibers/cm), Nm 14 for warp direction and 50 % of hemp + 50 % of cotton yarn, Nm 14 for weft direction, 100 % of cotton yarn.

All tests were initially prepared for the bioscouring. These were washed at 100°C in an AATCC standardized Lander-Ömeter, model M228-AA from SDL Atlas Company-US [4], air dried, conditioned in controlled atmosphere and weighed. The bioscouring treatment steps are presented in Figure 1.

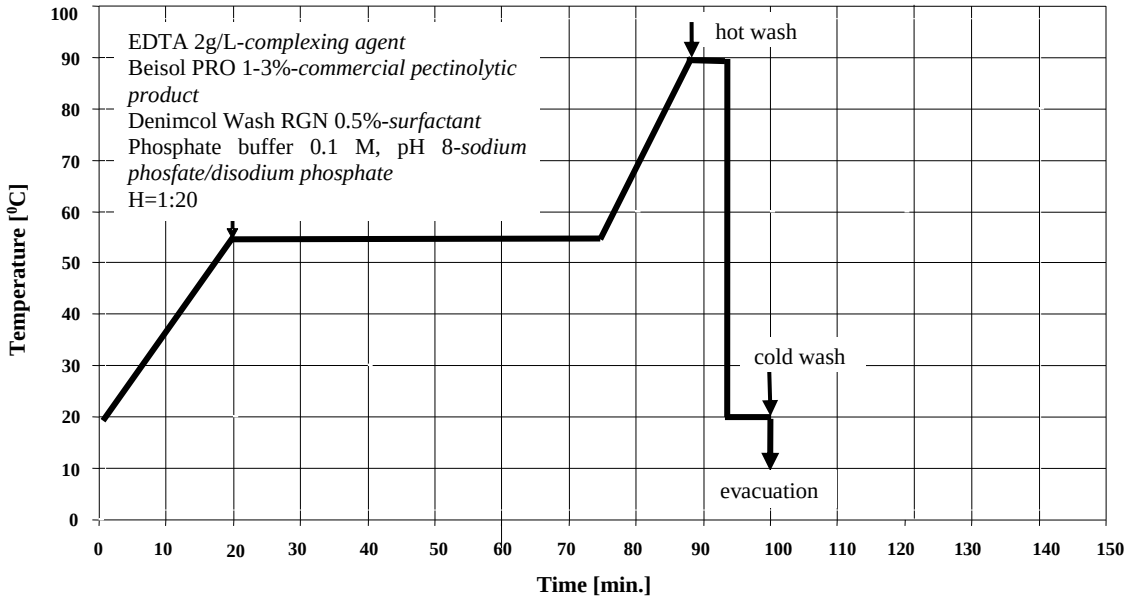


Fig. 1: *The bioscouring diagram*

The efficiency of the proposed pretreatment procedure was verifyed establishing the value of some important reference parameters: hydrophilicity, weight loss, calcium quatity, whiteness and yellowness degree.

RESULTS AND DISCUSSIONS

The values registered for hydrophilicity after enzymatic treatments are presented in Table 1.

Table 1: *Hydrophilicity registered for samples enzymatically treated in different conditions*

Sample	Enzyme concentration [%]	Treatment time [min.]	Hydrophilicity [s]
1	1.30	21.00	1.50
2	2.70	21.00	1.45
3	1.30	49.00	0.85
4	2.70	49.00	0.80
5	1.00	35.00	1.60
6	3.00	35.00	1.15
7	2.00	15.00	1.80
8	2.00	55.00	0.98
9	2.00	35.00	1.40
10	2.00	35.00	1.48
11	2.00	35.00	1.35
12	2.00	35.00	1.39
13	2.00	35.00	1.46
Control	-	60.00	120.00
Raw fabric	-	-	>500.00

The data presented in Table 1 show the effieciency of the pectinolytic treatment, with hydrophilicity values under 2 sec. (maximum value is **1.80** sec. at *2* % enzymatic product concentration and *15* min. treatment time). All bioscoured samples have a very good hydrophilicity compared with the control (*120.00* sec.) and raw fabric (*>500* sec). This parameter is relevant for further finishing processes and final destination of the material. The bioscouring process improves the fabrics cleaning processes and also contributes to lower fiber degradation.

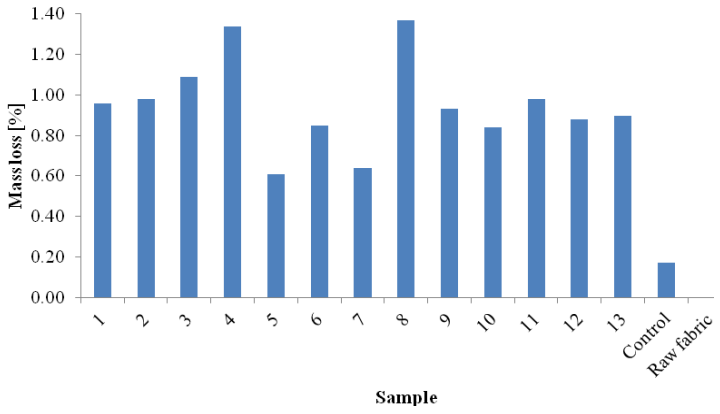


Fig. 2: *The mass loss of samples enzymatically treated in different conditions*

As shown in Figure 2, the higher mass loss is observed for samples *4* and *8* namely for the longest treatment time (*49* respectively *55* minutes). In all cases, it can be observed a linear dependence between the weight lost and the process parameters *enzyme quantity* and *exposure time*. Independent of the two variables the presented values decrease is lower than 1.5 %. Our results are sustained by data presented in the literature. The eco friendly treatments have a lower effect on the cellulosic structure of the natural fibers compared with the classical alkaline one [6]. This is a desirable outcome regarding the pretreatments applied on natural fibers, more accurate to remove non cellulosic components and with minimum cellulose degradation.

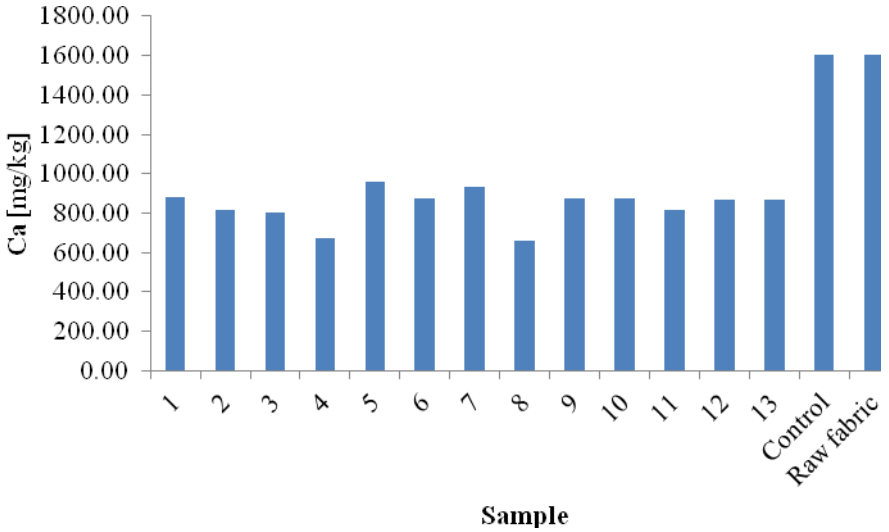


Fig. 3: *The calcium quantity determined for samples enzymatically treated in different conditions*

Hemp fibres have a heterogen chemical structure. Pectins represent around 1% of the other noncellulosic components [7]. They are presented in the cuticula and primarily plant cell walls. From chemical point of view pectins contain residues of 1, 4-linked α-D-galactosyluronic acid [8] which form three important polysaccharides chains: homogalacturonan, rhamnogalacturonan-I, and substituted galacturonan, linked throught Ca^{+2} bridges. Their solubilisation has been evidenced after treatment with aqueous buffers solutions and calcium ions chelators [8]. Our pretreatmens had been made using phosphate buffer 0.1, pH 8 in presence of EDTA. From figure 3 it can be observe that the quantity of Ca presented in the bioscoured samples is with approximately 50% lower compared to the untreated samples. In these situation, we can underline the hydrolytic efficiency of the pectinolytic treatment in removing the pectins from the fibres.

Using the Datacolor 500 spectrophotometer the whiteness and yellowness degree was measured for all enzymatic treated 13 samples, the control and the raw one. The two indexes were automatically calculated by the Datacolor Tools 2.0 software [7]. The reflectance (R%) was measure at 420 nm. The values obtained were compared with a barium sulphate white standard. In all cases the whiteness index registered has higher values compared with the control and raw fabric. Between the pretreated samples, the two indexes variation is lower but in compare with the control the whiteness index is almost two times higher reaching 59.02% in case of sample 8. Regarding the yellowness, the minimum value is approximately 50% of the one determined in case of the raw material.

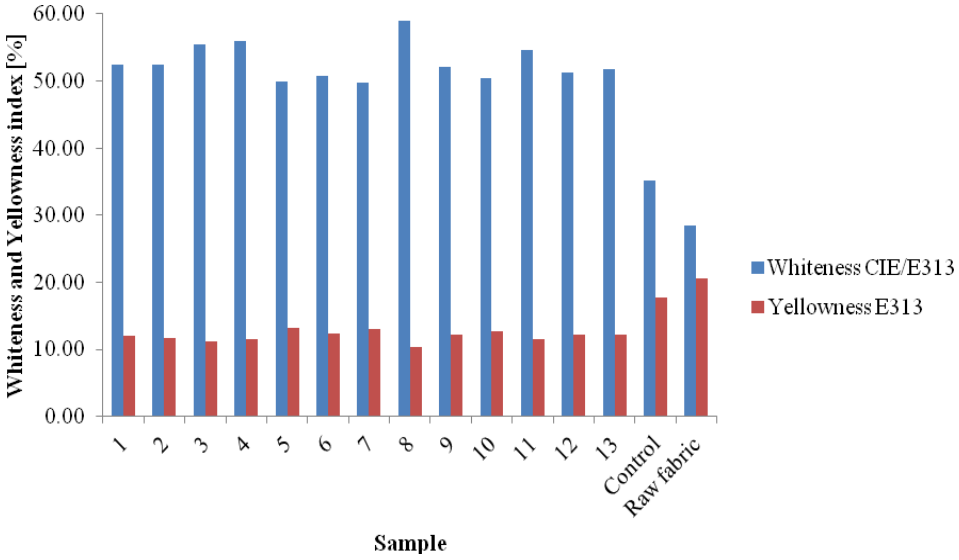


Fig. 4: *The whiteness and yellowness index for samples enzymatically treated in different conditions*

5. CONCLUSIONS

Summarizing the results of the investigations made, we can conclude the following:

- For all enzymatic treated samples was demonstrated the efficiency of the applied treatments. All hydrophilicity values are under 2 sec. (the higher value is 1.80 sec. at 2 % enzymatic product concentration and 15 min. treatment time) compared with the control (120.00 sec.) and raw fabric (>500 sec). These show an important wettability increase.
- As consequence of the proposed procedure we also notice a mass loss in all 13 cases analyzed. For sample *8* this parameter value (**1.37**%) is with 87.6% higher compared to the control sample (0.17%). All determined values are lower than **1.4**%. This is an effect of a proper removing of non cellulosic constituents and also a low degradation of the material.
- The decrease of calcium quantity presented in the bioscoured samples evidence the positive influence of the reaction mixture which contained phosphate buffer, EDTA as chelating agent and pectinolytic complex which led to pectin hydrolysation and calcium ions releas.
- The bioscouring treatment positively influenced the values of the chromatic indexes determined. The whiteness index reached almost 60%. The yellowness index value is approximately half from the control one.

ACKNOWLEDGEMENT

This work was supported by a grant of the Romanian National Authority for Scientific Research and Innovation, CNCS-UEFISCDI, project number PN-II-RU-TE-2014-4-1370, and

„Centru de Cercetare în Științe Tehnice și Naturale-CESTN" co-funded by European Union through European Regional Development Fund Structural Operational Program "Increasing of Economic Competitiveness" Priority axis 2. Operation 2.2.1. POSCCE Nr. 621/2014 POS-CCE.

REFERENCES

[1] M. Dochia, C. Sîrghie, M. S. Pernevan, M. Pustianu, " *Study regarding the influence of the bioscouring treatment in ultrasound on 60% cotton+40% hemp materials. PART II. Study regarding the influence of bioscouring treatment followed by a whitening treatment using various methods*", Annals of the University of Oradea Fascicle of textiles, leatherwork, vol. XN, No. 1, ISSN 1843-813X, pp. 99-102, 2014.

[2] S. Ouajai, R.A. Shanks, "*Composition, structure and thermal degradation of hemp cellulose after chemical treatments*", Polym. Degrad. Stabil., 89, 327-335, 2005.

[3] V. Rajulapati, A. Dhillon, K. K. Gali, V. Katiyar, A. Goyal, "*Green bioprocess of degumming of jute fibers and bioscouring of cotton fabric by recombinant pectin methylesterase and pectate lyases from Clostridium thermocellum*", Process. Biochem., 92, 93-104, 2020.

[4] G. Garg, S. S. Dhiman, R. Gautam, R. Mahajan, A. K. Patra, J. Sharma, "*Bioscouring of jute fabric by cellulase-free alkalo-thermostable xylanase from Bacillus pumilus ASH*", J. Mol. Catal., 85-86, 43-48, 2013.

[5] E.S. Abdel-Halim, W. Konczewicz, M. Zimniewska, S. S. Al-Deyab, Mohamed H. El-Newehy, "*Enhancing hydrophilicity of bioscoured flax fabric by emulsification post-treatment*", Carbohydr. Polym., 82, 195-201, 2010.

[6] E.S. Abdel-Halim, H.M. Fahmy and M. M.G. Fouda, "*Bioscouring of linen fabric in comparison with conventional chemical treatment*", Carbohydr. Polym., 74, 707-711, 2008.

[7] J. P. Manaia, A. T. Manaia and L. Rodriges, "*Industrial Hemp Fibers: An Overview*", Fibers, 7, 106, 2019, doi:10.3390/fib7120106.

[8] B. L. Ridley, M. A. O'Neill, D. Mohnen, "*Pectins: structure, biosynthesis, and oligogalacturonide-related signaling*", Phytochemistry, 57, 929-967, 2001.

[9] ASTM Method E313-05.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

CHARACTERISATION OF CARBON TAILORED FIBRE PLACEMENT REINFORCED COMPOSITES

DOMENECH-PASTOR Jorge[1], GONGA Eloi[1], CAMPOS Juan[1], DIAZ-GARCÍA Pablo[2], GARCIA Daniel[3]

[1] Asociación de Investigación de la Industria Textile – AITEX, Smart Textiles Research Group, Postal address, ES03801 Alcoy, Spain, E-Mail: jdomenech@aitex.es; egonga@aitex.es; jcampos@aitex.es

[2] Universitat Politècnica de València (UPV), Escuela Politécnica Superior de Alcoy, Ingeniería Textil y Papelera (DITEXPA), Plaza Ferrándiz y Carbonell 1, 03801, Alcoy, Spain, E-Mail: pdiazga@txp.upv.es

[3] Universitat Politècnica de València (UPV), Escuela Politécnica Superior de Alcoy, Instituto de Tecnología de Materiales (ITM), Plaza Ferrándiz y Carbonell 1, 03801, Alcoy, Spain, E-Mail: dagarga4@epsa.upv.es

Corresponding author: Domenech-Pastor, Jorge, E-mail: jdomenech@aitex.es

Abstract: *It is known that carbon reinforced composites are stronger at the orientation of the fibers. However, plain woven fabrics (PWF) are limited in terms of fibre orientation to 0º and 90º, except axial woven fabrics which could guide and orient fibres in some angles e.g.: 30º 45º 60º, etc. In this sense, material isotropy is increased by overlapping fabrics with 2D and 3D fabrics structures. For this reason, it is interesting to consider the development of customized composites with fibers in curved orientations that adapt to the design and shape of the final product, in order to improve the mechanical properties and behaviour of a piece. Orienting fibres in multiple directions offer a new perception to study the anisotropy of carbon fibre reinforced polymers.*

Tailored Fibre Placement (TFP) used in embroidery can produce textiles with curvilinear designs and align these reinforcing fibres in accordance with the product design, shape and geometry. TFP allows the adaptation of fibres to holes and locate the fibres in around the edge of the hole. This demonstrate the importance of stress and loads and the orientation of the fibres.

This study characterises and analyses the mechanical properties of carbon tailored fibre placement composites under tensile vertical efforts of a curvilinear design in comparison with unidirectional fibre placement composites.

Key words: *embroidery, polymers, anisotropy, textile, tensile, Resin Transfer Molding*

1. INTRODUCTION

Composite materials can satisfy multiple needs as they are very diverse in nature. The variety of options available such as type of fiber, resin, tools, processes and finishes allow to manufacture almost any composite part for almost any application. Combining these materials with the tremendous strength, rigidity, durability, and light weight that composites offer, is one of the reasons why in the last decades, the interest in polymeric composites is replacing other materiales such metal, wood and ceramics [1], [2].

Fiber reinforced polymeric composites are being used due to their high strength and low weight advantages in many industries such as automotive and aerospace [3]. However, one of the

main problems using fiber reinforced polymeric composites is that the carbon fibre fabrics dispose the fibers perpendicularly and unidirectionally, and when the pieces show different shapes, to obtain the right properties it is necessary to overlap several reinforcing fabrics.

In the composite industry, generally glass and carbon fibres are most widely used materials because of their high strength to weight ratio [4]. Nevertheless, carbon fibres are the predominant high strength and modulus reinforcement used in the fabrication of high-performance polymer-matrix composites. Carbon fibres typically contain more than 90 weight percentage of carbon and have remarkable properties. In general, they include high tensile strength (up to 7 GPa), good compressive strength (up to 3 GPa), high tensile modulus (200 up to 900 GPa), low density (1.75 up to 2.18 g/cm3), good temperature resistance, low thermal expansion, good electrical and thermal conductivity, and chemical resistance [5], [6]. In this sense, the combination of carbon fiber with polyester resin is something that has already been widely studied in the field of engineering and materials. Traditionally, these composites have been reinforced with plain woven fabrics of carbon fibers. These woven fabrics are limited in terms of the of fibers aligment since they can only vary the ligament causing visual or ornamental effects; and the only way to modify the orientation of the fibers is through axial fabrics that allow the fibers to be oriented at certain angles of inclination, but all of them in straight lines and unidirectional, without curves [7] [8]. This overlapping increases the time of processing the composite and it depends on the experience of the worker to dispose the reinforcing fabrics. Carbon reinforced composites are stronger at the orientation of the fibers [9]. For this reason, there are several studies of double and multiple fabrics made with axial fabrics that have managed to improve the isotropic behavior of the composite by overlapping reinforcing fabrics [10] [11]. The improvement in mechanical properties and behaviour by combining multiple fabrics with various fiber orientations and by aligning them in the stress direction is evident. However, it entails a high fiber expense and consequently a higher cost of the resulting composite. In this way, it seems evident that plain woven fabrics and traditional weaving technology is insufficient to develop high performance composites, with very concrete and specific applications, since the orientation of the fibers is limited to one direction and certain angles.

These are some of the most common weaving structures. All of them agree that they do not have an arrangement of fibers with curved shapes, arches and that in order to achieve a structure with greater isotropy, layers of fabrics are overlaped on each other. This implies that to achieve a certain behavior of the composite in a certain direction, it is necessary to overlap several fabrics, increasing the amount of fiber and the cost of the composite. This do not happen when using embroidery technology TFP (Tailored Fibre Placement), since it allows to manufacture composite with variable axial geometry, achieving laminar structures with fibers aligned in multiple directions in order to achieve the desired mechanical performance [12].

2. EXPERIMENTAL

2.1 Objetives

This study aims, without using plain fabrics, to evaluate the behaviour under vertical tensile strength efforts of tailored fibre placement reinforced polimers, produced by embroidery technology in two different structures. One with fibres oriented in horizontal and vertical direction (simulating woven fabrics) named as PWF1 and another with fibres with curvilienear orientations named TFP1.

2.1 Materials

The carbon fibre used to develop the composite samples was model TC-35 6K multifilament of 400TEX from manufacturer Tairyfil. This carbon fibre was embroidered on a polypropylene nonwoven substrate of 0.25mm thickness and 30g/m2. The placement of the carbon yarns on the

non-woven substrate is done covering the entire surface of the substrate, either vertically and horizontally in the first example (PWF1) or vertically and curvilinear-waved-horizontally in the second (TFP1). The weight per square meter of the products obtained does not present significant differences. The resulting PWF1 embroidered substrate have a weight per square meter of 491,52g/m^2 and the TFP1 479,86g/m^2.

As matrix of the composite it has been used a polyester DCPD (DiCycloPentadiene Resin) resin, RESICHIM 209 produced by Gazechim.

2.1 Equipment

The equipment necessary for the formation of the composite was, on the one hand, the RTM (Resin Transfer Moulding) equipment assisted by vaccumm to produce the composite; model CIJECT TWO provided by Composites Integration. On the other hand, an embroidery machine has been used to place carbon fibre on a PES nonwoven substrate. Tailored fibre placement was done with an embroidery machine from ZSK manufacturer, model SGZA 0109-825. In order to impregnate the reinforcing fabric (500x500mm) with the PES resin, the vacuum pump was used.

To cut the samples according to UNE-EN ISO 527-1:2019 a CNC (Computer Numerical Control) machine model 200W Mini CNC 3040 3 axis provided by ZHONG HUA JIANG was used.

For the tensile strength test, a universal testing machine, from the manufacturer IBERTEST, model ELIB-50-W, has been used. Samples with a section of 10x1.2mm were used.

2.2 Processes

Unlike the conventional approach of weaving the fibers of a composite in a perpendicular layout and then cutting the fabric to the required shape, the TFP technique organizes the fibers by aligning them exactly where they are most needed for structural performance and stitching them on a base substrate. This technique offers freedom of fibre placement, allowing fibers to be positioned in the optimal directions to transport loads, ensuring stability during processing and reducing fiber waste [13], [12]. The fibre deposition technique is carried out using a fibre guider that, by means of an oscillating zig-zag movement, fixes the fiber on a textile woven or non-woven substrate. This technique also allows the use of different thermoplastic fibers combined with structural elements like glass or carbon fibers. However, in this study only carbon fibres were used during the embroidery. It should be noted that for composite development the TFP technique must be combined with a subsequent closed-molding processes such as RTM or vacuum assisted resin infusion [14].

***Fig. 1**: PWF1 embroidering process, RTM equipment and composite plate obtained*

The process called RTM (Resin Transfer Molding) is the process of manufacturing composites in a rigid closed mold composed of two parts: male and female. The dry textile reinforcement is introduced inside the mold and it is hermetically closed so that there is no pressure

loss. The resin is injected from a lateral of the mold, directly into the reinforcing fiber package and the pressure generated by the injection causes the mold to fill. The mold has outlets at the furthest points from the injection hole, allowing the air inside the mold to escape and allow the resin to take its place, impregnate the reinforcing fibres and cover the whole surface [15], [16].

The RTM mold closure is mechanically assisted with screws and bolts. On the other hand, the mold must be rigid so as not to deform and resist the forces generated by the injection process. The mold is made of aluminium and has a sensor to control the temperature, which allows to accelerate the curing of the resin and reduce the cycle time. The injection is made from a single lateral point and the resin flows through a distribution chanel around the perimeter of the mold. In a central point of the mold is located a vacuum channel to evacuate the excess resin to the catch pot. In the case estudied, it was used a DCPD resin with low styrene content which prevent workers to be in contact with VOC (volatile organic compounds) from the resin. But in other occasions, the RTM process also allows resin loaded with low shrinkage additives to be used to achieve an excellent surface appearance of the finished part [17], [18].

2.3 Results

Two textiles obtained by embroidery processes were tested under vertical tensile strength efforts, because the samples were produced to be tested in that direction. Two designs of fibre placement where studied, one with yarns in vertical and horizontal (PWF1) and another with yarns oriented in vertical direction and curvilinear (TFP1) (Fig.2). Five samples from each design were tested under vertical tensile strength efforts. For the calculation of the tensile values and graphical representation only the 3 most coherent values were considered for this study.

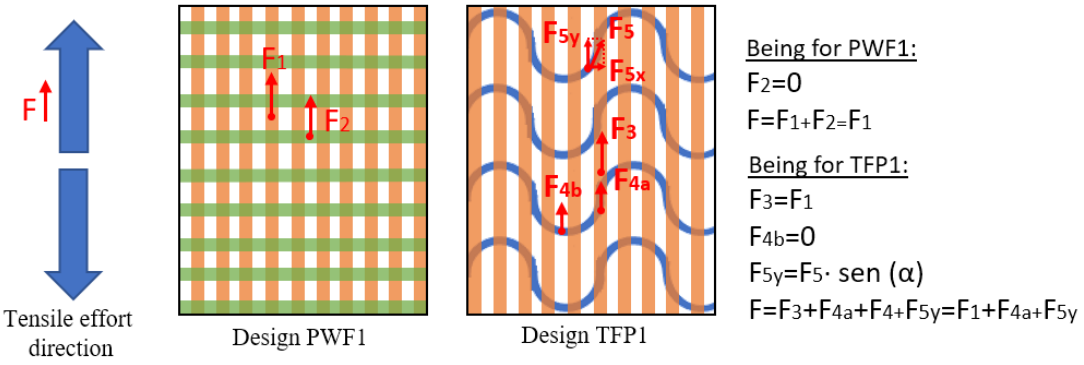


Fig. 2*: Design scheme of reinforce fibres in samples PWF1 and TFP1, and effort applied directions. F1 and F3 applied in orange coloured fibre, F2 applied in green fibres and F4 and F5 applied to blue fibres. Although gaps between threads are seen in the scheme, they do not exist in the sample. The threads are all juxtaposed.*

From the results obtained (Table 1) it is observed that curvilinear designs (TFP1) improve tensile properties as there is an increase in tensile strength from 125.7 MPa for the PWF1 sample to 140.7 MPa for the TFP1 sample, which represents an increase of 11.9%. Regarding the Young Module, a notable decrease can be observed with respect to the reference sample PWF1, going from 6267 MPa to 4371 MPa, which represents a decrease of 30.2%. Finally, regarding elongation, it can be seen how the TFP1 design shows a greater elongation with respect to the reference sample, producing an increase of 39.62%, going from 3.5 for the PWF1 sample to 4.9% for the TFP1 sample.

Table 1: *Tests results*

Sample	PWF1			TFP1		
	Elastic Modulos (Mpa)	Max. Tensile strength (MPa)	Elongation (%)	Elastic Modulos (Mpa)	Max. Tensile strength (MPa)	Elongation (%)
1	5400	113,4	3,4	5400	169,6	5,7
2	6650	150,8	3,3	4214	129,5	4,0
3	6750	112,8	3,7	3500	123,1	4,9
Average	6267	125,7	3,5	4371	140,7	4,9
Standard Dev.	752	21,8	0,2	960	25,2	0,9

5. CONCLUSIONS

Tailored fibre placement embroidery technology allows to improve the behaviour of regular fibre reinforced composite, due to the possibility to align the fibres in the direction of the effort. TFP also offers freedom of designs and structures in comparison with plain oven fabrics and axial woven fabrics where only some angles are possible.

Composites with axial fibre placement like PWF1 have a good behaviour in terms of mechanical properties when efforts are in the same direction than the fibre. In contrast, they obtain bad results when the effort is applied in a different direction (e.g. perpendicular) to the fibre. On the other hand, composites with curvilinear aligned fibres obtain better results due to the superposition of forces and decomposition of loads in normal (vertical and horizontal) forces components phenomenoms along the fibres and interfase of the resin matrix (F_3+F_{4a}+F_{5y}). As there are always some fibres in the direction of the force effort (F). This decomposition and superposition of efforts is the reason why maximum tensile strength is higher in TFP1 than in PWF1, because the aggregated forces F_3+F_{4a}+F_{5y} in TFP1 are higher than F_1 in PWF1.

In the case under study, an improvement of approximately 12% of maximum tensile strength is obtained using the same quantity of fibre in both composites and without increase costs. This increase of 12% can be considered a lot in some industrial domains and can be very important for high technique applications like automotive or aerospace industry. In addition, the TFP1 is less rigid than PWF1 and the TFP1 sample has a more elastic behaviour. Currently, within this promising new line of research, new fabric architectures manufactured by the embroidery machine are being studied with the aim of obtaining composite materials with improved mechanical properties.

ACKNOWLEDGEMENTS

This study has been done in the framework of LIGHTCOMP 2020 project. This project has the support of the Conselleria d'Economia Sostenible, Sectors Productius, Comerç i Treball of the Generalitat Valenciana through IVACE, and is co-financed by the FEDER funds of the EU, within the Operational Program FEDER of the Valencian Community 2014 -2020.

REFERENCES

[1] Matabola, K. P., De Vries, A. R., Moolman, F. S., & Luyt, A. S. (2009). Single polymer composites: a review. *Journal of Materials Science*, *44*(23), 6213-6222.

[2] Capiati, N. J., & Porter, R. S. (1975). The concept of one polymer composites modelled with high density polyethylene. *Journal of materials science*, *10*(10), 1671-1677.

[3] R. Keskin, I. Gocek, G. Ozkoc, "*Polyamide66 composites reinforced with short glass fibers*", Annals of the University of Oradea. Fascicle of Textiles, Leatherwork, No.1, vol. XIV, Ed. Editura Universitati Din Oradea, 2013, pp. 61–65.

[4] YUKSELOGLU S. Muge, CANOGLU Suat, "*Natural fibre composites: a review on flax fibres*", Annals of the University of Oradea. Fascicle of Textiles, Leatherwork, No.1, vol. XVIII, Ed. Editura Universitati Din Oradea, 2017, pp. 137–142.

[5] Chand, S. Review Carbon fibers for composites. *Journal of Materials Science* 35, 1303–1313 (2000). https://doi.org/10.1023/A:1004780301489

[6] da Rocha, R. J. B., Pina, L. M. P., Gomes, M., & Sousa, J. P. (2020). Evaluation of impact resistant composites for aircraft cockpit. *Materiales Compuestos*, *4*(1), 1-9.

[7] Irina, M. M. W., Azmi, A. I., Tan, C. L., Lee, C. C., & Khalil, A. N. M. (2015). Evaluation of mechanical properties of hybrid fiber reinforced polymer composites and their architecture. Procedia Manufacturing, 2, 236-240.

[8] Liang, Y., Wang, H., & Gu, X. (2013). In-plane shear response of unidirectional fiber reinforced and fabric reinforced carbon/epoxy composites. *Polymer Testing*, 32(3), 594-601.

[9] Villegas, D. F., Pedraza-Rosas, S. L., & Toloza-Meza, S. A. (2019, November). Tensile mechanical behavior of a polymeric composite reinforced with 4-axial carbon fiber woven. In *Journal of Physics: Conference Series* (Vol. 1386, No. 1, p. 012034). IOP Publishing.

[10] Warren, K. C., Lopez-Anido, R. A., & Goering, J. (2015). Experimental investigation of three-dimensional woven composites. Composites Part A: Applied Science and Manufacturing, 73, 242-259.

[11] Dai, S., Cunningham, P. R., Marshall, S., & Silva, C. (2015). Influence of fibre architecture on the tensile, compressive and flexural behaviour of 3D woven composites. *Composites Part A: Applied Science and Manufacturing*, 69, 195-207.

[12] Bittrich, L., Spickenheuer, A., Almeida, J. H. S., Müller, S., Kroll, L., & Heinrich, G. (2019). Optimizing variable-axial fiber-reinforced composite laminates: the direct fiber path optimization concept. *Mathematical Problems in Engineering*, *2019*.

[13] El-Dessouky, H. M., Saleh, M. N., Gautam, M., Han, G., Scaife, R. J., & Potluri, P. (2019). Tailored fibre placement of commingled carbon-thermoplastic fibres for notch-insensitive composites. *Composite Structures*, *214*, 348-358.

[14] Gabriel, F., Nebel, D., & Fürst, A. AUTOMATED CONTINUOUS FABRICATION OF LOAD-PATH ADAPTED THERMOPLASTIC FIBER PREPREGS

[15] Shojaei, A., Ghaffarian, S. R., & Karimian, S. M. H. (2003). Modeling and simulation approaches in the resin transfer molding process: a review. *Polymer Composites*, *24*(4), 525-544.

[16] Kendall, K. N., Rudd, C. D., Owen, M. J., & Middleton, V. (1992). Characterization of the resin transfer moulding process. *Composites Manufacturing*, *3*(4), 235-249.

[17] Choi, J. H., & Dharan, C. K. H. (2002). Mold fill time and void reduction in resin transfer molding achieved by articulated tooling. *Journal of composite materials*, *36*(19), 2267-2285.

[18] Chen, B., Lang, E. J., & Chou, T. W. (2001). Experimental and theoretical studies of fabric compaction behavior in resin transfer molding. *Materials Science and Engineering: A*, *317*(1-2), 188-196.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

EVOLUTION AND SOCIAL NECESSITY ASPECTS IN FUNCTIONAL CLOTHING PRODUCTS

FLOREA-BURDUJA Elena[1,3], RARU Aliona[2,3], IROVAN Marcela[1], FARÎMA Daniela[3]

[1] Technical University of Moldova, Faculty of Textile and Polygraphy, 4 Sergiu Radautan Street, Chisinau MD-2000, Republic of Moldova

[2] Technical University of Moldova, Direction of Academic Management and Quality Assurance, 168 Stefan cel Mare Street, Chisinau MD-2000, Republic of Moldova

[3] Gheorghe Asachi Technical University of Iasi, Faculty of Industrial Design and Business, 29 Mangeron Street, Iasi 700050, Romania

Corresponding author: Florea-Burduja Elena, E-mail: elena.florea@mctt.utm.md

Abstract: *The paper presents the functional clothing assortment study results by determining the current areas of its use. It is proposed the thorough study of the clothing product range for people with special needs. The main focus is on disabled people social inclusion which becomes possible thanks to adaptive clothing products. The paper is intended to theoretical knowledge grounding on functional clothing and its production rounds setting. The topicality of the subject is determined by the growing interest of specialists in the field and by the large number, worldwide and local, of people who represent a disability. The paper presents the fundamental notions regarding functional clothing, the modern assortment of functional clothing classification scheme and the scheme of the aimed at assortment design process. The functional clothing products development process stands for the clothes wearing conditions study in the interest of specific technical requirements processing, the dimensional typology data use, the "man-product" system ergonomic research carrying out, the original constructive solutions determining. One of the problems that are trying to be solved in this paper is finding solutions in order to increase the number of products types manufactured while increasing the functional clothing products quality for disabled people. The high-quality functional clothing products obtaining leads to a number increase of constructively made products and technologically manufactured homogeneous products. The design process scheme of clothing intended for disabled people is developed to facilitate the functional clothing products developing process.*

Key words: *people, special clothing, people with special needs, design process*

1. INTRODUCTION

Modern clothing organically combines aesthetic qualities with functional ones.

By the clothing function is meant its role in the man's life. By the clothing product functionality is meant its correspondence to the practical destination.

Functional clothing products are ergonomically designed as ensembles that have minimal inhibitory effect on movement and provide maximum comfort and performance to the user in the wearing process and/or that may have electronic functionality with communication and telemedicine applications. Functional clothing can be apparel that protects people exposed to dangerous

environments during work or sports activities; outfit that facilitate movement and body balance, improve endurance or reduce fatigue in athletes; attire that performs only the aesthetic function such as improving body shapes [1].

A major problem of modern society is people who have special needs of insurance via comfortable clothing products.

It is known that in the world there are one billion disabled people, eighty million disabled people live in the European Union; and in the Republic of Moldova, the estimated number of people with disabilities is 176.1 thousands, including 10.6 thousand children aged between 0-17 years. Disabled people are 6.6% of the total population in the country and children with disabilities represent 1.8% of the total number of children with habitual residence in the Republic of Moldova [2]. Many of them do not work, live below the subsistence minimum and face stigmatization and discrimination in most aspects of life.

In accordance with the Convention on the Rights of Persons with Disabilities (CRPD), disabled people include those who have physical, mental, intellectual or sensory lasting disabilities, impairments which, in interaction with various barriers, may hinder full and effective participation of people in society on an equal basis with others [3].

The people with disabilities quality of life increasing is a very important society issue both at national and international level. The disabled people group needs continuous support inclusively functional products offering that would allow a much easier social inclusion.

2. GENERAL NOTIONS REGARDING FUNCTIONAL CLOTHING

Functional clothing is defined as clothing specially designed and engineered to ensure the predetermined feat and/or functionality needs for the wearer [1, 4].

Based on the information in the literature and in other related fields, the functional clothing modern assortment and areas of use can be presented in the form of a scheme (Figure 1).

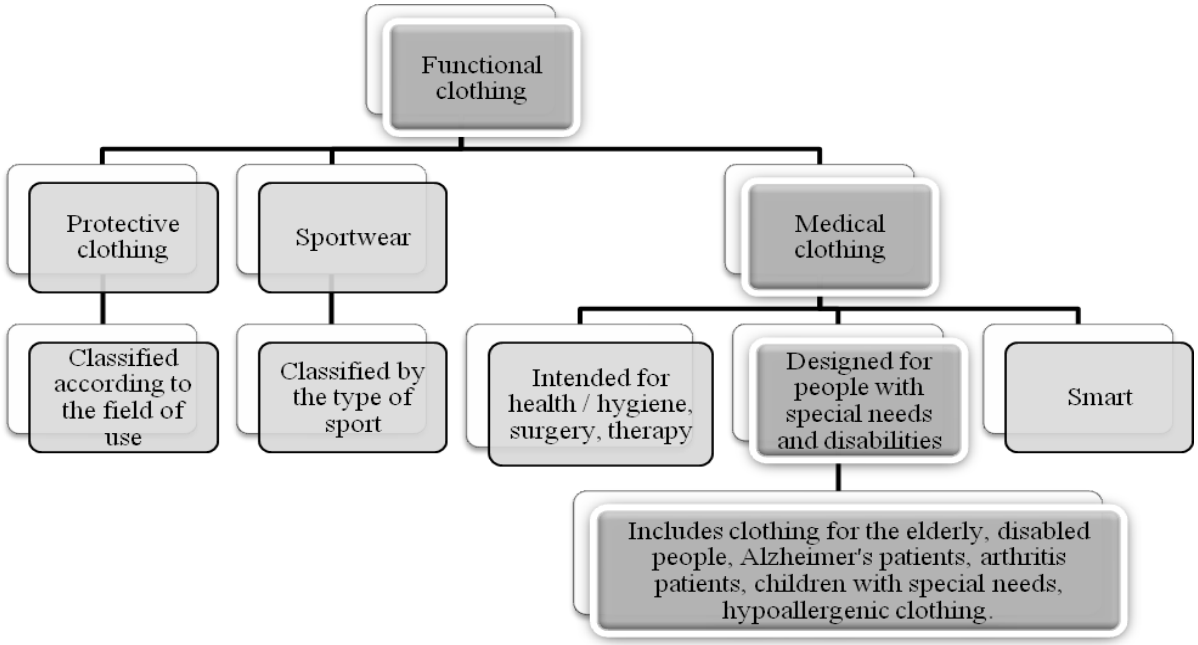


Fig. 1: *Functional clothing modern assortment*

The field of functional clothing for people with special needs and disabilities is relatively new for the domestic light industry. This field is of increased interest to specialists from various areas: textilists, designers, doctors, programmers, etc. The increased interest is argued by the large number of people with special needs at global and local level.

3. DESIGN STAGES OF FUNCTIONAL PRODUCTS FOR PEOPLE WITH DISABILITIES

The special clothing developing process requires a special methodology drawing up; this type of clothing performing strictly determined functions must correspond to a number of requirements and possess predetermined characteristics.

At the design stages functional clothing designers carry out activities for the clothing properties prognosis and responses to these properties at the manufacturing and service stages. The proposed solutions must ensure that the designed functional clothing corresponds to the conditions of operation and manufacture taking into account the complex of requirements imposed by the wearer and the restrictions imposed by manufacturing.

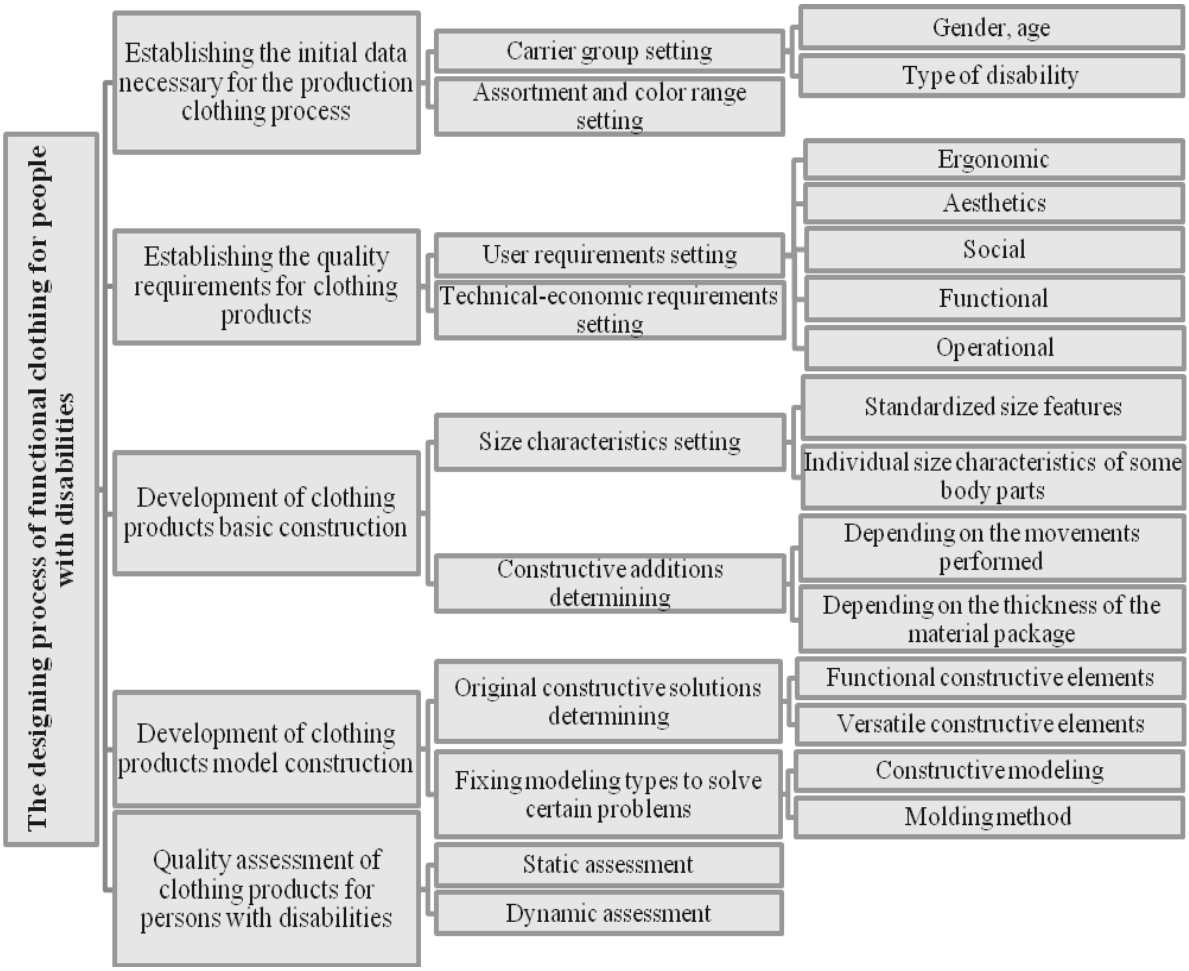


Fig. 2: *Stages of functional clothing designing process*

4. CONCLUSIONS

Functional clothing has the role of increasing the quality of life for people with special needs or disabilities.

The recommendation on wearing functional clothing should take into account the following aspects: its role in the process of wearing, the type of disability, the activities that are necessary to carry out for the wearer.

The development of clothing products for people with disabilities takes into account the fact that disability is complex, dynamic, multidimensional and contested. In recent decades, the movement of people with disabilities, together with many researchers in the social sciences and medicine, has identified the role of social and physical barriers in terms of disability.

The role of specialists in the field of clothing industry, in this regard, is to provide balanced clothing solutions that give a fair share to various aspects of disability.

The modern assortment of functional clothing includes products of protective clothing, sports clothing and medical clothing.

Due to the very wide diversity of types of clothing products, their design must be preceded by the specification of all the properties required by the destination and the operating conditions.

The task of the functional clothing constructive-technological design process lies in the creation of high-quality clothing products with increased ergonomic and functional properties.

In order to develop a unique methodology of functional clothing design, the stages of design of this type of products were established: setting the initial data necessary for the clothing development, establishing the quality requirements imposed on clothing products, developing the clothing products basic construction, developing the clothing products model construction and assessing the quality of the clothing product intended for people with disabilities.

It is proposed to carry out further research which would include analysis and selection of ergonomic parameters that influence the compliance of the article with the operating conditions, the processing of the obtained data and the obtained findings typing in accordance with the requirements imposed on the design situation.

REFERENCES

[1] J. Geršak. (2013). Clothing classification systems. [Online]. pp. 11-17. Available: https://www.sciencedirect.com/book/9780857097781

[2] Ghid pentru administrația publică locală, "*Convenția ONU privind drepturile persoanelor cu dizabilități*", Keystone Human Services International Moldova Association. [Online]. Chișinău, 2015. Available: https://www.soros.md

[3] *Raport mondial privind dizabilitate*. [Online]. Publicat de Organizația Mondială a Sănătății în 2011, sub titlul „World Report on Disability„ Ediție tipărită, București, 2012 Available: https://apps.who.int/iris/bitstream/handle/10665/44575/9789730135978_rum.pdf?sequence=20

[4] Gupta, D.(2011). Functional clothing-Definition and classification [Online]. 36, pp. 321-326. Available: https://www.researchgate.net/publication/296845630

[5] Comunicat de presă. "*Persoanele cu dizabilități în Republica Moldova în anul 2018*". [Online]. Chișinău, 2019. Available: https://statistica.gov.md

[6] S. Sanjeevani Ayachit, M. Thakur. (2017). Functional clothing for the differently abled. [Online]. 7, pp. 904-913. Available: https://www.academia.edu/36834962

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

EFFECT OF FULLERENES ON FLAME RETARDANCY OF POLYMERIC SUBSTRATES [REVIEW]

GOCEK Ikilem[1], KESKIN Reyhan[2]

[1] Istanbul Technical University, Textile Technologies and Design Faculty, Dept. of Textile Engineering, Gumussuyu, 34437, Istanbul, TURKEY, goceki@itu.edu.tr

[2] Pamukkale University, Engineering Faculty, Dept. of Textile Engineering, Kinikli, 20070, Denizli, TURKEY, E-mail: reyhank@pau.edu.tr

Corresponding author: Keskin, Reyhan, E-mail: reyhank@pau.edu.tr

Abstract: *Flame retardancy is a modern challenge especially in living area applications as many flame retardants such as halogenated and brominated chemicals possess health risks. Studies show that fullerenes have potential for flame retardant applications. Flame retardancy property of fullerene included polymers is explained in this paper. Fire hazards have been risks for human beings through all history. In modern era, closed areas such as houses, offices and cars are full of organic and polymeric materials and possess serious fire risks. Organic polymers are widely used in many daily applications due to their mechanical properties and price availability. As organic polymers are flammable naturally, the flame retardancy of polymeric materials is becoming an important issue in living areas. Conventional flame retardant materials have found a large usage; however, they have some drawbacks as need of high level loading and environmental issues.*
For flame retardancy applications, mainly seven elements are efficient in polymers: chlorine, bromine, aluminum, boron, phosphorus, nitrogen and antimony. Large amounts of conventional flame retardants are needed to ensure flame retardancy requirements. High loading levels of conventional flame retardants cause detrimental decreases in mechanical properties of the hosting polymer and cause transparency loss of the matrix material as well.
In conclusion, the effect of Fullerene (C60), as a nanocarbonaceous material, on flame retardancy properties of polymeric materials is explained. Fullerenes not only increase strength properties of polymeric substrates but also can enhance the flame retardancy of polymers. Fullerenes can alter the flammability of polymeric materials, which might find applications in many areas of our daily lives, and result in increased flame retardant properties of polymeric materials including textiles.

Key words: *Fullerene (C60), flame retardancy, nanocarbonaceous materials, polymers, fabric substrates*.

1. INTRODUCTION

Fullerenes are nanocarbonaceous materials consisting of at least 60 carbons and resembling soccer balls, illustrated in Figure 1. Fullerenes have been applied to polymeric substrates for a variety of properties including high energy storage, superconductivity, flame retardancy and reinforcing effect in polymers and polymeric fabrics as well [1-7].

Flame retardancy is a modern challenge especially in living area applications as many flame retardants such as halogenated and brominated chemicals possess health risks. Studies show that fullerenes have potential for flame retardant applications. Flame retardancy property of fullerene included polymers is explained in this paper.

Fig. 1: *An illustration of Buckminster fullerene (C60) (illustrated by Keskin Reyhan).*

2. FLAME RETARDANCY OF FULLERENE ADDED POLYMERS

Fire hazards have been risks for human beings through all history. In modern era, closed areas such as houses, offices and cars are full of organic and polymeric materials and possess serious fire risks; the flame retardancy of polymeric materials is becoming an important issue in living areas. Conventional flame retardant materials have found a large usage; however, they have some drawbacks as need of high level loading and environmental issues. For flame retardancy applications, mainly seven elements are efficient in polymers: chlorine, bromine, aluminum, boron, phosphorus, nitrogen and antimony [8]. Large amounts of conventional flame retardants are needed to ensure flame retardancy requirements [9]; hence, conventional flame retardants not only cause detrimental decreases in mechanical properties but also cause transparency loss in material [10].

To avoid mechanical property decreases, nano scale flame retardant materials are good alternatives to conventional flame retardants. Nano scale flame retardants offer good results in small loading levels [11]. As the flame retardant particle size decreases, particle distribution inside the polymer is increased and flame retardancy of the polymer matrix is improved [12].

Intumescent flame retardants have common usage due to their low toxicity and smoke release [12]. Intumescent flame retardants form a charred layer that cause a barrier for volatile chemicals so have a slowing effect in fires [13]. Kandola et al proved that intumescents can decrease the peak heat release values and enhance char formation [14]. Brominated flame retardants find large usage as they are not decreasing detrimentally mechanical properties of the hosting polymer; however, brominated flame retardants release large amounts of smoke and heat during combustion [15]. Nanoparticles such as nanoclays, carbon nanotubes and layered double hydroxides are also used as flame retardants in polymeric substrate, nanoparticulated flame retardants (nanoclays, carbon nanotubes) are environmentally friendly [9].

Char formation is a mechanism to promote flame retardancy [16]. As conventional flame retardants possess some health and environmental risks, efforts are increasing to find safer substitutes for conventional flame retardants [17]. Fullerene is another carbonaceous nanomaterial that has flame retardancy effect on polymeric materials [9].

Fire protection is a complex aspect. There are various parameters that are concerned in terms of flame retardancy such as cone calorimetry measurements (ignition time, heat release rate, peak heat release rate (PHRR) is about the danger of the fire, time to peak heat release rate, heat release rate (HRR) is about the speed of the fire, total heat release, average mass loss rate, average specific extinction area), nano scale flame retardants decrease peak heat release rate and suppress the danger level of the fire [9]. Carbon nanotubes and nanoclays decrease heat release rate [18, 19].

Fullerene, as a flame retardant, has potential to postpone beginning of combustion in fires [21]. Fullerenes are capable of capturing free radicals during combustion and improving the thermal stability of polymers [15]. Fullerene addition increases time for ignition and slows down combustion start; however, fullerene addition does not form a charred layer that forms a tortous path for volatiles [18, 19]. Fullerenes do not form a network and do not block the movement of polymer chains since

they are spherical nanoparticles; indeed they offer more movement for polymer chains by acting like plasticizers [20]. Fullerenes have high affinity to free radicals [21]; during combustion fullerenes trap free radicals. Fullerenes and free radicals form a gelled-ball crosslink network. The flame retardation mechanism of fullerenes is effective in the combustion process by preventing heat flow and oxygen transfer from outer surface to inner parts owing to these gelled-ball crosslink networks [20]. Fullerenes have cooling ablative effect in between 600-1000˚C temperature ranges besides their flame retardancy [22]. Fullerene has proven to increase not only time for ignition [23, 24] but also the LOI (limiting oxygen index) value [25] and to restrain combustion as well [26].

3. CONCLUSIONS

In conclusion, the effect of Fullerene (C60), as a nanocarbonaceous material, on flame retardancy property of polymeric materials is explained. Fullerenes not only increase strength properties of polymeric substrates but also can enhance their flame retardancy. Fullerenes can alter the flammability of polymeric materials, which might find applications in many areas of our daily lives, and result in increased flame retardant properties of polymeric materials including textiles.

As the result of this paper, fullerene (C60) appears to be a promising reinforcing nanomaterial for flame retardancy of polymeric materials. The addition of fullerene (C60) to polymeric materials can bring enhanced unflammability to many products used in the automobile industry, upholstery industry, construction industry and in polymeric composites.

ACKNOWLEDGEMENT

This research was supported by Pamukkale University Scientific Research Projects Institute (PAUBAP) under the project number 2011BSP019.

4. REFERENCES

[1] H. Murayama, S. Tomonoh, J.M. Alford and M.E. Karpuk, "*Fullerene Production in Tons and More: From Science to Industry*", Fullerenes, Nanotubes and Carbon Structures, vol 12, pp 1-9, 2004.

[2] A.L. Balch and M.M. Olmstead, "*Reactions of Transition Metal Complexes with Fullerenes (C-60, C-70, etc) and Related Materials*", Chemical Reviews, vol 98, pp 2123-2165, 1998.

[3] M. Prato, "*[60] fullerene chemistry for materials science applications*", Journal of Materials Chemistry, vol 7, pp 1097-1109, 1997.

[4] B.M. Ginzburg, E.Y. Melenevskaya, A.V. Novoselova, A.O. Pozdnyakov, O.F. Pozdnyakov, B.P. Redkov, A.S. Smimov, A.A. Shepelevskii, L.A. Shibaev and O.A. Shiryaeva, "*Structure of fullerene C-60 in a poly(methyl methacrylate) matrix*", Polymer Science Series A, vol 46, pp 169-175, 2004.

[5] G.N. Churilov, "*Plasma synthesis of fullerenes (review)*", Instruments and Experimental Techniques, vol 43, pp 1-10, 2000.

[6] H. Hoppe and N.S. Sariciftci, "*Organic solar cells: An overview*", Journal of Materials Research, vol 19, pp 1924-1945, 2004.

[7] T. Ogasawara, Y. Ishida and T. Kasai, "*Mechanical properties of carbon fiber/fullerene-dispersed epoxy composites*", Composites Science and Technology, vol 69, pp 2002-2007, 2009.

[8] M.M. Hirschler, "*Handbook of Fire Resistant Textiles*", 1st Edition, Chapter 6: Safety, health and environmental aspects of flame retardants, ISBN 9780857098931, pp 108-173, 2013.

[9] V. Mittal, "*Thermally Stable and Flame Retardant Polymer Nanocomposites*", Cambridge University Press, ISBN 1139495984, June 30, 2011.

[10] V. Mittal, "*Polymer layered silicate nanocomposites: A review*", Materials, vol 2, pp 992–1057, 2009.

[11] Y. Brechet, J.Y.Y. Cavaille, E. Chabert, L. Chazeau, R. Dendievel and L. Flandin, "*Polymer based nanocomposites: Effect of filler-filler and filler-matrix interactions*", Advanced Engineering Materials, vol 3, pp 571–577, 2001.

[12] K. Bocz, T. Krain and G. Marosi, "*Effect of particle size of additives on the flammability and mechanical properties of intumescent flame retarded polypropylene compounds*", International Journal of Polymer Science, vol 1, pp 1–7, 2015.

[13] J.N. Gavgani, H. Adelnia and M.M. Gudarzi, "*Intumescent flame retardant polyurethane/reduced graphene oxide composites with improved mechanical, thermal, and barrier properties*", Journal of Materials Science, vol 49, pp 243–254, 2014.

[14] B.K. Kandola, A.R. Horrocks, P. Myler and D. Blair, "*The effect of intumescents on the burning behaviour of polyester-resin-containing composites*", Composites Part A Applied Science and Manufacturing, vol 33, pp 805–817, 2002.

[15] Z. Guo, L. Zhao and Z. Fang, "*The flame retardant and smoke suppression effect of fullerene by trapping radicals in decabromodiphenyl oxide/Sb_2O_3 flame-retarded high density polyethylene*", Fire Materials, vol 41, pp 916–924, 2017.

[16] B.K. Kandola, M.H. Akonda and A.R. Horrocks, "*Use of high-performance fibres and intumescents as char promoters in glass-reinforced polyester composites*", Polym Degradation and Stability, vol 88, pp 123–129, 2005.

[17] A.R. Horrocks, B.K. Kandola, P.J. Davies, S. Zhang and S.A. Padbury, "*Developments in flame retardant textiles - A review*", Polym Degradation and Stability, vol 88, pp 3–12, 2005.

[18] Z. Fang, P. Song, L. Tong and Z. Guo, "*Thermal degradation and flame retardancy of polypropylene/C60 nanocomposites*", Thermochim Acta, vol 473, pp 106–108, 2008.

[19] P. Song, Y. Shen, B. Du, Z. Guo and Z. Fang, "*Fabrication of fullerene-decorated carbon nanotubes and their application in flame-retarding polypropylene*", Nanoscale, vol 1, pp 118–121, 2009.

[20] P. Song, Y. Zhu, L. Tong and Z. Fang, "*C(60) reduces the flammability of polypropylene nanocomposites by in situ forming a gelled-ball network*", Nanotechnology, vol 19, pp 1-10, 2008.

[21] P.J. Krusic, E. Wasserman, P.N. Keizer, J.R. Morton and K.F. Preston, "*Radical Reactions of C60*", Science, vol 254, pp 1183–1185, 1991.

[22] R.O. Loutfy and E.M. Wexler, "*Ablative and flame-retardant properties of fullerenes*", in: Osawa E. (eds) Perspectives of Fullerene Nanotechnology, Springer, Dordrecht, 2002.

[23] Y. Pan, L. Han, Z. Guo and Z. Fang, "*Improving the flame-retardant efficiency of aluminum hydroxide with fullerene for high-density polyethylene*", Journal of Applied Polymer Science, vol 134, pp 1–9, 2017.

[24] R. Wang, L.X. Wu, D.X. Zhuo, Z.Z. Wang and T.Y. Tsai, "*Fabrication of fullerene anchored reduced graphene oxide hybrids and their synergistic reinforcement on the flame retardancy of epoxy resin*", Nanoscale Research Letters, vol 13, pp 1-14, 2018.

[25] Y. Kanbur and U. Tayfun, "*Development of multifunctional polyurethane elastomer composites containing fullerene: Mechanical, damping, thermal, and flammability behaviors*", Journal of Elastomers and Plastics, vol 51, pp 262-279, 2019.

[26] Z. Guo, Z. Wang and Z. Fang, "*Fabrication of 9,10-dihydro-9-oxa-phosphaphenanthrene-10-oxide-decorated fullerene to improve the anti-oxidative and flame-retardant properties of polypropylene*", Composites Part B, vol 183, pp 1-8, 2020.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

NATURE-INSPIRED COLORS AND SHAPES IN CLOTHING DESIGN

INDRIE Liliana[1], ILIEVA Julieta[2], ZLATEV Zlatin[2]

[1]University of Oradea, Faculty of Energy Engineering and Industrial Management, Department of Textiles, Leather and Industrial Management, B.St.Delavrancea Str., no. 4, 410058, Oradea, Romania

[2]Trakia University, Faculty of Technics and technologies, 38 Graf Ignatiev str., 8602, Yambol, Bulgaria
,
Corresponding author: E-mail: liliindrie@yahoo.com

Abstract: *Nature is an inexhaustible source of inspiration for fashion designers when it comes to colours, materials, textures and pattern of garments or accessories. Its suggestive potential, the infinite imaginative resources that nature forms generates and reveals alwyas remain relevant, continuously feeding the creative imagination.*
The flexibility of shapes, angles, overlays of volumes, all these we find in clothes, in prints, in the search of cutouts, in the way that many designers chose to put their mark on their fashion creations in order to harness the expressive language of human body.
The purpose of this article is to offer models of clothing based on combinations of colors and shapes inspired bu natural sources. The colors used from natural sources and their values in the RGB color model were presented. Also, the procedure for obtaining a four-color wheel and the method for creating "rose" curves were described. Different geometric shapes based on the rose curve were defined. Based on he selected colors and the defined shapes, the design of 3 models of nature-inspired dresses was made in order to visualize how the proposesd colors and shapes will look in a completed garment, Discussion and a comparative analysis have been made with the results obtained by other authors.

Keywords: *eco-clothing, eco-fashion, identity construction, apparel design, flower colors, rose figure*

1. INTRODUCTION

Nature has always been a source of inspiration for artists; it has been and is being approached by various themes and motives, by different ways of expression: paintings, decorations, clothing and textiles, etc. The varities of plants, flowers and animals are highlighted by artists precisely through their chromatic dynamics. Natural colors have a great impact on art and design, especially in garments design.

Colors in nature are often less saturated and more pleasing to the eye than their artificial substitutes [1]. İşmal [2] proposes to use natural colors derived from waste products, biomass, when staining fabrics. After a number of studies, the author concludes that the color obtained on the textile material depends to a large extent on the type of material to be applied. This thesis is confirmed and supplemented by Samanta [3]. According to the author, research is needed regarding the stability of the colors obtained, standardization of the methods by which they are extracted, also the microbiological action and last but not least the education and training of specialists in the application of natural colors.

Starting with the premise that colours influence our behaviour due to the fact that we are constantly surrounded by colours and that we are taught to associate each color with certain values, characteristics and feelings, fashion designers explore how colours/colours combinations influence a design, pattern or detail.

The shape [4] and arrangement of geometric elements is another important factor in design. The diversity of natural forms, their bizare combinations and often their unexpected manifestations were also a model for those who formed the elements of the environment Marfo [5] proposes the use of mathematical relationships and methods for generating elements that can be used in textile design, jewelry and decoration of buildings.

The compositional shape of the clothing elements takes into account the commonalities between geometry, the human body and clothing. When designing clothing, it is necessary to strike a balance between functionality and aesthetics in geometry, the human body and clothing.

The purpose of the article is to offer models of clothing based on combinations of colors and shapes inspired by natural sources.

2. MATERIAL AND METHODS

A description of the colors used and their values in the RGB color model is made. The procedure for obtaining a four-color circle is described. The method for creating rose curves is presented. The software products used are described.

Colors used by manufacturers of food coloring agents: Kalsec (Kalsec Inc., USA); Kanegrade Ltd. (United Kingdom); NATCOL (NATCOL AISBL, Brussels, Belgium). Colors with their RGB values and their natural sources are summarized in Table 1.

Table 1: *Colors obtained from natural sources*

Color	RGB values			Natural source
	R	G	B	
Yellow	248	229	23	Eggs, milk, yeast
Yellow-orange	255	120	0	Carrots, oranges, red peppers, saffron, tomatoes
Pink-red	218	0	17	Hibiscus
Blue	0	159	223	Indigo Flower
Green	92	121	29	Alfalfa, nettles, parsley, spinach
Brown	205	79	0	Caramel
Red-blue	141	27	225	Black grapes, black currants, elderberry, strawberries
Red-pink	182	91	113	Beetroot
Black	0	0	0	Carbonized plant material

The colors are represented in the Lab four-color wheel. The color wheel is a clear and effective scheme designed to represent the concepts and terminology of color theory. There are many different color patterns, but there is hardly a color wheel that can fully describe the complexity and the way we perceive color from light. Obtaining polar coordinates in the four-color circle is based on their chroma and Hue.

The color components of the RGB color model (RGB [0 255]) were converted to Lab (L [0 100], a [-86.18 98.23], b [-107.86 94.47]), according to [6]. The chroma (C) and hue (h) values are determined by:

$$C = \sqrt{a + b} \qquad h^{\circ} = atan\left(\frac{b}{a}\right) \tag{1}$$

Forms of the shape "rose" shapes are used, which can be described in a Cartesian coordinate system, by the following mathematical formula:

$$\begin{aligned} x &= r.\cos(\theta) \\ y &= r.\sin(\theta) \end{aligned} \qquad \begin{aligned} r &= \cos(n.\theta) \\ \theta &= 0, \frac{\pi}{64}, 10^2.\pi \end{aligned} \qquad \textbf{(2)}$$

If n is odd, the rose has an n-leaf. If n is even, then the rose has 2.n leaves. If n is a rational number, then the curve closes at an angle in the polar coordinate system π.s.p, where p=1 if n is odd and p=2 if n is even. If n is irrational, then the rose has an infinite number of leaves.
The rose type curve was chosen because it has the shape of a flower. It was proposed by the Italian mathematician Guido Grande between 1723 and 1728 because it looks like a rose [7].

The following software products were used in the present work:

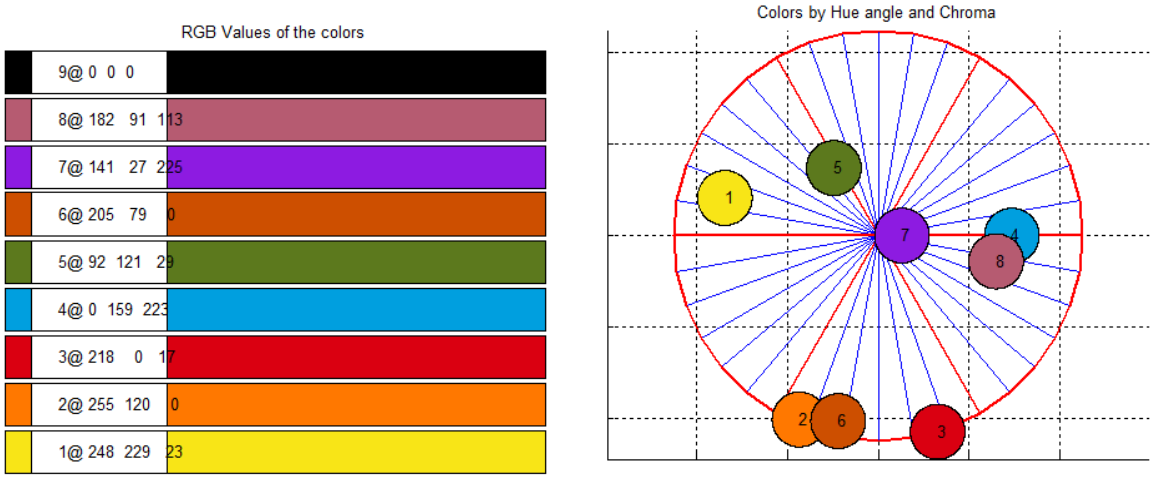
- ✓ Image processing with PhotoFiltre ver.6 software (http://www.photofiltre.com, Houilles, France).
- ✓ Vector processing was done with Inkscape ver.0.92 software (https://inkscape.org).
- ✓ The models were developed with the help of the online tool Art of Where Design Lab (https://artofwhere.com).

All data were processed at a level of significance α=0,05.

3. RESULTS AND DISCUSSION

The work presents the colors of natural sources in a four-color wheel, as well as their general appearance. Shapes based on a curve of the "rose" type are defined. Design models of clothing, representing the resulting figures and selected colors, were presented. Discussion and a comparative analysis have been made based on the results obtained by other authors.

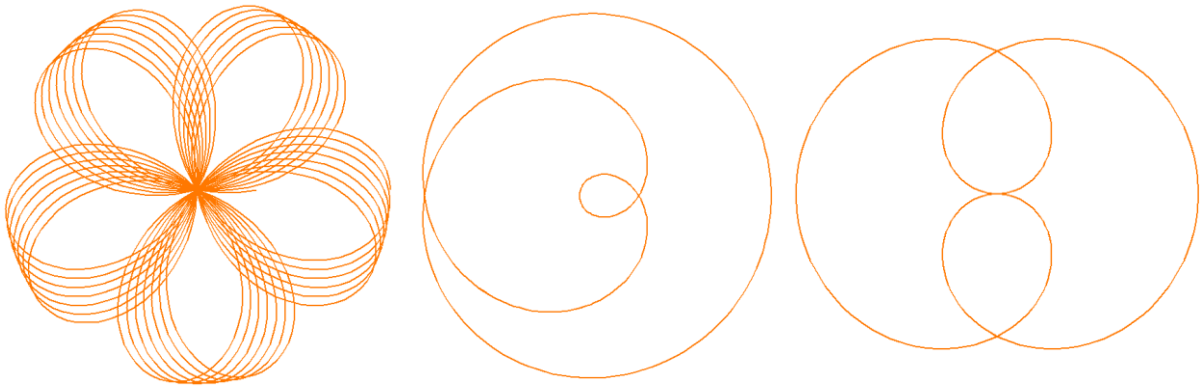
Figure 1 shows a general view of the natural colors used and their location on the Lab color wheel.



a) General view of the colors *b) Colors on Lab color wheel*

Fig. 1. *Natural colors*

Figure 2 shows the resulting shapes, depending on the coefficient "n". The motifs presented can be directly used in textile and fashion design. For the sake of greater model variety and convenience in the design of the patterns, different geometric shapes were used, based on the cow "rose".



a) Element 1, n=1,68 *b) Element 2, n=0,2* *c) Element 3, n=0,5*

Fig. 2. *Forms used*

Figure 3 shows the designed dress models. The models consist of three basic elements – a mannequin, a wig and dress. The models represent a dress of the cut style. It has an A-shaped silhouette. The neckline is round, sleeveless but with straps. It is cut in the waist and there are busts to form a bundle in the waist and to form a bust. For Model 1 Element 1 is used, the colors are 1 and 4 (blue and yellow). A 90 degree rotation of the element is applied. The colors 1, 3 and 4 (yellow, red and blue) were used in Model 2 in conjunction with Element 2. The repeat is reflection+glide reflection. Model 3, created by Element 3, consists of the three colors 7, 8 and 9 (pink-red, pink-blue and black). The repeat is the same as in Model 1 - 90 degree rotation.

The choice of colors in this paper confirms Baycheva's findings [6] that color is a major indicator that influences consumers when choosing a product.

The results presented in this paper complement and confirm those of Yueming [8]. The author points out that more and more clothing manufacturers are developing applications of geometric shapes in clothing. According to the author, the application of geometric shapes in a three-dimensional way is the key to success for contemporary designers. Research is also needed on the impact of geometric elements used on consumer desires and searches. The results of such studies could be used to create new garments. On the other hand, the way of combining forms is also a major aspect in the design of clothing, as stated by Kazlacheva [9]. According to the author, the use of the Fibonacci order and the gold section in the arrangement can be used to create beautiful and harmonious shapes directly or with the help of geometric shapes.

a) Model 1 *b)Model 2* *c)Model 3*

Fig. 3. *Designed models*

Curves are a proven effective geometric element for creating spectacular shapes [10]. The results obtained in the work confirm Kazlacheva's statement that the round shapes can be applied in the fashion design in different rhythms, different combinations of colors and in different proportions and directions according to the clothes.

4. CONCLUSIONS

Theoretical studies highlight that one of the main trends in the development of fashion in the future - the increasing penetration of eco-fashion. Another trend in fashion is the use of colors from natural sources in the field of textile production, focusing on their rationality and uniqueness.

Clothing models based on combinations of colors and shapes inspired by natural sources were proposed in this article. The researches made give the basic directions for the application of the selected eco-colors in the modern textiles. There are possibilities for their interpretation in accordance with the contemporary cultural-aesthetic, material-technical, scientific, ergonomic, ecological factors of the modern society.The software products used have the advantage of providing greater visibility into the results obtained, which are also presented graphically for better visualization of the results.

REFERENCES

[1].Vastrad J., Goudar, G., Walmiki, L., Mariyappannavar, S., Mahale, G. (2016). Empowerment of Women through Dyeing technology- Inspirations from nature (Research bulletin)., University of Agricultural Sciences, Dharwad.

[2].İşmal, Ö. (2016). Patterns from Nature: Contact Printing. Journal of the Textile Association, Vol. 77, No. 2, pp.81-91.

[3].Samanta, P. (2020). A Review on Application of Natural Dyes on Textile Fabrics and Its Revival Strategy. In Chemistry and Technology of Natural and Synthetic Dyes and Pigments, IntechOpen, pp.1-24.

[4].Kosinkova-Stoeva, A. (2019). Fashion design on the base of an investigation of Minoan costume and art. Applied Researches in Technics, Technologies and Education (ARTTE), Vol. 7, No. 4, pp.240-254.

[5].Marfo J., E. Martey (2015). Creating designs through mathematical functions. International Journal of Computer Applications, Vol. 123, No. 3, pp.24-30.

[6].Baycheva, S. (2016). Application of devices of measurement of color in analysis of food products. Innovation and entrepreneurship – Applied scientific journal, Vol. 4, No. 4, pp. 43-59.

[7].Hall, L. (1992). Trochoids, Roses, and Thorns--Beyond the Spirograph. College Mathematics Journal, Vol. 23, pp.20-35.

[8].Yueming, Y (2017). The discussion of clothing form with geometric modeling. Advances in Social Science, Education and Humanities Research, Vol. 185, pp.10-12.

[9].Kazlacheva, Z. (2017). An investigation of application of the golden ratio and Fibonacci sequence in fashion design and pattern making. IOP Conf. Series: Materials Science and Engineering, Vol. 254, Art. 172013, pp.1-6.

[10].Kazlacheva, Z. (2018). Fibonacci circle in fashion design. Latest trends in textile and Fashion designing, Vol. 1, No. 3, pp.56-57.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

ULTRASONIC DYEING OF COTTON FABRICS WITH RED REACTIVE DYESTUFF

KESKIN Reyhan[1], KESKIN Burcin [2]

[1] Pamukkale University, Engineering Faculty, Dept. of Textile Engineering, Kinikli, 20070, Denizli, TURKEY,
E-mail: reyhank@pau.edu.tr

[2] Pamukkale University, Graduate School of Natural and Applied Sciences, Textile Engineering, Denizli, TURKEY,
E-mail: burcinkeskin91@hotmail.com

Corresponding author: Keskin, Reyhan, E-mail: reyhank@pau.edu.tr

Abstract: *In this study, comparison of dyed 100% cotton knitted fabrics according to two different methods named "ultrasonic-conventional" and "conventional" methods is done by conducting rubbing fastness, washing fastness and water absorption tests. As well, color measurement of samples is measured with a spectrophotometer. Red DE2GF Remazol brand reactive dye is used as dyestuff. NaCl salt and Na_2CO_3 soda ash contents are kept constant during dyeing of samples. The variants during this study are selected as amount of dyestuff and time duration in sonication application. With the variants, we had 5 different samples for the "ultrasonic-conventional" dyeing method and 4 samples for the "conventional" dyeing method. With the comparison of both methods, the color depth of samples dyed with "ultrasonic-conventional" method gave higher results and it is concluded that target color shades might be obtained using less dyestuff amounts by the "ultrasonic-conventional" method. In this study, as the cost of "ultrasonic-conventional" method is calculated and not found high; the "ultrasonic-conventional" method has potential to be a promising method due to its less dyestuff amount consumption and less polluting effect to the environment.*

Key words: *Ultrasound, dyeing, cavitation, colour measurement, fastness.*

1. INTRODUCTION

Ultrasound is sound that human beings cannot hear and that are between 20 Hz and 20 kHz. Ultrasound waves have high energy and are used in many applications in several industries including diagnostic imaging in health sector [1].

Thakore experimented ultrasound in dyeing and concluded that the chemicals necessary for dyeing process are less when ultrasound is used for dyeing [2]. Zhao and Zhang found that during desizing with ultrasound there is a time saving and the process is applicable at a lower temperature [3]. Sanoop et al managed to produce coated anti-fungal cotton by applying ultrasound to the biopolymer solution and they proved that the fabric was cleaned with ultraviolet light [4].Dumitrescu et al dyed fabrics with ultrasound using annatto plant extracts and found that the fabrics were dyable ecologically without using enzymes and they achieved higher color values with the sonication dyeing method compared to conventional dyeing [5]. Coman et al compared ultrasonic dyed and conventionally dyed fabrics using red onion extracts and concluded that sonication dyeing gave better results and higher color shades [6]. In this study, we aimed to compare

sonication applied dyeing with conventional dyeing in terms of fabric properties and energy consumption.

2. EXPERIMENTAL APPROACH

Two dyeing methods were applied to cotton fabrics and compared in this study: "ultrasonic-conventional" dyeing and "conventional" dyeing. In "ultrasonic-conventional" dyeing ultrasound was applied to cotton in water that has dyestuff and sonicated solution together with the fabric was taken to conventional dyeing machine to complete the "ultrasonic-conventional" dyeing process. In "conventional" dyeing, the dyeing process was done with the conventional dyeing machine without sonication application. In dyeing experiments, Red DE2GF Remazol brand reactive dye is used as dyestuff for red coloring. NaCl salt and Na_2CO_3 soda ash contents are kept constant during dyeing of samples. The variants during this study are selected as amount of dyestuff and time duration in sonication application. Dyestuff weights used were: 0.003g (sample R01); 0.006 g (sample R02); 0.009 g (sample R03) and 0.012 g (sample R04) in conventionally dyed samples; while sonication durations were: 1 min (RE1), 3 min (RD1), 5 min (RC1), 10(RB1) min and 15 min(RA1) durations with 0.003 g of dyestuff Red DE2GF.

2.1 Materials and Method

10 grams of 100% single jersey knitted cotton fabric at 180 g/m^2 is used in each dyeing experiment in 250 ml distilled water. Salt at 1 g and ash contents at 1 g weights are kept constant during dyeing of samples; dyeing procedure was 50 min at 60C^o and rinsing was applied after dyeing, the "conventional" dyeing procedure is given in Figure 1. In the conventional dyeing, dye solutions are prepared by mechanically stirring at 400 rpm for 3 minutes before dyeing.

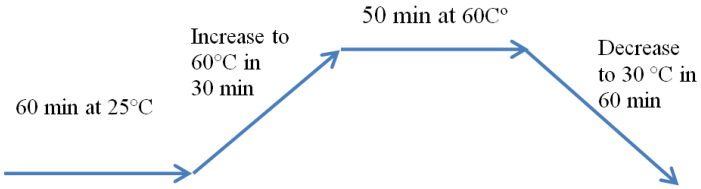


Fig. 1: *Dyeing procedure followed during experiments*

In the "ultrasonic-conventional" dyeing process, sonication was followed with the same dyeing process used in the "conventional" dyeing. Sonication was applied to the dye solution at 30 C^o and at 100 W power with a tip sonicator, Sonics VCX500, at 1 second working 1 second stopping mode to avoid over-heating during sonication. The energy values during sonication for each time interval is given in Table 1.

Table 1: *The energy values during sonication applied in the study*

Sonication time	1 min	3 min	5 min	10 min	15 min
Released energy (joule)	119	359	867	1120	1801

Color measurement is done with spectrophotometer Datacolor 600 at D65 light and 10^o angle settings. In color measurement: L givens lightness value, a* gives red-green axis values and b* gives yellow-blue axis values. Water absorption was tested with TS EN 14697 standard method;

as samples were mounted on a 45º angled base, the method was applied with a modified sample holder. Washing fastness tests were done according to TS EN ISO 105-C06 standard. Dry rubbing testing was done according to TS EN-ISO 105-X12 standard method.

The released energy values were given for 10 g of fabric and 250 ml of water. For energy consumption comparison, joules are converted to kilocalories with the given calculation method in Formula 1. The total energy consumption during reactive dyeing is given by Gulumser's research as 30 000 kcal for 60 ºC per 150 kg [7].

$$calory = joule\ x\ 4.184 \quad \text{.....} \quad \textbf{(1)}$$

2.2 Results

The color differences are compared with greige cotton fabric samples. The L, a, b and ΔE values of samples are given in Table 2. Hassan and Bhagvandas observed color depth increased with sonication applied during wool dyeing [8]. The dry rubbing fastness results of all samples were grade 5, which means dry rubbing fastness results were the best for all samples. As well, washing fastness results were all rated 5 for wool, acrylic, PES (polyester), nylon, cotton and acetate multifibres; accept for staining of R04 on cotton that was still at a good value of 4-5.

Table 2: *The L, a, b and Δ**E** values of samples in the study*

Sample	L	a*	b*	ΔE
RA1	76	22	4.2	5.2
RB1	76.4	22	4.3	4.6
RC1	76.9	21.8	4.5	4.5
RD1	77	21.5	4.6	4.3
RE1	77.3	20	5.2	_
R01	76.8	23	4.9	0.3
R02	73.2	28	3.02	8
R03	70.8	33.6	2.2	13.2
R04	69.5	34.6	2.1	15.6

A comparison between energy consumptions of conventional dyeing and ultrasonication process is given in Table 3; energy consumed by ultrasonication is far less then the dyeing process.

Table 3: *Comparison of energy consumption of conventional dyeing and the sonication process*

Process	Water (liter)	Temperature (ºC)	Fabric (kg)	Time (min)	Energy (kcal)	Energy/kg (kcal/ kg)
Conventional dyeing	1000	60	150	150	30 000	200
Sonication	0.25	29 (max)	0,01	1	0,50	50

Hassan and Bhagvandas (2017) studied ultrasonication in wool dyeing and concluded that dyeing with ultrasonication is a more sustainable method compared to conventional dyeing as sonication consumes less water, less energy and lower amounts of chemicals [8].

3. CONCLUSIONS

The samples dyed with the "ultrasonic-conventional" method were water repellent while samples dyed with "conventional" method were water absorbent; this result has not been stated before in any study, according to our knowledge. Water repellency is a desired property in some end-uses depending on customer expectations.

Washing fastness and dry rubbing fastness results were good for both dyeing methods compared. In color measurements, increasing the sonication duration resulted in lower color reflectance values which mean sonication increases color depth [8]. The energy consumption of sonication process is rather lower compared to conventional dyeing. Regarding the positive effect of sonication application, the lower energy consumption of sonication might be an opportunity to decrease costs of dyeing and finding a "greener" method for textile dyeing.

ACKNOWLEDGEMENT

This research was not supported by any project or fund.

4. REFERENCES

[1] A.P. Sarvazyan, M.W. Urban and J.F. Greenleaf, "*Acoustic waves in medical imaging and diagnostics*", Ultrasound in Medicine & Biology, vol. 39, pp.1133-1146, 2013.

[2] K.A. Thakore, "*Application of ultrasonics in dyeing of cotton fabrics with direct dyes: Part I – kinetics of dyeing"*, Indian Journal of Textile Research, vol 13, pp. 133-139, 1988.

[3] Q. Zhao, S. Zhang, "*Study on the enzyme desizing process for cotton fabric using ultrasonication*", Textile Engineering and Materials: advances in Textile Engineering (ICTEM 2011), pp 261-262, 2011.

[4] P. K. Sanoop, K. V. Mahesh, Nampoothiri K. M., Mangalaraja R. V., and Ananthakumar S., "*Multifunctional ZnO-biopolymer nanocomposite coatings for health-care polymer foams and fabrics*", Journal of Applied Polymer Science, vol. 126, pp. E232-E243, 2012.

[5] I. Dumitrescu, P.S. Vankar, J. Srivastava, M. Mocioiu and O.G. Iordache, *"Dyeing of cotton, silk and wool with Bixa orellana in the presence of enzymes"*, Industria Textila, vol. 63, pp. 327-328, 2012.

[6] Coman D., Oancea S., Vrinceanu N. and Stoıa M., "*Sonication and conventional dyeing procedures of flax fibres with allium cepa anthocyanin extract*", Cellulose Chemistry and Technology, vol. 48, pp. 145-157, 2014.

[7] Gülümser T., "*Comparison between naturally colored cotton fabric and white cotton fabric in manner of processes in the dyehouse*", Tekstil ve Konfeksiyon, vol. 26, pp. 291-292, 2016.

[8] Hassan M.M., and Bhagvandas M., "*Sustainable ultrasound-assisted ultralow liquor ratio dyeing of wool textiles with an acid dye*", ACS Sustainable chemistry and engineering, vol. 5, pp. 973-981, 2016.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

EFFECT OF SOLUTION PROPERTIES ON FIBER DIAMETERS OF POLYVINYL ALCOHOL NANOFIBROUS MATS

KOC Muhammed Zahid [1], KESKIN Reyhan [2]

[1] Pamukkale University, Graduate School of Natural and Applied Sciences, Textile Engineering, Denizli, TURKEY,
E-mail: mzahidkoc87@gmail.com

[2] Pamukkale University, Engineering Faculty, Dept. of Textile Engineering, Kinikli, 20070, Denizli, TURKEY,
E-mail: reyhank@pau.edu.tr

Corresponding author: Keskin, Reyhan, E-mail: reyhank@pau.edu.tr

Abstract: *In this study, PVA (polyvinyl alcohol) solutions with different concentrations (8, 10, 12, 14, 16 and 18 wt %) were prepared and nanofibers were produced with changing system parameters via electrospinning. Image analysis was performed after FESEM analysis using Image J programme. Prior to electrospinning, properties of solutions were measured, nanofiber diameter distributions were calculated and relationship between electrical conductivity and nanofiber average diameters was evaluated. In this study, we aimed to assess relation between solution properties and fiber diameter of produced nanofibrous mats. We obtained increased viscosity with increased solution concentration in our study; on the other hand there was not a proportional increase either in electrical conductivity or in surface tension of the solutions. Increasing solution viscosity gives higher nanofiber diameter; in our study we observed a general increase tendency in diameter; however, a diameter decrease from 14 wt % to 16 wt % increase in solution concentration is observed as well. We obtained 145.9 nm thickenesses in 16 wt % solutions and they were thinner than nanofibers produced from 14 wt % and 18 wt % solutions. Our fiber diameter averages show a tendency of being indirectly proportional with the exponential of electrical conductivity (**$1 / \tau_e^{0.1}$**) compared to the mathematical formulation relationship stated in a previous literature study conducted by An et al.*

Key words: *Nanofibrous mats, polyvinyl alcohol, viscosity, electrical conductivity, surface tension.*

1. INTRODUCTION

During electrospinning Taylor cone forms and propagates jet formation followed by nanofiber production. There are many parameters affecting nanofiber structure in electrospinning such as voltage, flow rate, solution concentration, viscosity, distance between needle and collector, polymer and its molecular weight, solvent type, additives and surfactants added to solution [1-7].

Surface tension is an important factor affecting jet formation during electrospinning [1]. Zhang et al observed that increasing voltages caused increases in fiber diameters; also, they concluded that distance between needle and collector did not have a strong effect on morphology of nanofibers produced [2]. Koski et al found that increasing molecular weight causes increases in nanofiber diameters [3]. Tsai studied which concentrations are suitable for electrospinning with PVA (polyvinyl alcohol) polymers and suggested 9-17 wt % solutions for PVA polymers at 50 000-85 000 g/mol range [4]. In literature, there are several studies on the effects of parameters on nanofibers showing either similar or conflicting tendencies to previous studies [5-7]. As Subbiah et

al reviewed, an era for mathematical formulations on electrospun nanofibers started in 1914 with Zeleny's study on the fluid behavior to electrostatic forces [8]. In this study, we aimed to assess relation between solution properties and fiber diameter of produced nanofibrous mats.

2. EXPERIMENTAL APPROACH

2.1 Materials and Method

With partially hydrolyzed polyvinylalcohol (PVA) with a molecular weight of 70 000 g/mol (Merck) and distilled water solutions were stirred using specific weights of PVA and water, Table 1, at 80ºC in 3 hours at 600 rpm; and were kept at 200 rpm until production. The viscosities and electrical conductivities were measured respectively with Brookfield DV50 viscometer and ADWA brand AD32 conductivity meter. Surface tension measurements were done using the droplet method using Pasteur pipettes. Table 2 lists measured properties of PVA solutions used in the study.

The production of pure PVA nanofibrous mats was done on a laboratory scale one-nozzled electrospinning machine (Inovenso, model Ne 100) using 23-28 kV voltage ranges. FESEM (Field Emission Scanning Electron Microscopy) analysis was conducted at backscattering mode on a Zeiss Supra 40 VP model. Figure 1 shows image of nanofiber produced with 8 wt % solution. Fiber diameter distributions were obtained by Image J software using around 100 fibers on FESEM image. Table 3 gives properties of nanofibrous mats produced in the study.

Table 1: *The parameters of PVA solutions used in the study*

Solution	PVA wt%	water (g)	PVA (g)
A	8 wt %	92	8
B	10 wt %	90	10
C	12 wt %	88	12
D	14 wt %	86	14
E	16 wt %	84	16
F	18 wt %	82	18

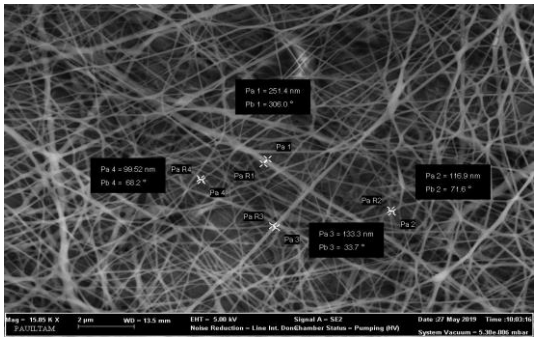


Fig. 1: *8 wt% PVA solution. 28 kV voltage, 10 cm distance, 0.1 ml/h flow rate (sample A)*

An et al (2014) studied the effects of viscosity, electrical conductivity and surface tension of solution on droplet formation during direct electrohydrodynamic printing which forms a Taylor cone as well and experimented that droplet formation was not giving directly proportional results to neither viscosity nor surface tension and electrical conductivity and found that the number of droplets formed in a time interval has a limitation to have Taylor cone formation. Researchers devised a dimensionless coefficient `$C_u$` ,given in Formula 1, to show relations of droplet formation and viscosity, surface tension and electrical conductivity besides other affecting factors [9].

Table 2: *Viscosities, electrical conductivities and surface tensions of PVA solutions used in the study*

Solution	PVA wt%	viscosity (cP)	Electrical conductivity (µS/cm)	Surface tension (dyne/cm)
A	8 wt %	84	0.85	61.12
B	10 wt %	137.6	0.87	59.97
C	12 wt %	221	0.88	58.17
D	14 wt %	244	0.89	56.77
E	16 wt %	404	1.05	55.77
F	18 wt %	913.3	0.91	62.44

Table 3: *Properties of nanofibrous mats produced in the study*

Sample	Voltage (kV)	distance (cm)	Flow rate (ml/h)	Nanofiber diameter (nm)	Standard Deviation
A	28	10	0.1	139.7	0.600
B	23	10	0.1	142.4	0.539
C	24	10	0.1	154.5	0.580
D	24	10	0.1	202	0.857
E	27	10	0.1	145.9	0.538
F	24	10	0.1	213.2	0.103

Table 4: *Calculations for electrical conductivity of PVA solutions*

Sample	$\tau_e^{0.1}$	$1 / \tau_e^{0.1}$
A	0.983	1.017
B	0.986	1.014
C	0.987	1.013
D	0.988	1.012
E	1.0049	0.995
F	0.99	1.010

$$C_u = Re^{10} \times We \times N_e \times \frac{\tau_f}{\tau_e^{0.1}} = \frac{(\rho u D)^{11}}{2} \left(\frac{V}{\sigma}\right)^2 \frac{K^{0.1} \varepsilon^{0.9}}{\mu^{10}} \quad \textbf{(1)}$$

Where:
Re: is the Reynolds number (about viscosity),
We: is the Weber number (about surface tension) and
τ_e: is the electrical conductivity

We decided to compare our results with the calculations of electrical conductivity factor in the formula of An et al. The calculations for electrical conductivity values of our study are given in Table 4. Our results show similarity with the formulation suggested by An et al. Our fiber diameter averages show a tendency of being indirectly proportional with the mathematical relation suggested for electrical conductivity as an exponential of electrical conductivity ($\mathbf{1 / \tau_e^{0.1}}$) formulated; however, researchers stated that drop generation will become unstable if electrical conductivity is increased and when there is decreased viscosity and decreased surface tension [9].

2.2 Results

In the equation given in Formula 1, viscosity has a high effect while electrical conductivity has a small effect. The formula suggested by An et al is suitable for our nanofiber diameters as the electrical conductivity increased in `solution E` leads to thinner nanofibers compared to nnaofibers producedfrom solution D and solution F.

3. CONCLUSIONS

We obtained increased viscosity with increased solution concentration in our study; on the other hand there was not a proportional increase either in electrical conductivity or in surface tension of the solutions. Increasing solution viscosity gives higher nanofiber diameter [2]; in our study we observed a diameter decrease from 14 wt % to 16 wt % increase in solution concentration. We obtained 145.9 nm thickenesses in 16 wt % solutions and they were thinner than nanofibers produced from 14 wt % and 18 wt % solutions. Our fiber diameter averages show a tendency of being indirectly proportional with the mathematical relation suggested for electrical conductivity as an exponential of electrical conductivity ($\mathbf{1 / \tau_e^{0.1}}$) formulated by An et al [9].

ACKNOWLEDGEMENT

This research was supported by Pamukkale University Scientific Research Projects Institute (PAUBAP) under the project number 2013FBE024.

REFERENCES

[1] J. Zhao, Z. Sun, Z. Shao, and L. Xu, "*Effect of surface-active agent on morphology and properties of electrospun PVA nanofibers*" Fibers and Polymers, vol 17, pp 896-901, 2016.

[2] C. Zhang, X. Yuan, L. Wu, Y. Han, and J. Sheng, "*Study on morphology of electrospun poly(vinly alcohol) mats*", European Polymer Journal, vol 41, pp 423-432, 2005.

[3] A. Koski, K. Yim, S. Shivkumar, *"Effect of molecular weight on fibrous PVA produced by electrospinning"*, Materials Letters, vol 58, pp 493– 497, 2004.

[4] P.P. Tsai, W. Chen and J.R. Roth, *"Investigation of meltblown microfiber and electrospun nanofiber fabrics treated with a one atmosphere uniform glow discharge plasma (OAUGDP)"*, Proceedings of the 13th International TANDEC Nonwovens Conference, pp 1-23, Knoxville, USA, 2003.

[5] C. Burger, B. S. Hsiao, and B. Chu, *"Nanofibrous Materials and Their Applications"*, Annual Review of Materials Research, vol 36, 333–368, 2006.

[6] S.Rafiei, S.Maghsoodloo, M.Saberi, S.Lotfi, V. Motaghitalab, B.Noroozi and A.K. Haghi, "*New horizons in modeling and simulation of electrospun nanofibers: A detailed review*", Cellulose Chemistry and Technology, vol. 48, pp. 401-424, 2014.

[7] D.H. Reneker, A. Yarin, E. Zussman, S. Koombhongse and W. Kataphinan, "*Nanofiber manufacturing: Toward better process control*", in Polymeric Nanofibers, H. Fong, Ed. New York, United States of America: American Chemical Society, 2009, pp 7-20, ISBN 9780841239197.

[8] T. Subbiah, G.S. Bhat, R.W. Tock, S. Parameswaran and S.S. Ramkumar, "*Electrospinning of nanofibers*", Journal of Applied Polymer Science, vol. 96, pp. 557-569, 2005.

[9] S. An, M,W, Lee, NY Kim, C Lee, SS Al-Deyab, SC James and SS Yoon, "*Effect of viscosity, electrical conductivity and surface tension on direct-current- pulsed drop-on-demand electrohydrodynamic printing frequency*", Applied Physics Letters, vol. 105, 2014.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

ACCELERATED WEATHERING TESTS ON PROTEIN FIBERS

LITE Mihaela-Cristina[1,2], SĂNDULACHE Irina-Mariana[1,2], SECĂREANU Lucia-Oana[1], MITRAN Elena-Cornelia[1], IORDACHE Ovidiu[1], PERDUM Elena[1]

[1] National Research and Development Institute for Textiles and Leather, Bucharest (INCDTP), Department of Materials' Research and Investigation, 16 Lucretiu Patrascanu, 030508, Bucharest, Romania, E-Mail: office@incdtp.ro

[2] Politehnica University of Bucharest, Faculty of Applied Chemistry and Materials Science, 1-7 Gheorghe Polizu Street, 011061, Bucharest, Romania, E-Mail: secretariat@chimie.upb.ro

Corresponding author: Lite Mihaela-Cristina, E-mail: cristina.lite@incdtp.ro

Abstract: *Protein-based textiles, such as wool and silk, possess special properties and they are ranked higher on the hierarchical scale than the cellulosic ones (e.g., cotton, linen, hemp), in terms of quality. Wool is composed of keratin as the main protein component and silk consists of approx. 80% fibroin and 20% sericin. The degradation of protein-based fibers is a complex process and it is influenced by temperature, humidity and light. Also, these factors may favor a perfect environment for the development of certain microorganisms, which leads to further degradation. In the case of wool fibers, the mechanism of biodegradation involves keratinolysis (sulfitolysis, proteolysis and deamination) and for silk this mechanism is based on the proteolytic decomposition of sericin and fibroin. For the present work, protein-based fibers (wool and silk) were subjected to an accelerated aging process by using UV light, temperature and humidity. Samples from both types of fibers have been collected at a fixed time interval. The level of degradation was evaluated in terms of changes in fiber morphology, using Scanning Electron Microscopy. Also, an Energy Dispersive X-Ray spectrum was recorded in order to estimate the composition at different degrees of degradation of the samples. Moreover, chromatic parameters measurements were carried out in order to quantify the color modifications of the fibers.*

Key words: *protein fibers, wool, silk, textiles degradation*

1. INTRODUCTION

Natural fibers of animal provenience represent the elite of textiles, being considered a luxury [1]. They are divided into wool (from sheep, camel, cashmere goat, mohair, angora, alpaca), fur (rabbit, fox etc.) and silk (from silkworms) [2]. The main wool protein is keratin and it is a sulfur-rich protein which can form disulfide (bonds). These bonds are responsible for the cross-linked chains in the protein which give wool its high breaking strength [3]. Silk is biosynthesized as a cocoon by the larva of the silkworm *Bombyx mori* and consists of approx. 80% fibroin and 20% sericin [4,5]. Fibroin is a two-filament protein, i.e., heavy-fibroin (H-fibroin) and light-fibroin (L-fibroin) in a 1:1 ratio, linked together by a disulfide bridge. Fibroin has a high degree of crystallinity, while sericin presents a more amorphous structure, acting as a glue and coating the two filaments of fibroin [6]. Silk is also characterized by a high mechanical resistance, having application in various fields (clothing, industry, medicine etc.) [7].

Accelerated aging studies have been previously performed to identify the analytical markers for the degree of degradation of historic heritages [8]. Also, Mengüç studied the effects of sunlight

exposure on the performance of paragliding fabric [9]. The degradation of protein-based fibers is a complex process and it is influenced by temperature, humidity and light [10, 11]. For this study, wool and silk fibers were subjected to an accelerated aging process, in a UV chamber with controlled temperature and humidity. The degree of degradation was evaluated for the collected samples by using Scanning Electron Microscopy in order to analyze the morphology, Energy Dispersive X-Ray Spectroscopy, to estimate the composition at different stages of degradation and chromatic parameters analysis, to quantify the color change of the fabrics.

2. EXPERIMENTAL

2.1. Materials and methods

For this study, five samples of silk (60 g/m^2) and five samples of wool (198 g/m^2), all measuring 11×9 cm were exposed to accelerated aging conditions, in a UV chamber. For this, a QUV accelerated weathering tester device with the following working cycle was used: 8 hours of UV light exposure at a temperature of 70^{o}C, followed by 4 hours of humidity exposure (60%), at 50^{o}C. The instrument was equipped with fluorescent UV-B lamps (UVB-313), with a wavelength peak at around 313 nm, having nearly all their energy concentrated between 280 nm and 360 nm.

Both types of samples were collected every three days, having in the end five samples of each type at different degrees of degradation. These samples were characterized and compared to a reference sample (unexposed textile material).

2.2. Characterization techniques

The fiber morphology and elemental composition of the samples were evaluated with a FEI Quanta 200 Scanning Electron Microscope (SEM), equipped with an ET detector, as well as with an Element Energy-Dispersive X-ray Spectroscopy System (EDX) from EDAX-AMETEK.

The chromatic parameters L*, a*, b* C*, H* have been measured for each sample, using a Datacolor spectrophotometer (with a D65/10 lamp).

3. RESULTS AND DISCUSSIONS

3.1. Visual observation

The visual effect of the weathering process of the samples is their increasing yellowing after every time interval. Moreover, in the case of silk, the change of color is accompanied by an aggressive disruption of the fabric, as presented in Table 1.

Table 1: *Images of silk and wool fabrics at different times of exposure*

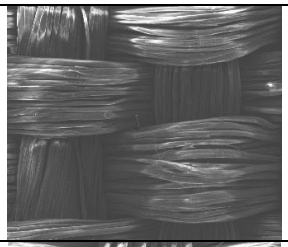
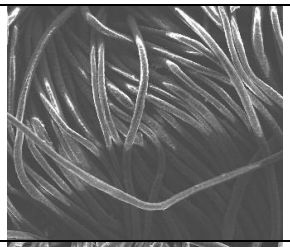
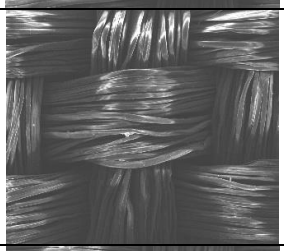
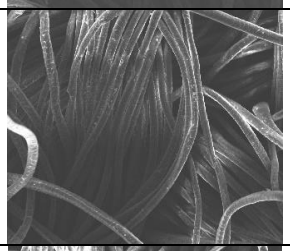
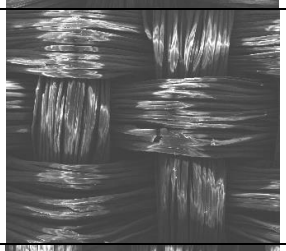
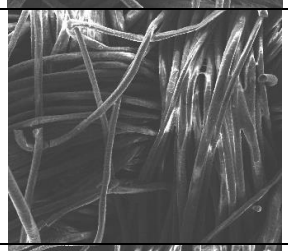
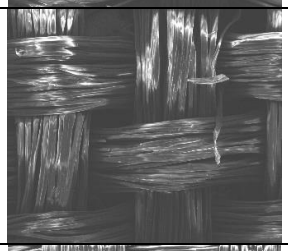
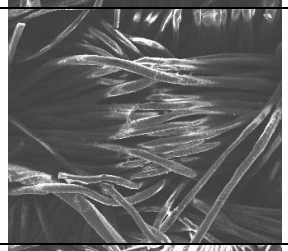
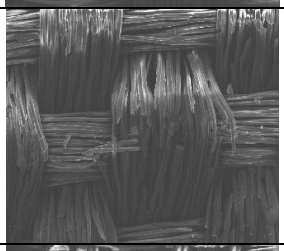
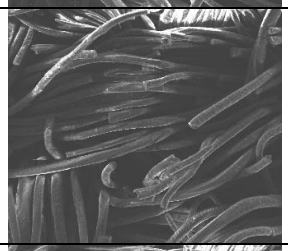
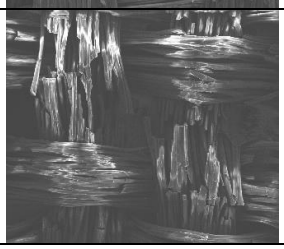
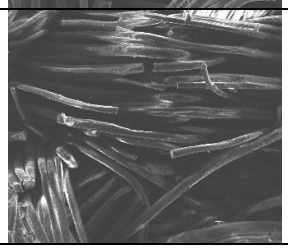
Exposure time	t_0	t_1	t_2	t_3	t_4	t_5
Silk						
Wool						

3.2. Scanning Electron Microscopy characterization

Table 2 contains the SEM micrographs of the samples, collected every three days, where t_0 represents the start of the experiment (unexposed fabric). All images were collected at 500X

magnification and an accelerating voltage of 10 kV, in high vacuum mode.

Table 2: *SEM micrographs of silk and wool fibers at different times of exposure*

Exposure time	Silk	Wool
t_0		
t_1		
t_2		
t_3		
t_4		
t_5		

The SEM results for silk at different stages of degradation show that the fibers are strongly affected starting with t_2. At t_4 and t_5, the disruptions of the fibers become significantly visible. On the other hand, wool fibers seem to keep their integrity up to t_3. This enhanced resistance might be due to the presence of sulfur bonds in the keratin structure, the main constituent protein of wool.

3.3. Energy-Dispersive X-Ray Spectroscopy analysis

The EDX measurements were performed in order to study the composition of the materials. For silk, the results show that it contains only the specific elements of the constituent amino acids: carbon, nitrogen and oxygen, dispersed in a uniform manner on the entire surface (Fig. 1). In contrast, besides these elements, wool also contains sulfur (from the disulfide bonds) and fluorine, which might come from the dye used in the case of this sample (Fig. 2). For both materials, multiple measurements were performed, at different exposure times, but no considerable difference in composition and distribution on the elements was observed.

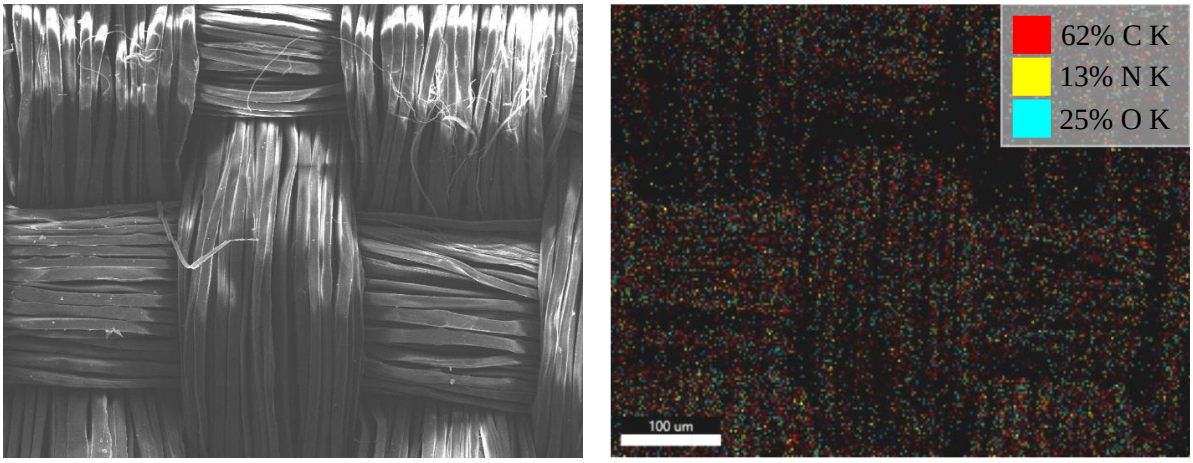


***Fig. 1**: SEM micrograph for the silk sample at t_0 (left) and its elemental mapping (right)*

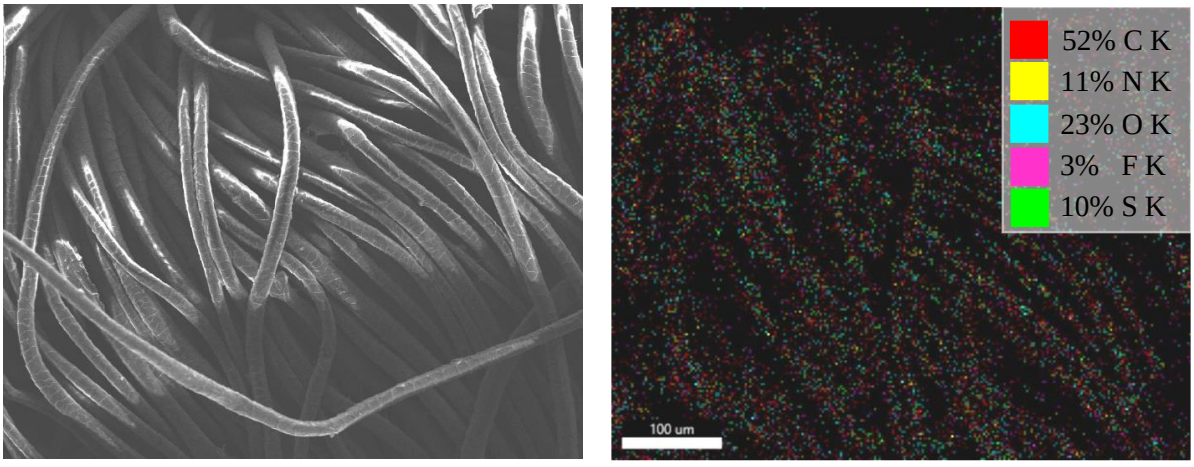


***Fig. 2**: SEM micrograph for the wool sample at t_0 (left) and its elemental mapping (right)*

3.4. Chromatic parameters measurements

The chromatic parameters measured for each sample are listed in Table 3, for silk and Table 4, for wool. In both cases, the color has considerably changed. The values suggest a strong modification of the color, up to t_2. In the further stages of the experiment, the color change slightly varies.

Table 3: *The chromatic parameters and white indices of silk samples*

Exposure time	L*	C*	DL*	DC*	DE*	White index Berger	White index CIE	T	Remarks
t_0	90.95	6.80	-	-	-	45.84	46.94	-4.20	-
t_1	84.85	23.52	-6.09	16.72	17.0	-25.54	-49.20	-15.18	Darker More saturated Greener
t_2	82.26	27.15	-8.69	20.36	22.13	-36.42	-74.12	-19.28	Darker More saturated Greener
t_3	82.47	25.54	-8.47	18.74	20.57	-31.67	-65.59	-18.28	Darker More saturated Greener
t_4	81.73	27.30	-922	20.51	22.48	-36.96	-76.29	-19.93	Darker More saturated Redder
t_5	83.44	28.56	-7.51	21.76	23.03	-39.95	-77.86	-18.31	Darker More saturated Greener

Table 4: *The chromatic parameters and white indices of wool samples*

Exposure time	L*	C*	DL*	DC*	DE*	White index Berger	White index CIE	T	Remarks
t_0	74.57	8.64	-	-	-	The textile used was dyed in a shade of pink			-
t_1	73.49	20.05	-1.08	11.41	13.69				Darker More saturated More yellow
t_2	71.49	27.79	-3.08	19.15	21.35				Darker More saturated More yellow
t_3	70.72	31.11	-3.85	22.47	24.69				Darker More saturated More yellow
t_4	70.27	32.66	-4.31	24.02	26.23				Darker More saturated More yellow
t_5	68.82	35.18	-5.76	26.54	28.83				Darker More saturated More yellow

4. CONCLUSIONS

Accelerated weathering test have been performed on silk and wool fibers, in order to evaluate the degree of degradation of protein-based textiles. The weathering process consisted of UV exposure, accompanied by temperature and humidity. The samples were collected every three days,

in order to observe the stages of degradation. The samples were characterized in terms of morphology and composition, using a Scanning Electron Microscope coupled with an EDX detector. The SEM results revealed an early degradation of the silk samples, occurring from stage t_2 of the experiment and a relatively better resistance of the wool fibers compared to the silk ones, which showed discontinuities of the fibers starting with stage t_4. EDX analysis did not show any significant changes in the elemental composition of any of the two fiber types. The chromatic parameters measurements indicated significant color changes starting with t_2. This kind of experiments might be a starting point for investigating the degradation processes occurring in heritage textiles and for testing potential conservation treatments for heritage textiles.

ACKNOWLEDGEMENTS

This work was supported by a grant of the Romanian Ministry of Research and Innovation, CCCDI-UEFISCDI, project number PN-III-P1-1.2-PCCDI-2017-0878/55PCCDI, within PNCDI III. The publication of the paper is funded by the Ministry of Research and Innovation within Program 1 - Development of the national RD system, Subprogram 1.2 - Institutional Performance - RDI excellence funding projects, Contract no. 6PFE/2018.

REFERENCES

[1] J. W. S. Hearle, "*Protein fibers: structural mechanics and future opportunities*", J Mater Sci, vol. 42, pp. 8010-8019, 2007.

[2] B. Gutarowska, K. Pietrzak, W. Machnowski, J. M. Milczarek, "*Historical textiles – a review of microbial deterioration analysis and disinfection methods*", Textile Research Journal, vol. 87, pp. 2388-2406, 2016.

[3] J. Szostak-Kotowa, "*Biodeterioration of textiles*", International Biodeterioration & Biodegradation, vol. 53, pp. 165-170, 2004.

[4] M. Geba, G. Lisa, C. M. Ursescu, A. Olaru, I. Spiridon, A. L. Leon, I. Stanculescu, "*Gamma irradiation of protein-based textiles for historical collections decontamination*", J Therm Anal Calorim, vol. 118, pp. 977–985, 2014.

[5] R. H. Wardman, "*Textile Fibres*", in An Introduction to Textile Coloration, Ed. John Wiley & Sons Ltd, 2018, pp. 66-74.

[6] T. Dyakonov, C. H. Yang, D. Bush, S. Gosangari, S. Majuru, A. Fatmi, "*Design and Characterization of a Silk-Fibroin-Based Drug Delivery Platform Using Naproxen as a Model Drug*", Journal of Drug Delivery, Article ID 490514, 2012.

[7] O. Hakimi, D. P. Knight, F. Vollrath, P. Vadgama, "*Spider and mulberry silkworm silks as compatible biomaterials*", Composites Part B: Engineering, vol. 38, pp. 324-337, 2007.

[8] F. Vilaplana, J. Nilsson, D. V. P. Sommer, S. Karlsson, "*Analytical markers for silk degradation: comparing historic silk and silk artificially aged in different environments*", Anal Bioanal Chem, vol. 407, pp. 1433–1449, 2015.

[9] G.S. Mengüç, E. Temel, F. Bozdoğan, "*Sunlight exposure: the effects on the performance of paragliding fabric"*, Industria Textila, vol. 69, pp. 381–389 2018.

[10] I. A. Adelere, A. Lateef, "*Degradation of Keratin Biomass by Different Microorganisms*", in Keratin as a Protein Biopolymer, S. Sharma, A. Kumar, Ed. Springer, 2019, pp. 123-162.

[11] B. Gutarowska, A. Michalski, "*Microbial Degradation of Woven Fabrics and Protection Against Biodegradation*", in Woven Fabrics, H. Y. Jeon, Ed. InTech, 2012, pp. 267-296.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

STUDY OF THE EFFECT OF THE CONCENTRATION OF HYDROTALCITE IN THE RECOVERY OF COLORANTS IN TEXTILE WASTEWATER

LÓPEZ Daniel [1], MICÓ-VICENT Bàrbara [2,3], BONET-ARACIL Mariles [1], BOU-BELDA Eva [1]

Universitat Politècnica de València, epartamento de Ingeniería Textil y Papelera,
Plaza Ferrándiz y Carbonell s/n, Alcoi, Spain

[2]Universitat Politècnica de València, Departamento de Estadística e Investigación Operativa Aplicadas y Calidad, Plaza Ferrándiz y Carbonell s/n, Alcoi, Spain

[3] Departamento Óptica Farmacología y Anatomía, Universidad de Alicante
Carretera de San Vicente del Raspeig s/n, Spain

Corresponding author: Eva BOU-BELDA, Email: evbobel@upv.es

Abstract: *The absorption capacity of calcined hydrotalcite at different concentrations in a solution of 0.05 g • L-1 of 4 different dyes has been compared; Direct Blue 199, Direct Red 23, Direct Blue 71 and Reactive Yellow. For this, the Lambert-Beer lines of each dye have been previously made. Two different concentrations of clay, 5 and 10 g • L-1, have been worked. Then the dye has been introduced into the clay by stirring for 24 hours in 100 ml of solution of each dye, to later filter it and allow to dry. In all cases, the absorption of the dye by the nanoclay has been almost absolute, leaving the initial solution very clean, which are excellent results from the point of view of cleaning wastewater. However, when obtaining very similar results when scaling it to an industrial production, it would be more optimal to use the lowest concentration in order to reduce costs. Finally, a color measurement was made using a Jasco V-670 spectrophotometer, double beam spectrophotometer between 190- 2700 nm and color differences are calculated and represented in a color chart. Again, no large differences are observed and reinforce the idea of using a low concentration.*

Key words: *nanoclay, dye recovery, clay pigment, direct dye recovery, reactive dye recovery.*

1. INTRODUCTION

In the last decades, environmental alerts have grown, which increases the concern for caring for the environment. The textile industry discharges organic and inorganic residues that produce bioaccumulations and can cause high degrees of toxicity. The part of the textile chemical industry is the one that most affects wastewater and is the industry with the greatest chemical activity on earth [1]. The recycling of industrial wastewater has been a need that is becoming increasingly noticeable. The concentration of dyes in the effluents is around 50-1000 ppm, although cases of lower 10-50 ppm can be found [2]. Currently there is a wide variety of nanoclays and many of them have a very efficient capacity to help recover dyes from wastewater. Nanoclay is the general term used to refer to mineral clays with a phosilicate or lamellar structure with dimensions of the order of nm and surfaces of 50-150 nm or more. The mineral base can be synthetic or natural, and is hydrophilic. The clay surface can be modified with specific compounds to improve its affinity and be able to make

them compatible, for example, with polymers. The surface area of the nanoclays is very large, around 750 m2 / g. When small amounts of these materials are incorporated into polymeric matrices, the result is called a nanocomposite [3]. This work aims to study the absorption capacity of dyes in the textile industry through the use of nanoclays. Previous work has demonstrated the efficacy of this type of element and the success of the corresponding trials [4-9]. The characteristics of clays give them a great capacity to absorb the dye and, above all, the ability to fix these dye molecules within their structure. Once the colorant has been introduced into the clay, we will see how the new hybrid compound acquires a characteristic color, which makes it susceptible of being used later, for example, as a pigment.

2. MATERIALS AND METHODS

Different dyes were used in this study. Direct dyes were: Direct Blue 199 CI 74.180, Direct Red 23 CI 29160, Direct Blue 71 CI 34140 as Reactive dye: Reactive Drimaren Yellow HF-3GL was studied. As clay we used calcinated hydrotalcite (HC) which was prepared according to Dos Santos R.M.M. [10] In figure 1 a SEM image of HC nanoclay is shown.

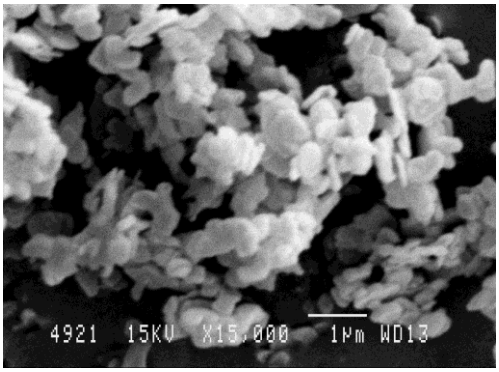


Fig 1. *SEM image of HC*

Dilutions of each of the dye were prepared to obtain the Lambert-Beer line [11] . With these lines we can know the concentration of dye that remains in the wastewater once the clay is applied. Table 1 shows the equations of the lines and the regression (R).

Table 1. *Lambert-Beer line equations and* R^2

Colorant	Equation	R^2
Direct Blue 199	y = 21.784 x - 0.015	0.9982
Reactive Yellow	y= 14.943 x – 0.0021	0.9993
Direct Red 23	y= 34.357 x – 0.0148	0.9991
Direct Blue 71	y= 17,09 x – 0.0233	0.9987

100 mL of concentration solution 0.05 $g \cdot L^{-1}$ were taken by each dye. We introduce 10 $g \cdot L^{-1}$ and 5 $g \cdot L^{-1}$ of the clay were introduced and mixture was put under stirring [12], during the first two hours at maximum stirring and then it went to 600 r.p.m. The solution is then filtered with the clay for 48 hours and measure with the spectrophotometer to calculate the concentration of dye that has not been absorbed by the clay [13, 14]. The nanoclays with the dye were measured in a Jasco V-670, double beam spectrophotometer between 190-2700 nm and the color differences were calculated.

3. RESULTS AND DISCUSSSION

The results in Table 2 show how after the clay action the dye concretions have gone from $5 \cdot 10^{-2}$ g·L^{-1} to values between $3.41 \cdot 10^{-4}$ and $1.6 \cdot 10^{-3}$ g·L^{-1}. A bigger approach can be seen in the reactive dye with respect to direct dyes. No significant differences are observed between the use of different concentrations of nanoclay

Table 2. *Difference in concentration after HC absorption*

	Sample ref.	HC conc. g·L^{-1}	Initial conc g·L^{-1}	Final conc g·L^{-1}	% absorption
Direct Blue 199	B199-5	5	0.05	$7.80 \cdot 10^{-4}$	98.44
	B199-10	10	0.05	$7.80 \cdot 10^{-4}$	98.44
Direct Red 23	DR-5	5	0.05	$5.47 \cdot 10^{-4}$	98.91
	DR-10	10	0.05	$5.76 \cdot 10^{-4}$	98,85
Direct Blue 71	B71-5	5	0.05	$1.54 \cdot 10^{-3}$	96.92
	B71-10	10	0.05	$1.60 \cdot 10^{-3}$	96,80
Reactive Yellow	RY-5	5	0.05	$4.08 \cdot 10^{-4}$	99.18
	RY-10	10	0.05	$3.41 \cdot 10^{-4}$	99.32

The color measurements of the dye-clay hybrids represented in chromatic diagrams are shown Figure 2. As in the absortion results, no significant differences were observed between the compounds obtained at 5 or 10 g·L^{-1}

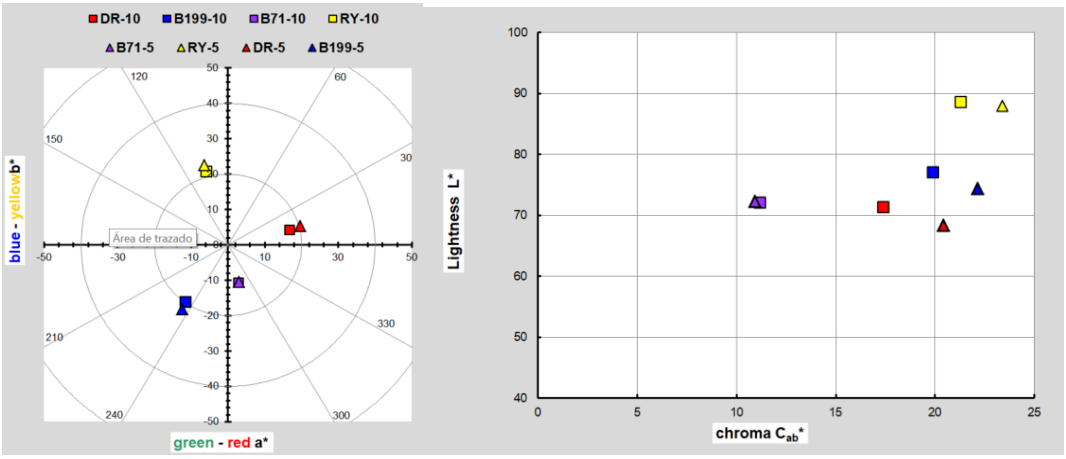


Fig. 2: *Color measurements of HC nanoclays using different concentration of dye*

4. CONCLUSIONS

In view of the results, we can conclude that the results and interpretations provided in other studies are reproduced in our trials. The HC shows a great capacity for absorption and fixation of the dye within its structure. Furthermore, the increased use of this nanoclay has not shown very different results both in the absorption of dye and the color obtained in the hybrid, despite using twice the concentration. So in case of industrializing this method it would be interesting to work at the best possible concentration of clay that provides the most optimal results, allowing to reduce costs and avoid the unnecessary use of material.

REFERENCES

[1] M. Wakkel, B. Khiari, and F. Zagrouba, "Textile wastewater treatment by agro-industrial waste: Equilibrium modelling, thermodynamics and mass transfer mechanisms of cationic dyes adsorption onto low-cost lignocellulosic adsorbent," *J. Taiwan Inst. Chem. Eng.*, vol. 96, pp. 439–452, Mar. 2019.

[2] M. L. Mathew, A. Gopalakrishnan, C. T. Aravindakumar, and U. K. Aravind, "Low – cost multilayered green fiber for the treatment of textile industry waste water," *J. Hazard. Mater.*, vol. 365, pp. 297–305, Mar. 2019.

[3] F. M. Micó Vicent, Barbara; Martinez Verdu and J. E. Gilabert Perez, "Optimización de la síntesis de nanopigmentos de origen natural para biopolímeros mediante el uso del diseño de experimentos."

[4] M. Ogawa, R. Takee, Y. Okabe, and Y. Seki, "Bio-geo hybrid pigment; clay-anthocyanin complex which changes color depending on the atmosphere," *Dye. Pigment.*, vol. 139, pp. 561–565, Apr. 2017, doi: 10.1016/J.DYEPIG.2016.12.054.

[5] F. López Arbeloa, V. Martínez Martínez, J. Bañuelos Prieto, and I. López Arbeloa, "Adsorption of Rhodamine 3B dye on Saponite colloidal particles in aqueous suspensions," *Langmuir*, vol. 18, no. 7, pp. 2658–2664, 2002, doi: 10.1021/la0113163.

[6] M. I. Carretero, M. Pozo, C. Sánchez, F. J. García, J. A. Medina, and J. M. Bernabé, "Comparison of saponite and montmorillonite behaviour during static and stirring maturation with seawater for pelotherapy," *Appl. Clay Sci.*, vol. 36, no. 1–3, pp. 161–173, Apr. 2007, doi: 10.1016/J.CLAY.2006.05.010.

[7] D. Guillermin *et al.*, "New pigments based on carminic acid and smectites: A molecular investigation," *Dye. Pigment.*, vol. 160, pp. 971–982, Jan. 2019, doi: 10.1016/J.DYEPIG.2018.07.021.

[8] E. M. Moujahid, R. Lahkale, H. Ouassif, F. Z. Bouragba, and W. Elhatimi, "New organic dye/anionic clay hybrid pigments: Preparation, optical properties and structural stability," *Dye. Pigment.*, vol. 162, pp. 998–1004, Mar. 2019, doi: 10.1016/J.DYEPIG.2018.11.021.

[9] J.-Z. Yi and L.-M. Zhang, "Removal of methylene blue dye from aqueous solution by adsorption onto sodium humate/polyacrylamide/clay hybrid hydrogels," *Bioresour. Technol.*, vol. 99, no. 7, pp. 2182–2186, May 2008, doi: 10.1016/J.BIORTECH.2007.05.028.

[10] dos Santos, R. M. M., Gonçalves, R. G. L., Constantino, V. R. L., da Costa, L. M., da Silva, L. H. M., Tronto, J., & Pinto, F. G. (2013). Removal of Acid Green 68: 1 from aqueous solutions by calcined and uncalcined layered double hydroxides. Applied Clay Science, 80, 89-195.

[11] J. L. Bigman, "Monitoring of Chemicals and Water," *Handb. Silicon Wafer Clean. Technol.*, pp. 619–657, Jan. 2018, doi: 10.1016/B978-0-323-51084-4.00011-3.

[12] Silva, M. M., Oliveira, M. M., Avelino, M. C., Fonseca, M. G., Almeida, R. K., & Silva Filho, E. C. (2012). Adsorption of an industrial anionic dye by modified-KSF-montmorillonite:Evaluation of the kinetic, thermodynamic and equilibrium data. Chemical engineering journal, 203, 259-268.

[13] B. Micó-Vicent, FM Martínez-Verdú (2017) Method for optimising the synthesis of hybrid nanopigments,WO2017072382A1.

[14] H. Fischer, L.F. Batenburg, (2001) Coloring Pigment, patent WO0104216.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

INVESTIGATION OF THE BENDING BEHAVIOUR OF WOVEN SPACER FABRICS

SADOUGHI Mahlagha[1], ASAYESH Azita[2], EZAZSHAHABI Nazanin[3], HAMZEH Saeed[4]

[1, 2, 3,4] Amirkabir University of Technology, Textile Engineering Faculty, 424 Hafez Ave, 15875-4413, Tehran, Iran

E-Mail: m.sadoughi@aut.ac.ir, a_asayesh@aut.ac.ir, ezazshahabi@aut.ac.ir, Saeed2.hamzeh@gmail.com

Corresponding author: Sadoughi, Mahlagha, E-Mail: m.sadoughi@aut.ac.ir

Abstract: *Spacer fabrics are a category of 3D textiles and consist of two distinct fabrics which are connected together by spacer (pile) yarns. Spacer fabrics are produced by weaving, warp knitting and weft knitting systems and have many applications in different industries. The aim of this study was the production of woven spacer fabrics and analysis of their bending behavior. Thereafter, six different spacer fabrics were produced based on two variables: spacer yarn pattern and spacer yarn density. The resistance to bending of the spacer fabrics was measured based on the standard test method for evaluation of the fabric stiffness, by the circular bend procedure. In this regard, the maximum bending load and bending energy of spacer fabrics were recorded. The results showed that resistance to bending in spacer fabrics with V pattern of spacer yarns in the structure and also spacer fabrics with full threading of spacer yarns in the weaving reed was more than other kinds of spacer fabrics. By increasing the pile density and the number of spacer yarns, the fabric's bending became more difficult. Statistical analysis of results at the confidence range of 95%, also revealed that the spacer yarn pattern and spacer yarn density have significant effect on bending resistance of spacer fabrics.*

Key words: *Spacer Fabric, Weaving, Bending Load, Bending Energy, Weave Structure.*

1. INTRODUCTION

Spacer fabrics are a kind of three-dimensional fabrics where two surface layers are connected to each other by means of spacer (pile) yarns. Spacer fabrics are commonly produced by the circular knitting process (weft-knitted spacer fabrics), double needle bar warp knitting process (warp-knitted spacer fabrics) or weaving process (woven spacer fabrics). However, woven spacer fabrics show exclusive mechanical properties, such as higher stiffness, strength and dimensional stability, than knitted spacer fabrics and are used for technical applications such as aerospace, automotive and medical industries and so on [1,2,3]. Spacer fabrics are characterized by their special mechanical properties compared to two-dimensional textiles, which also depends on the properties of the spacer yarns connecting the surface layers [4,5]. Many researches have been performed to investigate the mechanical properties of spacer fabrics.

Yip et al (2007), investigated the bending and compression behavior of warp knitted and weft knitted spacer fabrics using monofilament and multifilament as the spacer yarns. The results showed that spacer fabrics produced by monofilament spacer yarns presented better resistance

against compression and bending deformations, because monofilaments are less flexible than multifilaments. It was also revealed that the angle of the spacer yarns in the fabric structure affects the mechanical properties of the spacer fabrics [6].

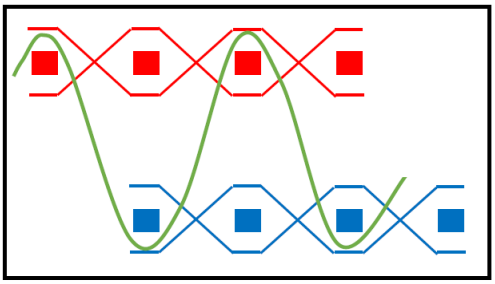
Liu et al (2012), tried to find out the effect of structural parameters on compression behavior of warp knitted spacer fabrics used for cushioning applications. In this regard, it was declared that by increasing the number of underlaps in the fabric, the angle of spacer yarns and therefore, the compressional resistance of the fabric decreases [7].

The aim of this study is to produce woven spacer fabrics with various structural parameters and considering the effect of fabrics' structural parameters on their bending behavior.

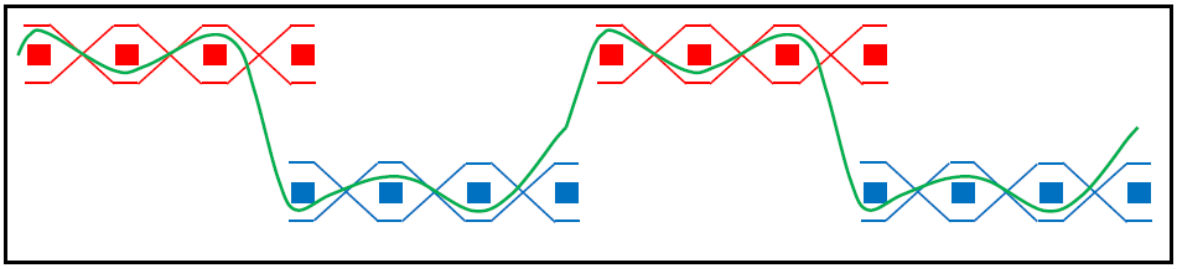
2. EXPERIMENTAL

2.1 Sample preparation

The spacer fabrics were produced by weaving mechanism, using a shuttle loom. In this regard, six different spacer fabrics were produced by utilization of polyester ($10_{/3}$ Ne) as warp and weft yarns, and cotton ($12_{/3}$ Ne) as spacer yarns. Variables of the woven spacer fabrics consist of spacer yarn pattern (V pattern and W pattern) and spacer yarn density (full threading of spacer yarn (D-1), every other one theading of spacer yarn (D-01), and every other two threading of spacer yarn (D-001)), as shown in Figure 1 and Figure 2, respectively. The plain weave pattern was chosen as the pattern of both layers. It should be noted that the spacer yarn is also a group of warp yarns that connects the upper and lower layers of the spacer fabric.

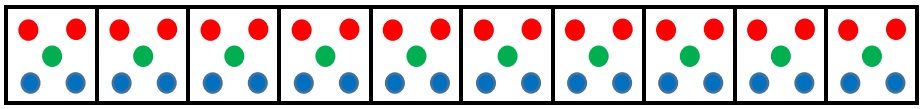


a) V pattern of spacer fabric

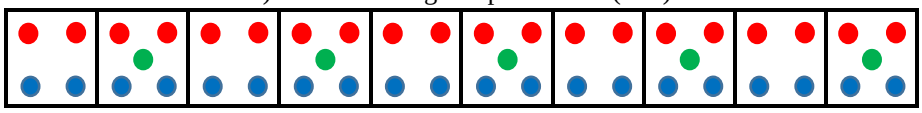


b) W pattern of spacer fabric

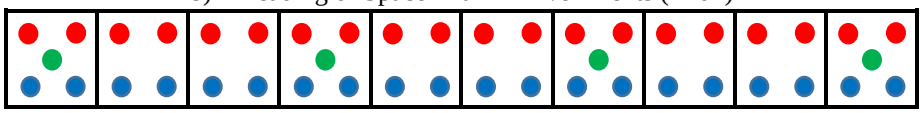
Fig. 1: *Schematic of spacer fabrics with V and W patterns*



a) Full Threading of Spacer Yarn (D-1)



b) Threading of Spacer Yarn in Even Dents (D-01)

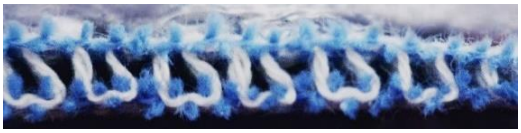


c) Threading of Spacer Yarn Once in a Three Dent Repeat (D-001)

Fig. 2: *Different threading of spacer yarn in weaving reed (Red dots: warp yarns for upper layer, Blue dots: warp yarns for lower layer, Green dots: spacer yarns)*

In Figure 3, the images of the longitudinal and transverse cross sections of the spacer woven fabrics are presented.

a) Cross section of Spacer fabrics (V pattern)



b) Cross section of Spacer fabrics (W pattern)

c) Transverse cross section

Fig.3: *Longitudinal and transverse cross section of spacer fabrics with V and W pattern*

Moreover, the constructional and physical characteristics of the woven spacer fabrics, are gathered in Table 1.

As it is clear in Table1, the warp and weft densities of the upper and lower layers of the woven spacer fabrics were constant and only the change in the pattern and density of spacer yarn, resulted in the variation of different samples' properties.

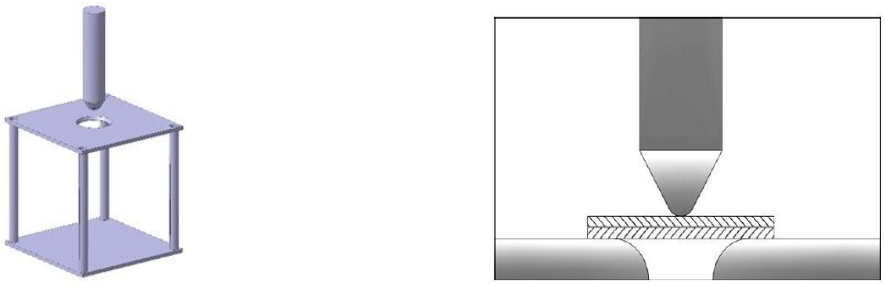
Table 1: *Specifications of the woven spacer fabrics*

Sample Code	Spacer yarn pattern	Type of threading in weaving reed	Warp density (cm^{-1})	Weft density (cm^{-1})	Fabric thickness (mm)	Areal weight ($^{g}/_{m^2}$)	Spacer yarn density (cm^{-2})
S1	V	D-001	9	10.5	10.08	978	15.6
S2	V	D-01	9	10.5	9.63	1021	26.0
S3	V	D-1	9	10.5	8.49	1283	52.1
S4	W	D-001	9	10.5	6.45	798	13.5
S5	W	D-01	9	10.5	8.63	964	22.5
S6	W	D-1	9	10.5	7.89	985	33.3

2.1 Testing Method

Measuring the bending resistance of the spacer fabrics have been performed based on the standard test method for stiffness of fabric by the circular bend procedure (ASTM D 4032). The circular bend procedure offers a load value related to fabric stiffness, simultaneously averaging stiffness in all directions. In this platform, the fabric is placed on a smooth plate ($200 \times 200\ mm^2$) with a 40 mm orifice on it and a plunger which is mounted concentric with the orifice, forced the fabric down through the orifice on the plate. The lap edge of the orifice should be at a 60° angle in order to decrease the stress concentration. The platform was placed on the Instron testing machine 5566 and the required force to pass the fabric through the orifice was recorded by the load cell. The platform and the placement position of the samples are shown in Figure 4.

The test was carried out, using $5 \times 5\ cm^2$ samples and the speed of the test was set on 100 $mm/_{min}$. Maximum bending force (the peak force of the load-displacement curve) and bending energy (area under the curve) were reported as the results of the test.



(a) (b)

Fig.4: *(a) The platform in circular bend procedure and (b) the placement of the sample*

3. RESULT AND DISCUSSION

The average value of maximum bending force and bending energy of spacer woven fabrics with two different spacer yarn patterns and three different spacer yarn densities are reported in Table 2.

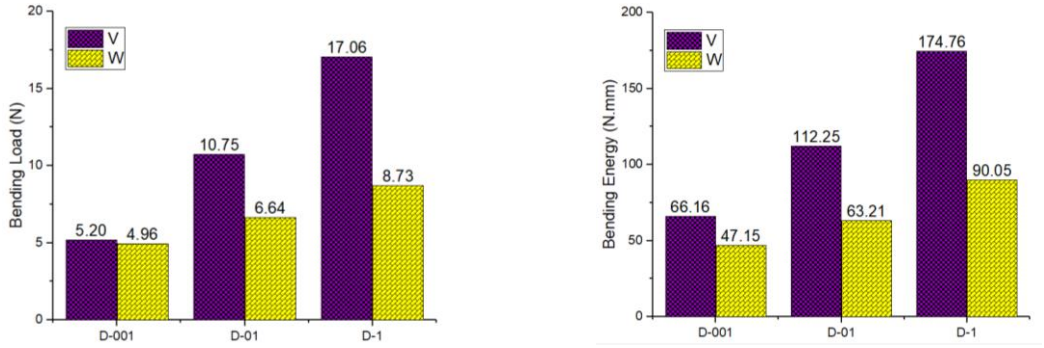
Table 2: The results of bending force and bending energy

Sample Code	Bending force (N)	Bending energy (N.mm)
S1	5.20	66.16
S2	10.75	112.25
S3	17.06	174.76
S4	4.96	47.15
S5	6.64	63.21
S6	8.73	90.05

The comparison of maximum bending force and bending energy between different spacer fabrics are shown Figure 5 (a) and (b), respectively. According to these graphs, the maximum bending load and bending energy in spacer fabrics with V pattern are higher than spacer fabrics with W pattern. Increasing the bending resistance is related to the difference in fabric structure. In spacer fabrics with V pattern, for any single warp and weft yarns, there is one vertical spacer yarn which connects the upper and lower layers, in the spacer fabric structure. So the number of spacer yarns per unit area increases and fabric's resistance to the applied bending load and bending energy rises.

The graphs of Figure 5 also revealed that by considering the constant spacer yarn pattern,

bending resistance of spacer fabrics with D-001 threading pattern (threading of spacer yarn once in a three dent repeat) in weaving reed is less than spacer fabrics with D-01 (threading of spacer yarn in even dents) and D-1 threading patterns (full threading of spacer yarn), respectively. This phenomenon occurred because of difference in density of spacer yarn in the fabric structure. In spacer fabrics with D-001 threading pattern of spacer yarn, the density of spacer yarns in per unit area is less than two other kinds of threading. Therefore, bending resistance decreased in this kinds of spacer fabrics and their flexibility increased. On the other side, in case of spacer fabrics with D-1 threading pattern, the density of spacer yarns per unit area was much more than other spacer fabrics and this fact made the spacer fabric stiffer and less flexible.



(a) (b)

Fig.5: *Comparison of (a) bending load and (b) bending energy in woven spacer fabrics*

In order to investigate the effect of spacer yarn pattern (V and W pattern) and spacer yarn density (D-1, D-01 and D-001 threading patterns in the weaving reed) on maximum bending load and bending energy of woven spacer fabrics, statistical analysis of the results was performed, using the ANOVA test at the confidence level of 95%. The results of statistical analysis are shown in Table 3.

Table 3: Statistical analysis of variables on bending resistance

Bending parameter	P-Value		
	Spacer yarn pattern	Spacer yarn density	Spacer yarn pattern*spacer yarn density
Maximum bending load	0.000	0.000	0.000
Bending energy	0.000	0.000	0.000

According to Table 3, the effect of spacer yarn pattern, spacer yarn density and interaction between these two variables are significant on the maximum bending load and bending energy. This result confirms the trends of graphs in Figure 5.

4. CONCLUSION

Spacer fabric is a three-dimensional fabric consisting of two separate substrates, which are joined together or kept apart by spacer yarns and can be produced in weaving, warp knitting and weft knitting systems. In this study, in the first step, woven spacer fabrics were produced with different spacer yarn patterns and densities, using a shuttle loom. Polyester yarn was chosen as the warp and weft of the fabrics, and cotton was selected as the spacer yarn. Considering two spacer yarn patterns and three different densities for spacer yarns (three kinds of threading in weaving reed), six different samples were produced. In the second step, bending resistance of woven spacer

fabrics were analyzed based on the circular bend procedure. The maximum bending load and bending energy were recorded and the results were analyzed. According to the outcomes of the tests, it was observed that increasing the number of spacer yarns per unit area of the fabric makes the spacer fabric inflexible and higher load is required to bend the fabric. This trend was also observed in spacer fabrics with V pattern and full threading of spacer yarn in the fabric structure. Furthermore, statistical analysis revealed that the effects of spacer yarn pattern and density, on the bending resistance of spacer fabrics are significant.

REFERENCES

[1] B. K. Behera and P. K. Hari, "*Woven Textile Structure: Theory and Applications"*, First ed, Woodhead Publishing, 2010.

[2] X. Chen, L. W. Taylor and L. J. Tsai, "*An Overview on Fabrication of Three-Dimensional Woven Textile Preforms for Composites*", Textile Research Journal, vol. 81(9), pp. 932-944, 2011.

[3] V. Arumugam, R. Mishra, J. Militky and J. Salacova, "*Investigation on Thermo-Physiological and Compression Characteristics of Weft-Knitted 3D Spacer Fabrics*", The Journal of the Textile Institute, vol. 108(7), pp. 1095-1105, 2017.

[4] X. Chen, "*Advances in 3D Textiles"*, First ed, Elsevier, 2015.

[5] Lawrence, C, *High performance textiles and their applications*, Woodhead Publishing Series in Textiles: Number 153, (2014).

[6] J. Yip and S. P. Ng, "*Study of Three-Dimensional Spacer Fabrics: Physical and Mechanical Properties*", Journal of materials processing technology, vol. 206(1-3), pp. 359-364, 2008.

[7] Y. Liu, H. Hu, L. Zhao and H. Long, "*Compression behavior of warp-knitted spacer fabrics for cushioning applications",* Textile Research Journal, vol. 82(1), pp. 11-20, 2012.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

RECONCEPTION OF WOMEN'S BLOUSE BASED ON FUNCTIONAL ANALYSIS

MALCOCI Marina[1], POPA Parascovia[2]

[1, 2] Tehnical University of Moldova, Faculty of Textiles and Polygraphy, Bd. Ștefan cel Mare 168, Chișinău, R. of. Moldova, E-mail: marina.malcoci@mtcp.utm.md

Corresponding author: Malcoci, Marina, E-mail: marina.malcoci@mtcp.utm.md

Abstract: *In order to achieve quality products from a qualitative and economic point of view, it is necessary to redesign the current products, insisting on both the techniques and the performing machines, as well as on their functional optimization. At present, there are numerous optimization methods, which differ in particular, by the way of the succession of the steps in the admissible field, but lead to a common end. The paper aims to optimize a garment product using value analysis. The authors selected 20 functions for the analyzed product. From the study, it was found that consumers give preference to the features of the products, the ease of dressing-undressing, easy maintenance, psychosensory comfort, etc., and the manufacturer of the technological and economic ones. Based on the results obtained, a collection of proposal models was developed. The proposed models are close to the basic model, due to the combination of consumer requirements and production requirements. Due to the great diversity of the types of clothing products, it is necessary to know the functions imposed by the destination and the specific operating conditions. Knowing all the functions of the clothing products will allow us to make optimal decisions regarding the launch of the products in the manufacture that correspond to the consumers' requirements. Identifying the needs and wants of the beneficiaries, knowing the potential of the producers will allow the elaboration of a collection of models that will meet at a high level the ever increasing demands of the consumers.*

Key words: *consumer requirements, technological operations costs, material costs, collection, functions.*

1. INTRODUCTION

Clothing is a means of covering, beautifying and protecting the human body from external factors with which it comes in direct contact. It is also a way of expressing the personality of each carrier, even if the choice of one or another product is limited by its destination, assortment or by a certain function of it [1].

The design of new products and the optimization of the existing ones occupy an important place in the textile manufacturers' concerns. In order to achieve quality products from a qualitative and economic point of view, it is necessary to redesign the current products, insisting on both the techniques and the performing machines, as well as on their functional optimization. At present, there are numerous optimization methods, which differ in particular, by the way of the succession of the steps in the admissible field, but lead to a common end. Among the most important methods used to optimize products, we can mention: the method of associations garlands, analogy, brainstorming, empathy, evocation, idea map, synthesis, analysis and value engineering. The paper aims to optimize a garment product using value analysis.

2. FUNCTIONS OF CLOHING PRODUCTS

The function of a product represents the property, the property, the elemental characteristic of it, which arising from the user's need, directly or indirectly confers utility and implicit value on the object. Each object usually has several functions. These can be classified according to several criteria, namely [2, 3]: according to the possibilities of measuring the technical dimensions; after contributing to the use value; how the user perceives it; after the moment of the study; according to the importance for the object, etc.

Speaking about the functions of each assortment of clothing, they fall into two broad categories [4, 5]: utilitarian and informational-aesthetic. The given functions are divided, as a result of the very different destination that the garment products have, in elementary functions that reflect a well-defined property of the respective product.

Analyzing the specialized literature, the authors identified several functions, which could be grouped in [6-8]: aesthetics; gnoseologic; ergonomic; comfort; reliability; maintainability; protection; medicines etc. The number of functions in a product varies depending on the destination. Some functions are missing in some products, while in other clothing items they are present. By establishing the correct number of functions and giving due importance to them, the manufacturer will obtain: reductions in production costs, simplification of manufacturing processes, products that meet the needs of consumers, etc.

3. FUNCTIONAL OPTIMIZATION OF THE WOMEN'S BLOUSE

In order to carry out the case study, a blouse for women was manufactured at the company "Portavita" L.T.D., Chisinau city. The authors selected 20 functions for the analyzed product contained in table 1 [6-8].

Table 1: *Women's blouse product functions*

The notation done	**Function name**	**The notation done**	**Function name**
F1	The novelty of the model	F11	Ventilation capacity
F2	Matching the model with the lifestyle and clothing of the wearer	F12	Psychosensory comfort
F3	The appearance of the product	F13	The degree of body coverage
F4	Aesthetics of technological processing	F14	Fixing the product on the body
F5	Advertising function	F15	Resistance to mechanical stresses
F6	Carrier of information	F16	Resistance to surface wear
F7	Dimensional correspondence	F17	Stability of shapes and dimensions
F8	Ease in dress-undress	F18	Resistance to the action of biological factors
F9	Moisture absorption	F19	Easy maintenance
F10	Humidity transfer	F20	Reconditioning capacity

In order to establish the relative importance of women's blouse functions, an opinion poll was conducted among 10 consumers aged 20-30 years, women.

Consumers applied the direct ordering process, so each function is assigned a rating of between 1 and 20, depending on the importance or value of each. For each of the 20 functions, the notes given by the user were summed vertically, obtaining a total, an average for each function and a weight of them. As a result, it was possible to make an order of the importance of the functions, from which it was found that the most important function is considered F3 - the aspect of the product with the minimum weight (1,99%), followed by F8 - the ease in dress-undress (3,61%).

In order for a product to meet the high demands of consumers, it is necessary to consume certain resources. Of the resources consumed for the realization of a product we mention [2, 3]: intellectual resources, physical resources, material resources, financial resources, energy resources.

The following is how to allocate financial resources by technological functions and operations (tab. 2). The distribution of the cost of the product and its components by functions requires a logical reasoning, an analysis of the characteristics of the materials, parts and operations that make up the product. Often, a landmark or operation contributes to one or more functions. Therefore, in order to determine the cost of a function, which is sometimes determined by a part of a landmark or operation, we must deepen the analysis beyond the limit of the accounting records.

Table 2: *Economic dimensioning of functions*

Function:	**Name of technological operations:**				**Total, lei**	**Share, kj**
	Stitching	**Processing**	**Finishing**	**packing**		
F1	-	2	-	-	2	0,9
F2	16	1,5	-	-	17,5	7,5
F3	33,5	-	-	-	33,5	14,33
F4	20	-	-	-	20	8,6
F5	14,7	1,2	-	-	15,9	6,8
F6	27,5	2,3	-	-	29,8	12,75
F7	17	-	3,9	-	20,9	8,9
F8	25	-	-	-	25	10,7
F9	-	-	2	-	2	0,9
F10	-	-	2,5	-	2,5	1,1
F11	-	-	3,5	-	3,5	1,5
F12	-	-	-	0,8	0,8	0,34
F13	13,5	-	-	-	13,5	5,8
F14	23	-	-	-	23	9,8
F15	-	-	1,5	-	1,5	0,6
F16	-	-	-	0,5	0,5	0,21
F17	3,58	-	0,87	-	4,45	1,9
F18	-	-	-	0,341	0,341	0,15
F19	-	-	4,5	-	4,5	1,92
F20	9	0,821	2,8	-	12,62	5,4
Cost of materials, lei	198	6,5	21	1,5	227	97
The cost of the work, lei	4,780	1,321	0,571	0,141	6,813	3
The total cost, lei	202,78	7,821	21,571	1,641	233,813	100

Both the costs by groups of technological operations, as well as those of the purchase of raw materials, auxiliary materials and maneuver were taken from the technical documentation of the product concerned and distributed to the functions depending on their importance. Then the weight of each cost in the total cost of the product was calculated, the results being listed in table 2.

Systematic analysis of functions allows the identification of oversized, well dimensioned and economically undersized functions. This analysis is performed by comparing two categories of weights (tab. 3): the weight in the use value (pj) and the weight in the production cost (kj). Based on the data in table 3, the cost chart was drawn up (fig. 1).

Table 3: *Systematic analysis of functions*

Function	p_j	k_j	p_j^2	$k_j \bullet p_j$	$a \bullet p_j$	$k_j - a \bullet p_j$	$(k_j - a \bullet p_j)^2$
F1	4,48	0,9	20,0704	4,032	3,98944	-3,0894	9,54463951
F2	5,14	7,5	26,4196	38,55	4,57717	2,92283	8,54293521
F3	1,99	14,33	3,9601	28,5167	1,7721	12,5579	157,700978
F4	4,63	8,6	21,4369	39,818	4,12302	4,47699	20,0433947
F5	5,52	6,8	30,4704	37,536	4,91556	1,88444	3,55111411
F6	6,45	12,65	41,6025	81,5925	5,74373	6,90628	47,6966344
F7	4,67	8,9	21,8089	41,563	4,15864	4,74137	22,4805421
F8	3,61	10,7	13,0321	38,627	3,21471	7,4853	56,0296412
F9	5,98	0,9	35,7604	5,382	5,32519	-4,4252	19,5823065
F10	5,86	1,1	34,3396	6,446	5,21833	-4,1183	16,960642
F11	5,43	1,5	29,4849	8,145	4,83542	-3,3354	11,1249932
F12	3,99	0,34	15,9201	1,3566	3,5531	-3,2131	10,3239795
F13	5,52	5,8	30,4704	32,016	4,91556	0,88444	0,78223411
F14	4,46	9,8	19,8916	43,708	3,97163	5,82837	33,9698969
F15	5,98	0,6	35,7604	3,588	5,32519	-4,7252	22,3274205
F16	4,81	0,21	23,1361	1,0101	4,28331	-4,0733	16,5918136
F17	6,32	1,9	39,9424	12,008	5,62796	-3,728	13,8976858
F18	5,56	0,15	30,9136	0,834	4,95118	-4,8012	23,0513294
F19	3,82	1,92	14,5924	7,3344	3,40171	-1,4817	2,19546452
F20	5,35	5,4	28,6225	28,89	4,76418	0,63583	0,40427343
Total	**100**	**100**	**517,635**	**460,953**	**-**	**-**	**496,8019**

The cost chart allows us to consider:

- function F3 as an oversized one;
- the functions F2, F4, F6, F7, F8, F14 are economically well dimensioned;
- functions F1, F5, F9, F10, F11, F12, F13, F15, F16, F17, F18, F19, F20 - economically oversized.

Figure 1 shows concrete solutions for the redesign activity, namely: for economically oversized functions, a reduction of costs is required, and for undersized functions an increase of economic dimensions is possible. The economic oversizing is generated by the special importance given by the manufacturer to the product's appearance.

This oversize can be viewed in two forms. The first is that the appearance of the product can be a decisive criterion that determines the consumer to purchase the product and therefore the

expenses for carrying out this function are justified. And second, if the company does not have the financial resources to carry them out, then the manufacturing unit will have to resize these functions.

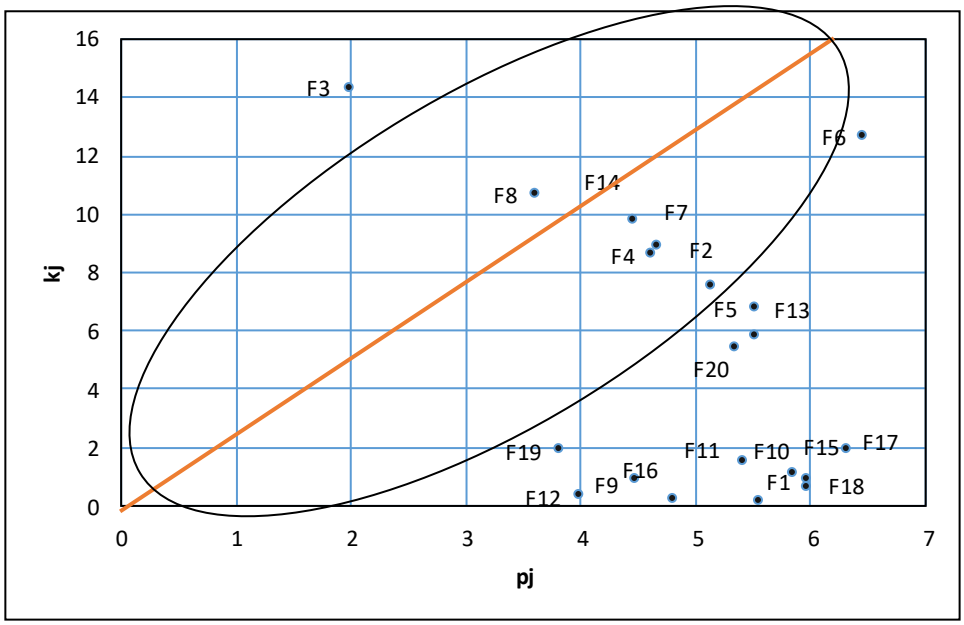


Fig. 1: *Systematic analysis of the functions for the analyzed product*

Of the economically undersized functions only the F12 (psychosensory comfort) and F19 (light maintenance) functions are of importance to consumers, being ranked 4 and 3 in the order of their importance. In order to resize these functions it is proposed to renounce the functions that consumers do not consider important (eg F9, F10, F15 and F18) and their financial resources to be allocated to functions F12 and F19.

From the study, it was found that consumers give preference to the features of the products, the ease of dressing-undressing, easy maintenance, psychosensory comfort, etc., and the manufacturer of the technological and economic ones.

Based on the obtained results, the collection of proposal models was elaborated, presented in figure 2. The proposed models are close to the basic model, due to the combination of consumer requirements and production requirements.

4. CONCLUSIONS

Due to the great diversity of the types of clothing products, it is necessary to know the functions imposed by the destination and the specific operating conditions. Knowing all the functions of the clothing products will allow us to make optimal decisions regarding the launch of the products in the manufacture that correspond to the consumers' requirements.

Identifying the needs and wants of the beneficiaries, knowing the potential of the producers will allow the elaboration of a collection of models that will meet at a high level the ever increasing demands of the consumers.

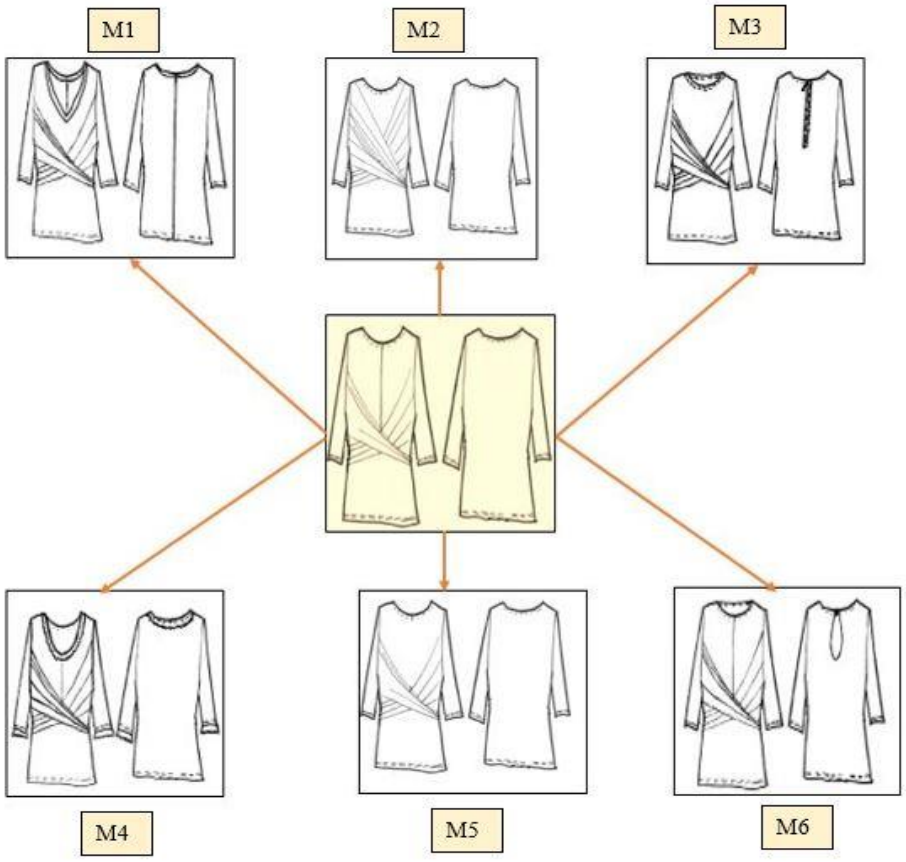


Fig. 2: *Colecția de modele propunere*

REFERENCES

[1] C. Preda, L. Cioară, S. Preda, L. Leon, "*Structura și calitatea materialelor pentru produsele de îmbrăcăminte",* Editura Performantica, Iași, România, 2004.

[2] R. M. Ciobanu, Gh. Condurache, "*Ingineria valorii",* Editura TEHNICA-INFO, Chișinău, Moldova, 2001.

[3] Gh. Condurache, "*Management aplicat. Managementul valorii produsului",* Editura Gh. Asachi, Iași, România, 1999.

[4] E. Filipescu, "*Structura și proiectarea confecțiilor textile",* Editura Performantica, Iași, România, 2012.

[5] M. Pascal, I. Tutunaru, "*Funcții și cerințe impuse produselor vestimentare pentru copii de vârstă peşcolară",* Conferința Tehnico-Științifică a Studenților și Doctoranzilor consacrată Anului Fizicii, Editura UTM, Chișinău, Moldova, 2005, pag. 281-282.

[6] P. Nicolaiov, "*Perfecționarea sistemelor de fabricație în confecții, prin optimizarea proceselor de tratare umidotermică",* Teză de doctorat, Iași, România, 1998.

[7] P. Nicolaiov, C. Rusu, I. Ionescu, "*Definirea funcțiilor produselor de îmbrăcăminte",* În revista Industria textilă, nr. 2, București, România, 1999.

[8] M. Malcoci, "*Contribuții la diversificarea și optimizarea produselor și proceselor de fabricație în industria de marochinărie",* Teză de doctorat, Iași, România, 2002.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

EFFECT OF MISS STITCH ON THE TENSILE STRESS RELAXATIONOF RIB WEFT KNITTED FABRICS

MIRAKHORLI Sara[1], ASAYESH Azita[2]

[1, 2] Amirkabir University of Technology, Department of Textile Engineering, Textile Excellence & Research Centers, 424 Hafez Ave, 15875-4413, Tehran, Iran,
E-Mail: s_mirakhorli@aut.ac.ir, A_Asayesh@aut.ac.ir

Corresponding author: Mirakhorli, Sara, E-Mail: s_mirakhorli@aut.ac.ir

Abstract: *Stress relaxation is a time-dependent mechanical behavior in textiles. Textile deformations occurred as a result of stress relaxation, induces disturbances in textile function, and further disproportion between performance and application. Stress relaxation can be observed in pressure garments, varicose stockings, pressure bandages, etc.*
The aim of this study is to investigate the effect of miss stitch on the tensile stress relaxation of rib weft knitted fabrics. For this purpose, Rib fabrics with six different knit patterns differing in the number of miss stitches on successive rows were produced from 450/5 denier textured polyester yarn. The stress relaxation of the fabrics was measured in the course and wale directions under 20% strain for 30 minutes.
The results revealed in all fabric structures, the stress created in the fabric decreases with time and that the amount of measured stress in both directions depends on the textile structure, as well as an increase in the number of miss stitches in the fabric structure leads to an increase in the initial stress, residual stress and stress relaxation of the fabric in the course and wale directions. Also, the values of the measured stress in the wale direction were higher than in the course direction.

Key words: *Stress relaxation, Weft knitted, Miss stitch, Pressure garment, viscoelastic materials*

1. INTRODUCTION

Viscoelastic materials are materials whose relationship between stress and strain depends on time. The strength and stiffness of the materials are usually obtained by stress and strain diagrams, which are obtained by applying a constant rate of strain to part of the material. When a viscoelastic material is subjected to a constant strain, the resulting stress decreases over time, which is called the stress relaxation [1]. The applied strain rate, loading velocity, and temperature are the factors that influence the material stress relaxation [2]. Fabrics that have a viscoelastic response to applied load are of particular importance. These fabrics are used for applications such as compression garment, pressure bandages, varicose stockings and more. They are used for clinical treatment, maintaining pressure on the wound area and within a specific range as instructed by physicians or therapists. The reduction of pressure in these fabrics affects their efficiency [3]. The efficacy of compression therapy using compression bandages depends on the amount of compression applied and the pressure maintained during the treatment period. For this purpose, Kumar et al. in 2012 attempted to predict the pressure profile generated by compression bandages using constitutive equations describing the relaxation behavior of viscoelastic materials. It is observed that this pressure profile is highly correlated with the stress relaxation behavior of the bandage. Also to model the pressure profile, the

stress relaxation behavior of compression bandages was studied and modeled using three mechanical models: The Maxwell model, the standard linear solid model and the two-component Maxwell model with a nonlinear spring. It was observed that the models with more component values explained the experimental relaxation curves better [4]. Hashemi et al. in 2015 investigated the effect of the fabric structure, strain amount and strain direction on the stress relaxation of two bar warp-knitted fabrics. The results of this study showed that fabric structure, strain value, and strain direction are important factors affecting the stress and stress relaxation percent of the fabrics [5]. Ardakani et al. in 2016 investigate the effect of the fabric structure, strain percentage, and course density on the stress and stress relaxation of the warp-knitted structures which have longer underlaps in the front bar. The results of this study demonstrated that fabric structure, strain value, and fabric density are important and effective factors in stress and the percentage of stress relaxation in the course and wale directions [6]. Kumar et al. in 2014 examined the impact of pressure bandage materials and structures on the change of bandage pressure over time. The purpose of this research was to explore the influence of different materials and varying structures on the interface pressure profile generated by the bandages overtime during the static state of the limb. According to the results, the reduction of interface pressure for these bandages was higher when wrapped at a higher tension level. Lower reduction of interface pressure was obtained for the sample having higher thread density as compared with lower thread density in the structure, for the same applied tension level during wrapping [7].

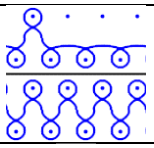
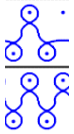
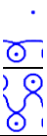
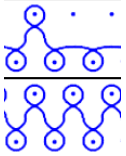
The aim of this research is to investigate the effect of fabric structure on the tensile stress-relaxation of rib weft knitted fabrics.

2. EXPERIMENTAL

To investigate the effect of fabric structure on the stress relaxation of rib weft knitted fabrics, fabrics with six different structures differing in the number of miss (float) stitches on successive rows were produced from 450/5 denier textured polyester yarn. The fabric structures are shown in Table 1. In the fabric code, *k* denots as knit stitch and *m* represents for miss stitch. The first and the two last fabric structures are rib (R), Half Milano (HM) and Full Milano (FM) respectively.

Before tests, the fabrics were relaxed on a flat surface and left to condition for 48h in the laboratory environment. To identify the elastic region for various fabric structures, the tensile test was performed on the fabric samples using an Instron-5566 at a speed of 20 mm/min. Then, the average stress-strain curves of the fabrics were plotted in both course and the wale directions. Thereafter, stress relaxation test was performed utilizing the same instrument and the same speed. The stress relaxation test was conducted in both course and wale directions at 20% strain (common strain in the elastic region of all fabrics) for 30 minutes. From each fabric structure, five samples were tested in each direction and the mean stress relaxation diagrams were plotted over time.

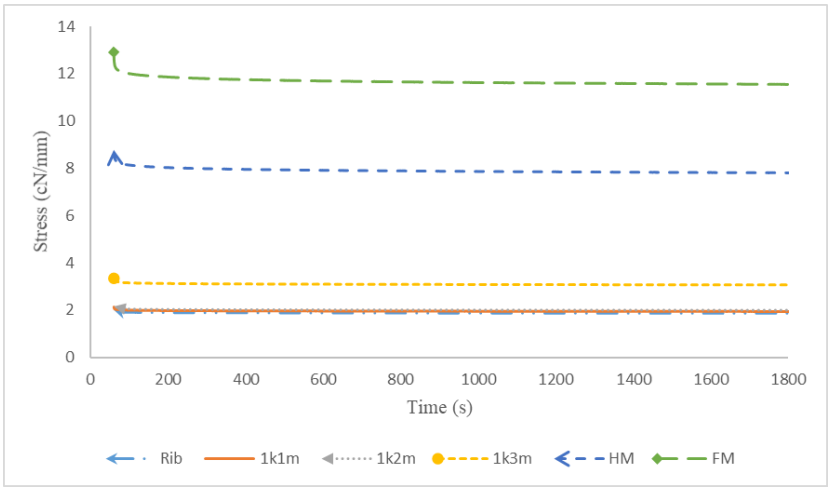
Table 1: *Fabrics structures*

Fabric code	Running notation	Fabric code	Running notation
R		1K3M	
1K1M		HM	
1K2M		FM	

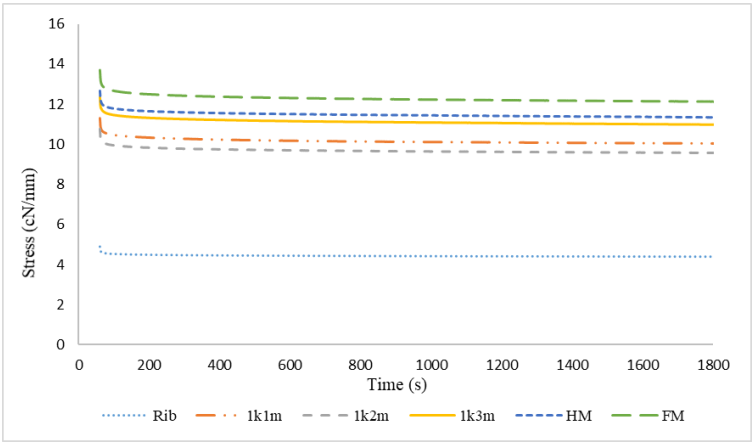
3. RESULT AND DISCUSSION

3.1. Stress decay of the fabrics in the course and wale directions

The plots of average stress decay for different fabric structures in the course and wale directions are illustrated in Fig. 1. As can be seen, in all fabric structures and both directions, the stress created in the fabric decreases with time. Moreover, the fabric structure has significant effect on the fabric stress at any given moment, including the initial stress and residual stress. Full Milano structure (FM) demonstrates the highest initial and residual stresses, whilst rib structure (R) exhibits the lowest initial and residual stresses.



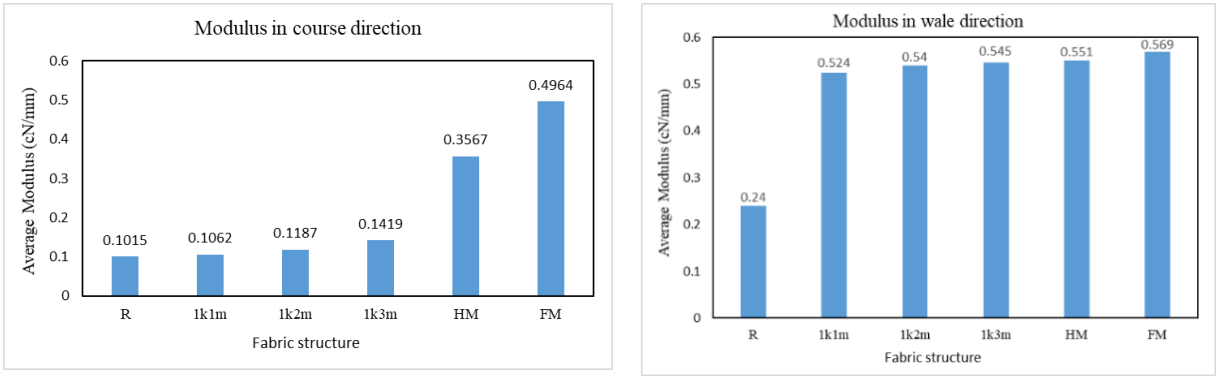
(a)



(b)

***Fig. 1**: Effect of fabric structure on the stress decay in the (a) course direction b) wale direction*

The difference in stress values can be attributed to the difference in elastic modulus of the fabrics. The elastic modulus of each fabric structure in the course and wale directions is shown in Figure 2. Due to the same strain applied to fabrics with different structures, according to Hooke's law, the stress created in fabrics will be proportional to their elastic modulus. In the other word, the higher the elastic modulus of the fabric, the greater the initial stress. Therefore, as shown in Fig.2, by inecreasing the elastic modulus of the fabric from rib to FM, the fabric stress at any moment including the initial stress and the residual stress increases. Besides, as can be seen, the stress decay graphes of rib, 1k1m and 1k2m in the course direction are close to each other due to the slight difference between the elastic modulus of these fabrics in the course direction. The same trend is observed in case of HM, 1k3m, 1k2m and 1k1m in the wale direction, due to the same reason.



(a) (b)

***Fig. 2**: Elastic modulus of fabrics in the a) course direction b)wale direction*

The difference of elastic modulus of fabrics with different structures is due to the presence of miss stitch and their number in the fabric structure. As can be seen in table 1, the orientation of miss stitches in the fabric structure are straight compared to knit stitches which are zigzag. Moreover, miss stitches reduce fabric length because the higher yarn tension on the held loops causes it to rob yarn from adjacent knitted loops, making them smaller [8]. As a result, the fabric's course density increases. Consequently, by increasing the number of miss stitches in the fabric structure, the fabric strength and modulus increase in

the course direction. In the wale direction, due to straight orientation of miss stitches in the fabric structure, the wales approach each other, which leads to increase in the fabric's wale density. Thus, as previously mentioned, the fabric strength and modulus increase in the wale direction as well.

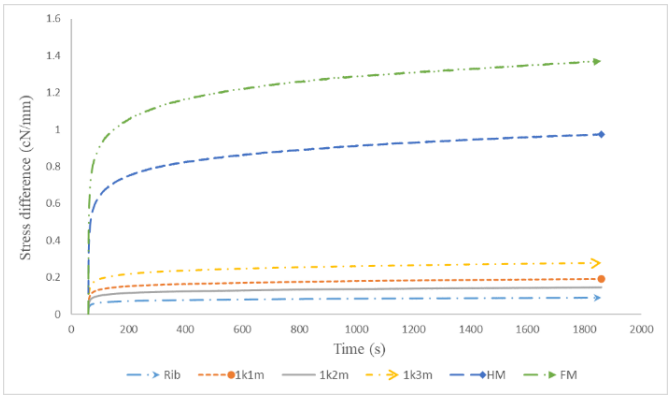
3.2. Stress relaxation of the fabrics in the course and wale directions

The fabrics stress relaxation was calculated at each moment using equation 1, then the stress relaxation diagram was plotted for each fabric structure in the course and wale directions (Fig. 3).

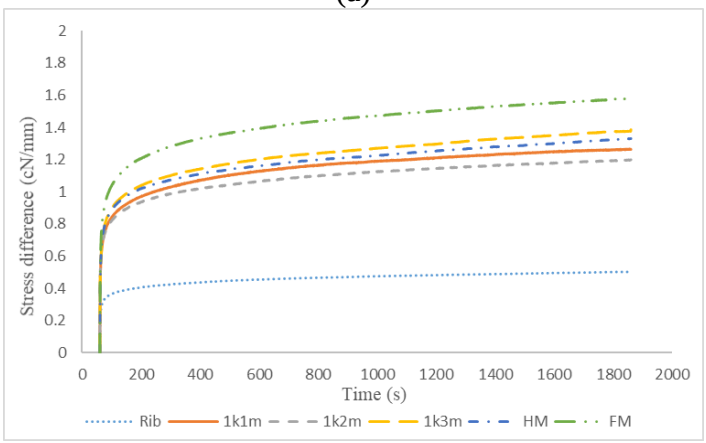
$$\Delta\sigma_t = \sigma_i - \sigma_t \quad (1)$$

In this equation, σ_i is the initial stress or stress at the beginning of the test, σ_t is the stress at time t and $\Delta\sigma_t$ is the stress relaxation at time t.

Figure 3 reveals that for all fabric structures, stress relaxation of the fabric increases with time, but the rate of stress relaxation decreases gradually. In the other word, the slope of the stress relaxation plot decreases with time. Furthermore, fabric structure has remarkable effect on the stress relaxation. By increasing the number of miss stitches in the fabric structure, the stress relaxation increases in both directions. As mensioned formerly, this is due to the fact that, increasing the number of miss stitches leads to higher initial stress in the fabric structure. Consequently, the fabric release more stresses to reach the relaxed state.



(a)



(b)

***Fig. 3**: Fabric stress relaxation under 20% strain in the (a) course direction b) wale direction*

4. CONCLUSIONS

In order to investigate the tensile stress relaxation of rib weft knitted fabrics, polyester fabrics were manufactured with six different structures. Stress relaxation tests were performed for 30 minutes in both course and wale directions with a 20% strain on each fabric. It can be deduced that in all fabric structures, the stress created in the fabric decreases with time. Moreover, the structure of fabrics has significant effect on the fabric stress and stress relaxation. By increasing the number of miss stitches in the fabric structure, stress at any given moment, including initial stress, residual stress and the stress relaxation increases in both directions. Furthermore, in both directions, Rib and Full Milano structures exhibited the lowest and highest stress relaxation respectively.

REFERENCES

[1] Özkaya, N. and Nordin, M. Mechanical properties of biological tissues. In *Fundamentals of Biomechanics* (pp. 195-218). Springer, New York, NY, 1999.

[2] Šajn, Dunja, Jelka Geršak, and Rado Flajk. "Prediction of stress relaxation of fabrics with increased elasticity." *Textile research journal* 76.10: 742-750, 2006.

[3] Frency, S. (1994). The stress relaxation and shrinkage of pressure garment. International Journal of Clothing Science and Technology, 6, 17–27.

[4] Kumar, B., Das, A. and Alagirusamy, R. Prediction of internal pressure profile of compression bandages using stress relaxation parameters. Biorheology, 49(1), pp.1-13, 2012.

[5] Hashemi, N., Asayesh, A., Jeddi, A. A. A., & Ardakani, T. (In press). The influence of two bar warp-knitted structure on the fabric tensile stress relaxation part I: (reverse locknit, sharkskin, queens' cord). The Journal of the Textile Institute, 2015.

[6] Ardakani, T., Asayesh, A. and Jeddi, A.A.A. The influence of two bar warp-knitted structure on the fabric tensile stress relaxation Part II (locknit, satin, loop raised). The Journal of the Textile Institute, 107(11), pp.1357-1368, 2016.

[7] Kumar, B., Das, A. and Alagirusamy, R. Effect of material and structure of compression bandage on interface pressure variation over time. Phlebology, 29(6), pp.376-385, 2014.

[8] D. J. Spencer "Knitting Technology-A comprehensive handbook and practical guide: Technology & Engineering", 3rd ed., Vol.16, p.99, Woodhead Publishing, Cambridge, 2001.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

ANALYSIS OF THE EFFECT OF FABRIC STRUCTURE AND APPLIED VOLTAGE ON THE HEAT FLUX OF THE THREE-LAYER HEATING FABRICS

NAZEM BOUSHEHRI Arash[1], EZAZSHAHABI Nazanin[2], AMANI TEHRAN Mohammad[3]

[1, 2, 3] Amirkabir University of Technology, Textile Engineering Faculty, 424 Hafez Ave, 15875-4413, Tehran, Iran
E-Mail: nazem.arash@aut.ac.ir, ezazshahabi@aut.ac.ir, amani@aut.ac.ir

Corresponding author: Nazem Boushehri, Arash, E-Mail: nazem.arash@aut.ac.ir

Abstract: *In recent years, the use of electrical heating garments was dramatically intensified because of their wide range of application in different industries. One of the common ways to produce these textiles is integration of heating elements in fabric. Taking into account this conditions, in this research 8 groups of three-layer heating fabrics were produce using different weave pattern on the front and back layers, two levels of weft to heating element ratio and two warp ratio of back and front layer. The mentioned three layer fabrics were warp stitched woven fabrics in which the heating element (tungsten) was embedded in the middle layer as wadded weft. In order to report the heat performance of fabrics, thermal parameters such as the heat flux under two different voltages and at different sides of the fabrics were evaluated by using flux meter sensor. Moreover, this sensor was situated at different positions in relation to the fabric, in order to simulate various functional conditions of the heating fabric. According to the results, the voltage, ratio of weft to element and ratio of warp yarns in front and back layer, had significant influence on the measured heat flux. On the other hand, the weave pattern and technical side of the fabric did not have significant effect on the heat flux.*

Key words: *Heat Performance, Voltage, Thermal Behaviour, Fabric Structure, Tungsten Heating Element*

1. INTRODUCTION

Recent growth in the field of wearable electronics, have abounded new areas of application such as health care, defense and ergonomic monitoring. Meanwhile, much focus has been shifted toward electrical heating garments. The aim of using electrical heating textiles is to produce heat for the wearer. These textiles usually contain sensors, activators, data processors, energy source and user interface [1, 2]. There are many research works going on in the field of electrical heating garments, in past few years. Muthukumar et al. (2019) designed and developed electric heating fabrics by copper wires in weft and acrylic yarns in warp, which can be used with a minimum power supply in order to obtain a wearable system [3]. Nazem Boushehri et al. (2019) fabricated a three-layer heating fabric and measured the rate of increasing temperature and found the best element type in order to be used in these fabrics [4]. Park et al. (2016) investigated the influence of the distance of heating unit from body in multilayered winter clothing system on heating efficiency. It was found that the closeness of the heating unit to the skin would result in higher heating efficiency of electric heating clothing [5]. Neves et al. (2015) used a numerical approach to study the heat transport through a blanket with an embedded smart heating system. In this research it was revealed that to ensure an optimal comprise between the thermal performance of product and temperature of the surface, the

distance between the wires should be small [6]. Hao et al. (2012) presented an improved fabrication method for the flexible heating fabrics which were developed by silver filaments or coated silver yarns. In this regard, the resistance thermostability and extreme load current of various conductive materials were analyzed to present the best conductive material to be utilized in the mentioned fabrics [7]. Kayacan et al. (2009) developed electric heating pads using steel fabrics and investigated the heat generation. It was found that power supply, size of pads, number of plies and amount of conductive yarns are the most important parameters that affect the heating performance of electrical heating textiles [8].

In this research it is intended to study the influence of fabric structural parameters and also the amount of exerted voltage on the heat flux of the woven three-layer heating fabrics.

2. EXPERIMENTAL

2.1 Sample preparation

Eight kinds of three-layer warp stitched woven fabrics were designed and produced on a handloom machine with 8 shafts, in the way that the front layer and back layer fabrics consisted of two kinds of weave patterns (Twill 2/2 and Plain) and the tungsten heating element were embedded in the middle layer as wadded weft. Moreover, the presence of heating element in the fabric structure had two conditions of 6 and 12 (for example after 6 weft yarn insertion, 1 heating element was embedded). In addition, there was two different ratios of warp yarn in back and front layer. In four groups of the fabrics, the number of warp yarns in both layers were the same (1:1) and in the other groups this ratio was 1:2. The specifications of the three layer woven fabrics are shown in Table 1.

Table 1: *fabrics specifications*

Sample No.	Weight (g/m^2)	Thickness (mm)	Weave pattern "Front Layer"	Weave pattern "Back layer"	Element ratio to weft	Ratio of warp yarn in front to back layer	Weft density (cm^{-1})
1	578.13	3.03	Twill 2/2	Twill 2/2	6	1	48.9
2	517.47	2.48	Twill 2/2	Plain	6	1	38.8
3	542.28	3.16	Twill 2/2	Twill 2/2	12	1	45
4	513.23	3.03	Twill 2/2	Plain	12	1	39.8
5	473.96	2	Twill 2/2	Twill 2/2	6	2	25.5
6	475.97	1.88	Twill 2/2	Plain	6	2	24.7
7	462.53	1.97	Twill 2/2	Twill 2/2	12	2	23.9
8	462.87	1.96	Twill 2/2	Plain	12	2	23.5

As an example, the weave pattern, drafting plan and the peg plan for weaving of the sample No. 4 is shown in Figure 1. It is necessary to mention that the heating element insert after 6 or 12 weft. All the samples were woven using 24/2 Nm Acrylic yarns for both weft and warp yarns of the front and back layers.

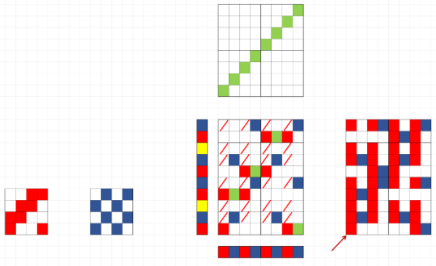
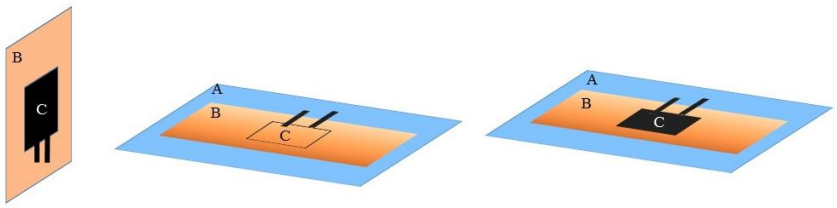


Fig. 1*: The weave pattern, drafting plan and the peg plan of sample No. 4*

In order to evaluate the heating performance of three-layer heating fabrics such as the maximum heat flux and maximum temperature, the heating sensor (FHF02SC) which had the ability to measure both temperature and heat flux at the same time, was utilized. The mentioned sensor was laid out in 3 different positions relative to the fabrics, as shown in Figure 2. In this figure (a, b and c) are insulation area, heating fabric and heart flux sensor respectively.



Beside hanging fabric *Under the fabric* *Above the sample*

***Fig. 2**: Schematic of position of sensor related to the fabrics*

Three positions flux-meter with regards to the heating fabrics are:

- Positioning of the sensor on the three-layer heating fabric which is situated on an insulated surface
- Positioning of the sensor below the three-layer heating fabric (between the fabric and an insulated surface)
- Positioning of the sensor on a hanging fabric

The main reason to conduct this experiment was to find out the performance and heat loss of heating fabric in different situations.

The output value of the sensor is voltage and the maximum heat flux is calculated according to the following equation:

$$S = 5.95 \times 10^{-6}\, V \qquad \textbf{(1)}$$

Where V is the voltage (mV) and S is the amount of heat flux passing through the sample (W/m^2) and 5.95 is the specific coefficient related to the heat flux sensor.

3. RESULT AND DISCUSSION

3.1. Heat flux of heating fabrics

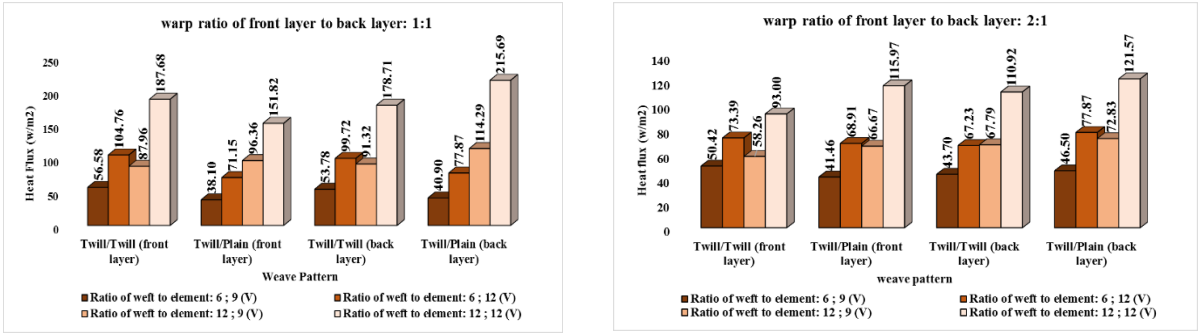
Heat flux of electrical heating fabric is one of the most important features of these textiles. In this regard, the heat flux of woven fabrics was measured under two voltages of 9 (V) and 12 (V), in different positions of sensor against the fabrics. The amount of maximum heat flux in the samples are gathered in Table2.

***Table 2:** Maximum heat flux (W/m^2) in three different positions of sensor*

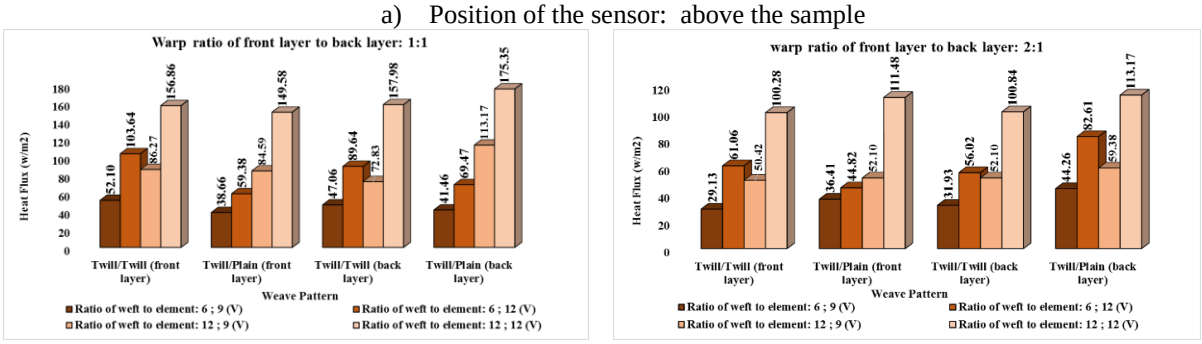
Sample No.	on the hanging fabric				under the sample				above the sample			
	Back layer		Front layer		Back layer		Front layer		Back layer		Front layer	
Voltage (V)	12	9	12	9	12	9	12	9	12	9	12	9
1	111.5	58.82	120.4	76.19	89.64	47.06	103.6	52.1	99.72	53.78	104.7	56.58
2	85.71	49.30	71.15	40.34	69.47	41.46	59.38	38.66	77.87	40.9	71.15	38.10
3	187.1	97.48	177	103.08	158	72.83	156.9	86.27	178.7	91.32	187.7	87.96

4	177.6	92.44	181	95.80	175.4	113.2	149.58	84.59	69.22	114.3	151.9	96.36
5	75.63	42.58	76.19	43.14	56.02	31.93	61.06	29.13	67.23	43.7	73.39	50.42
6	74.51	42.02	75.07	43.14	82.61	44.26	44.82	36.41	77.87	46.50	68.91	41.46
7	113.8	59.94	118.3	71.15	100.9	52.10	100.3	50.42	111	67.79	93	58.26
8	123.8	66.67	129.4	80.11	113.2	59.38	100.9	52.1	121.6	72.83	116	66.67

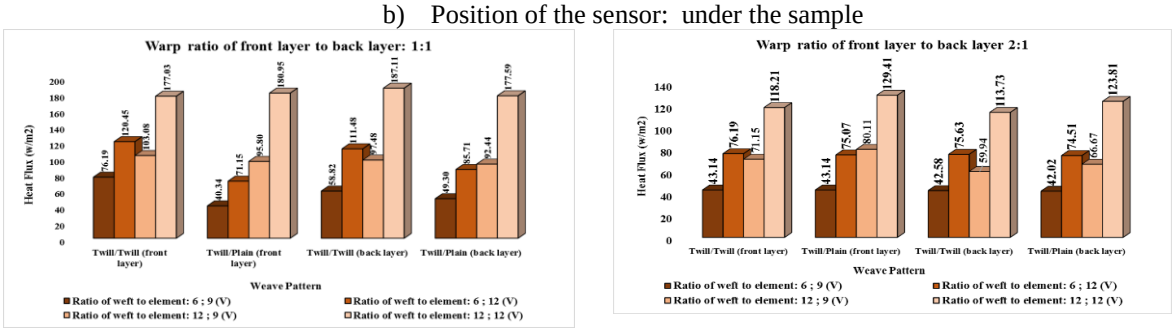
The results of the maximum heat flux are shown in Figure 3. As the plots demonstrates, the heat flux of samples subjected to 12V voltage had higher heat flux, compared to the heated samples exposed to the voltage of 9V. Moreover, the samples that were woven by ratio of weft to element 12, presented higher heat flux in comparison to the samples woven by ratio of weft to element 6, because the same voltage was applied to shorter length of tungsten heating element. According to the result, the measured heat flux in samples woven with the warp ratio of front layer to back layer 2:1 was lower than other samples. This phenomenon occurred because of the different weft density of the mentioned fabrics as shown in Table 1.



a) Position of the sensor: above the sample



b) Position of the sensor: under the sample



c) Position of the sensor: on the hanging sample

***Fig. 3**: The maximum amount of heat flux in different positions*

After measuring the heat flux of woven fabrics and investigation the effect of fabric

structure on maximum heat flux, an ANOVA statistical analysis was performed at 95% confidence range. The result of statistic test is shown in Table 3.

Table 3: *Statistical analysis of maximum heat flux*

	P-Value				
	Warp yarn ratio of each layer	Weave pattern	Ratio of weft to element	Technical side	voltage
Above sample	0.000	0.877	0.000	0.629	0.000
Under sample	0.000	0.208	0.000	0.184	0.000
Beside hang out sample	0.000	0.054	0.000	0.424	0.000

As the results show, warp yarn ratio of each layer, ratio of weft to element and voltage have significantly affected the maximum heat flux. Also it could be concluded that the weave pattern of each side of the fabric and also the technical side did not have significant impact on the maximum heat flux.

In the next step, in order to classify the position of heating sensor against the fabric, statistical analysis of results using the ANOVA test and the post hoc Duncan test was conducted (significance level α=0.01). The outcome of the Duncan test is presented in Table 4. According to the results, the testing condition in which the sensor was positioned above the sample or on the hanging sample, were categorized in the same group. Because of the presence of the insulating surface under the fabric, whenever the sensor was situated under the fabric, the measured heat flux was at the minimum level.

Table 4: *Statistical analysis on maximum heat flux*

Duncan Test			
Position of the sensor	N	Subset	
		1	2
Under	96	79.7395	
Hang out	96		91.2011
Above sample	96		92.5030
Sig.		1.000	0.666

On the other hand, when the sensor was positioned above or on the hanging fabric, the heat loss occurred from both sides of the sample. Therefore, the heat transfer from the sample to the environment was greater. It should be noted that, in addition to conductive heat transfer, due to the presence of air flow around the sample, a portion of heat was also transferred to the environment by means of convective heat loss process. Thus, the overall heat flux in these two states was greater than the state that the sense was placed under the sample.

4. CONCLUSION

In this study, eight groups of three-layer warp stitched woven fabrics with tungsten heating elements, two kind of weave patterns in each layer, two kind of heating element density and two different warp ratio of front to back layer were designed and produced. After the production of fabrics, the effects of fabric structural parameters and the applied voltage to the heating system were investigated on the heating performance of the fabric. According to the results the highest amount of heat flux was obtained in case of application of the voltage 12 (V) to the fabric with the weft to

element ratio of 12, which means that the combination of shorter length of the wire and higher voltage produces the maximum heat flux. Moreover, from statistical point of view, these parameters have significant effect on the heat flux. Different ratios of warp yarns in front and back layer affects the construction and the consequent porosity of the fabric. Therefore, this parameter statistically has affected the maximum heat flux passing through the fabric. Another result was that the weave pattern and technical side of the fabric did not affect the heat flux, considerably. Finally, the position of the sensor against the three-layer heating fabric influenced the measured heat flux significantly in each situation. The mentioned result is an indication to the fact that thermal performance of fabrics is different in various environmental conditions.

REFERENCES

[1] A. Pragya, H. Singh, B. Kumar, H. Gupta, and P. Shankar, *"Designing and Investigation of Braided-Cum-Woven Structure for Wearable Heating Textile"*, Engineering Research Express, vol. 2(1), pp 015003, 2020.

[2] F. Wang, C. Gao, and I. Holmer, *"A Review of Technology of Personal Heating Garments"*, International Journal of Occupational Safety and Ergonomics, vol. 16(3), pp.387-404, 2010.

[3] N. Muthukumar, G. Thilagavathi, T. Kannaian, and S. Periyasamy, *"Development and Characterization of Metal Woven Electric Heating Fabrics"*, In Functional Textiles and Clothing, pp. 119-127, 2019.

[4] A. Nazem Boushehri, N. Ezazshahabi, and M. Aman Tehran, *"Fabrication of Three-Layer Heating Woven Fabric and Analysis of the Effect of Fabric Structural Parameters and Element Type on Heating Behaviour"*, presented at the 20th Int. Sci. Conf. Innovative solutions for sustainable development of textiles and leather industry, Oradea, Romania, pp. 77-82, 2019.

[5] H. Park, S. K. Hwang, J. Fan, & Y. Jeong, *"Impact of Electrical Heating on Effective Thermal Insulation of a Multi-Layered Winter Clothing System for Optimal Heating Efficiency"*, International Journal of Clothing Science and Technology, vol. 28(2), pp. 254-264. 2016.

[6] S. F. Neves, S. Couto, J. B. L. M. Campos, and T. S. Mayor, *"Advances in the Optimisation of Apparel Heating Products: A Numerical Approach to Study Heat Transport Through a Blanket with an Embedded Smart Heating System"*, Applied Thermal Engineering, vol. 87, pp. 491-498, 2015.

[7] L. Hao, Z. Yi, C. Li, X. Li, W. Yuxiu & G. Yan, *"Development and Characterization of Flexible Heating Fabric Based on Conductive Filaments"*, Measurement, vol. 45(7), pp. 1855-1865, 2012.

[8] O. Kayacan, E. Y. Bulgun, *"Heating Behaviors of Metallic Textile Structures"*, International Journal of Clothing Science and Technology, vol. 21(2/3), pp. 127-136, 2009.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

CALCULATING THREAD CONSUMPTION IN THE CASE OF ASSEMBLY BY SEWING OF ADHESIVE-BACKED MATERIALS

PORAV Viorica

University of Oradea, Faculty of Energy Engineering and Industrial Management, Departement of Textiles Leather and Industrial Management, University Street no. 1, 410087, Oradea, Romania

Corresponding author: PORAV Viorica, E-mail: viorica.porav@gmail.com

Abstract: *In the textiles industry, specific consumptions for each type of material are calculated based on product range, complexity, and secondary and auxiliary materials used. One of the inputs calculated beforehand is the specific consumption of thread, which depends on many factors, among which the thickness of materials to be assembled. The doubling of materials through the thermobonding process aims to give stability to surfaces or contours and to ensure a spatial shape of the product, without negatively affecting the sanogenetic and comfort parameters.*
There are cases of sewing assembly of two or more textile layers doubled by thermobonding or non-doubled, with woven or non-woven, chemicalized textile inserts. There is an increase of thread consumption for layers doubled by thermobonding with chemicalized inserts, for a single layer of the assembly or for both layers, due to the increase of the thickness to be assembled by sewing. For the assembly of two layers of non-adhesive base material, the simple seam section has an elliptical appearance. For the assembly of two layers of basic material of which one layer is doubled by thermobonding with a chemicalized insert and the second layer is not doubled, the section of the seam has a parabolic appearance. For the assembly of two layers of basic material of which both layers are doubled by thermobonding with a chemicalized insert, there is an increase in the rigidity of the part and the section of the seam has a rigid appearance. Depending on how these layers of material are assembled, doubled or not doubled with the chemicalized inserts, the thread consumption per linear meter varies considerably.

Key words: *seam stitch, thermofusing, thermobonding, thread consumption, stitch structure, stitch density, bonded assembly thickness.*

1. INTRODUCTION

Calculating thread consumption for a particular stitch density, which forms the basis of the assessment of thread requirements for the assembly of clothing, depends on the structure, thickness and flexibility of the aggregate, the fineness of the thread and the number of stitches per unit of length [1,2]. All these factors contribute to establishing the shape of the stitch along its section, this being the basic element for the calculation of thread consumption, corresponding to a particular stitch step [1,3].

2. GENERAL INFORMATION

2.1 The section of a seam stitch.

By doubling the base material with a chemicalised insert, its flexibility is also influenced, by increasing its rigidity. The section through a seam assembly of two materials doubled using a

chemicalized insert and with a thickness of more than 2 mm has a shape corresponding to rigid materials (Fig. 1) [3, 4, 5, 6].

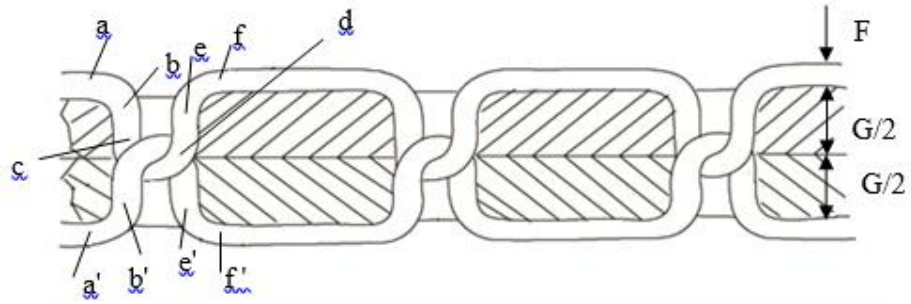


Fig. 1. *Seam stitch. Rigid structure*

Due to the increased rigidity, materials that are assembled by sewing, suffer a certain deformation in the a-b and e-f curved zones, due to the needle thread and in the a'-b' and e'-f' zones, due to the bobbin hook thread. These areas can be considered as arcs of a circle with a radius equal to the thickness (F) of the sewing thread, alternating with areas of straight line in the b-c and d-e zones.

In the case of a proper adjustment of the needle and bobbin hook tension of the thread, the braiding takes place in the middle of the thickness (G) of the assembly and the length of the threads for a seam step is equal to:

$$l_a = l_s \quad \textbf{(1)}$$

where: l_a – represents the length of the needle thread;
l_s – represents the length of the bobbin hook thread

Knowing the thickness (G) of the assembly, the fineness (F) of the thread (P) and using the geometric formulas [3,4,5], the total length (l) for sewing a seam step is:

$$l = l_a + l_s = 2\,l_a = 2\,l_S \quad \textbf{(2)}$$

$$l = 2P + 2G + 0{,}56F \quad \textbf{(3)}$$

The deformation of the materials that are assembled by sewing depends mainly on their flexibility.

For sewing two layers of material, of which only one is glued, the flexibility is greater than in the case of sewing two materials, both doubled by thermobonding.

In this case, the seam structure has a parabolic shape (Fig. 2.)

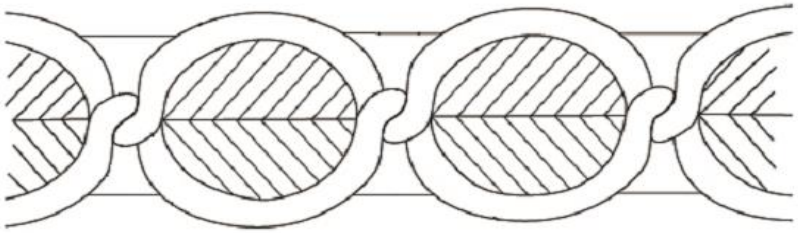


Fig. 2. *Seam stitch. Parabolic structure*

The relationship between the step size (P), the fineness of the thread (F) and the thickness (G) of the assembly is:

$$(P–F)/G>0,75 \quad \textbf{(4)}$$

In the case of assembly by stitch sewing of 2 layers that are not doubled using thermobonding, the seam structure can be considered elliptical [3-6].

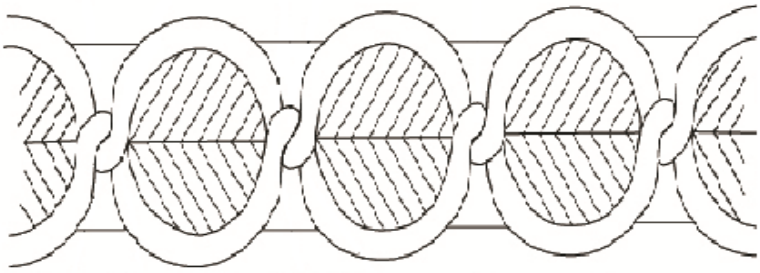


Fig.3. *Seam stitch. Elliptical structure*

In this case:

$$(P–F)/G\leq 0,75 \quad \textbf{(5)}$$

2.2. Methodology. Results.

Three samples of the base material are used, to be assembled by stitching, with a length of 1 meter. One sample consists of two layers of base material, not doubled by thermobonding. The second sample has a single layer doubled by thermobonding and the third sample has both layers doubled by thermobonding.

Seam stitching assemblies are executed in a straight line over a length of 1 meter, keeping constant the thread fineness and the step size.

Table 1: *Seam stitch thread consumption*

Type of assembly	**Assembly thickness (G) mm.**	**Fineness of the thread (F) mm.**	**Stitch step size (P) mm.**	**Stitch density(steps/ 100mm)**	**Thread length for one stitch step (mm)**	**Thread length for 1 meter of stitching (m)**
Two layers of base material, **not** doubled through thermobonding using a chemicalized insert.	0.40	0.235	2.00	50	4.431	2.26
Two layers of base material, out of which **one** is doubled through thermobonding using a chemicalized insert.	0.80	0.235	2.00	50	5.600	2.80
Two layers of base material, out of which **both** are doubled through thermobonding using a chemicalized insert.	1.20	0.235	2.0	50	6.532	3.26

3. CONCLUSIONS

In the textile industry, there are a variety of types of sewing assemblies, a variety of types of textile materials, yarn and sewing machines.

The study reveals one of the important elements of influence on the consumption of thread, namely, the thickness of the layers of the assembly. An increase in consumption of thread, using the same fineness of the thread (F), the same stich step size (P) and the same stich densty (steps/100 mm), is observed, when the thickness of the assembly increases because the layers are doubled using thermobonding or not .

The calculation of the thread requirements for the assembly of a garment product made of textile materials depends on many variables, of which the ones with the most influence are:

- manufacturing technology;
- the type of seams used and their parameters;
- the fineness of the thread;
- areas assembled using stitching, which can be doubled using thermobonding or not;
- the thickness and type of layers assembled using stitching;
- the type of machinery used for stitching.

REFERENCES

[1]. Brumariu, A. *"Proiectarea îmbrăcămintei"* Îndrumar de laborator, Tipografia I.P. Iaşi , 1985.

[2]. Mitu, S. *"Confortul şi funcţiile produselor vestimentare"* Ed. Gh. Asachi Iaşi, 2000.

[3]. Mitu, S.; Mitu, M.; *"Bazale tehnologiei confecţiilor textile"* Vol. I . Ed. Performantica Iaşi, 2005.

[4]. Mitu, S.; Mitu, M.; *"Bazale tehnologiei confecţiilor textile"* Vol. II. Ed. Performantica Iaşi, 2005

[5]. Mitu,S.; Pintilie,E.; Mitu,M.; *"Bazale tehnologiei confecţiilor textile"* Îndrumar de laborator. Ed. Performantica Iaşi, 2003.

[6]. Papaghiuc, V. *"Procese şi maşini pentru coaserea matrerialelor textile"*, Ed. Performantica Iaşi.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

ANALYSIS OF ROLLING ON THE EDGES OF AN ASSEMBLY DOUBLED USING THERMOFUSION

PORAV Viorica

University of Oradea, Romania, Departement of Engineering and Industrial Management in Textiles and Leatherwork, Faculty of Energy Engineering and Industrial Management, University Street no. 1, 410087, Oradea, Romania

Corresponding author: PORAV Viorica, E-mail: viorica.porav@gmail.com

***Abstract*:** *In this paper we analyze an undesirable effect that appeared as a result of the thermal or humidothermal thermofusion operation, due to the incorrect choice and use of the thermofusion parameters, the angle of overlap of the warp threads of the two materials (in the case of a chemicalized weaved insertion), or, most commonly, due to the incompatibility of the shrinkage percentage of the chemicalized insertion with the percentage of shrinkage of the base material. Thus, a twisting effect of the edges of the assembly, consisting of the base material and the insert with adhesive, may appear (especially for fused parts with a small surface). The twisting edge may be towards the chemicalized insert, in this case being considered positive, when the percentage of shrinkage is greater in the insert, and can be considered negative when the twisting is towards the base material, when this has a contraction rate higher than the insertion. In fused assemblies - base material and adhesive chemicalized insert - with large surfaces, the difference between the contraction percentage of the coated insert and the base material manifests itself in the form of bubbles, which can be observed better during rolling or handling of the material while performing certain work operations. In contrast to fused assemblies with small surfaces, for which the difference in the percentage of contraction is observed immediately, for fused assemblies with large surfaces, this difference is observed during manipulations in technological processing, during wearing, or after cleaning.*

Key words: *contraction percentage, humidothermal treatment, thermofusing, chemicalized insert, twisting, flaking, differential contraction*

1. INTRODUCTION

The paper examines the issue related to one of the thermal processes specific to the textile industry, namely, the heat fusing process, where, under optimum conditions, it is necessary for the treated materials to have resistance to high temperatures such that under cooling polymer modifications should be reversible [1] .

2. GENERAL INFORMATION

The undesirable phenomena related to the differentiated contraction of thermal materials are conditioned, besides the improper choice of the thermofusion parameters, also by the selection of a qualitatively unsuitable insertion, basic material, product or destination. The tendency for twisting the edges of parts of textile garments, due to the method of doubling the base material with a chemicalized insert, manifests itself under these conditions as an undesirable effect [2,3].

This phenomenon, called twisting, bending, or shrivelling, is more pronounced in small-surface thermofused assemblies. In certain variants of heat treatment, this unwanted phenomenon is so obvious that the assembly becomes twisted in the shape of a pipe. For large parts, the differentiated contraction manifests itself in the form of bubbles.

In this paper we highlight some results obtained on systems doubled by thermofusing, where the directions of the warp threads of the two materials coincide [4,5].

2.1. Methodology. Results

For the assessment run, thermofused samples were used in the form of a disc with an area of 100 cm². After conditioning in standard atmosphere (φ = 65 % and T = 20 ± 2°C), the samples were moistened until reaching a mass of 150 % of the initial mass, then the excess moisture was removed using filter paper. The drying was carried out in the oven at a temperature of 100 - 150 °C for 60 minutes.

In order to measure the twisting phenomenon, it is necessary to measure the geometric shape of the sample in the process of wetting - drying [5].

The geometric form can be measured across the twisting radius or across the surface of the projection of the sample. The measurement of the twisting as an unwanted effect after thermofusing was made by measuring the projection of the twisted sample.

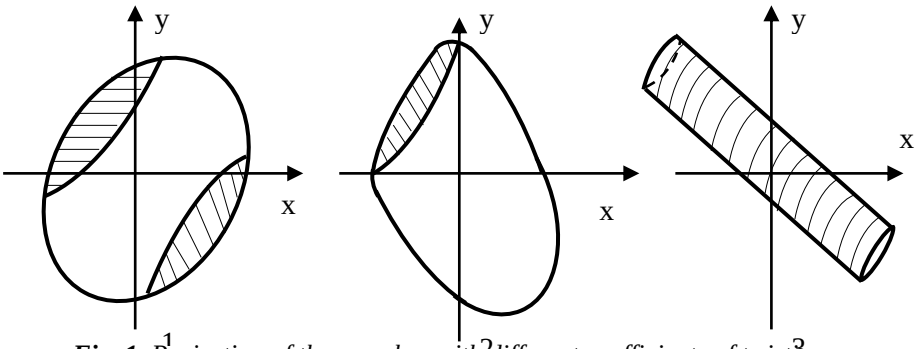


Fig. 1. *Projection of the samples, with different coefficients of twisting.*

The surface of samples of various shapes was determined by planimetry and the intensity of its twist was expressed mathematically by the coefficient of rotation K.

$$K=S/S_0 \quad \textbf{(1)}$$

where: S – represents the surface of the projection of the material disk, after twisting (cm²);
S_0 – represents the initial surface of the sample which is 100 cm².

Experimental research has shown that the value of the coefficient for most textile systems ranges from 0.2 to 1. Systems with a coefficient K < 0.5 are considered unstable systems. A value of the coefficient between 0.5 and 0.8 represents moderately stable systems, and those with a coefficient value K > 0.8 are stable systems that do not exhibit an essential deviation from the circle shape.

The twist is positive when it is toward the chemicalized insert (the chemicalized insert has a higher contraction coefficient than the base material) and is considered negative when it is toward the outer layer (base material contracts more than the chemicalized insertion layer) [5] .

The intensity of the twist is in accordance with the thickness of the base material layer.

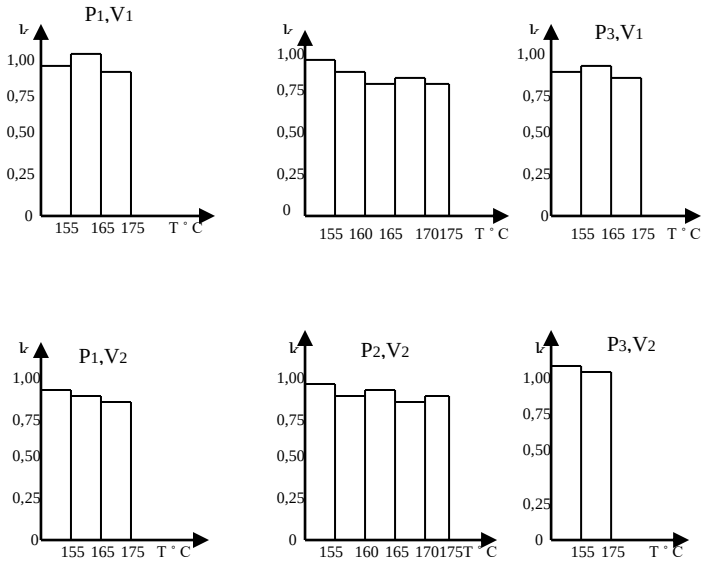


Fig.2. *The relation between the twist coefficient, the thickness of the base material and the parameters of the thermofusing operation [6]*

The thinner the fabric of the base layer, the the less it opposes the contraction of the insertion. Experiments were conducted on contractions along the warp (C_u) and weft directions (C_u) in the basic material, and in the chemicalized insert, respectively [6] .

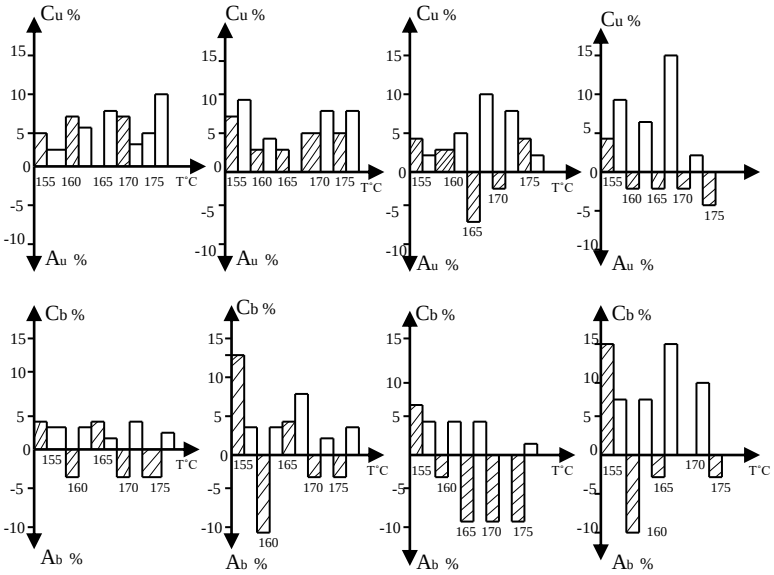


Fig. 3. *Experimental data obtained from the analysis of contractions in the U and B directions of the two thermofused materials [6]*

The hashed portion corresponds to the base material, and the unhashed portion corresponds to the insert with thermoadhesive [6].

3. CONCLUSIONS

Considering the experiments and the obtained results, the following conclusions can be drawn:

- At a suitable choice of the thermofusion parameters, as well as a correct correlation of the particularities of the materials in the system, the value of the twisting coefficient K is higher than 0.8, the system being considered stable, without an essential deviation of the shape from the disc;
- Keeping the pressure (P) constant and varying the treatment time or speed (V) of movement of the system in the treatment area, or maintaining a constant speed and varying the pressure,

the value of coefficient K changes essentially for the temperatures of 155 °C, 165 °C and 175 °C;

- By analyzing the results it can be concluded that in these cases, the optimal parameters of thermofusion corresponds to the values: T = 165 °C; V = 30 m/min; P = 3.5 bar.
- The contraction of the materials in the system is 2.27% for the base material and 0% for the insertion with thermoadhesive. The differential contraction coefficient is 0.9708, the system being considered stable. The groups of treatment parameters are chosen so that this condition is met.

The combination of variants is inexhaustible, because the sensitivity of the materials to the thermal and humidothermal treatments can be noticed even from the laboratory phase, on the basis of which appropriate settings for treatment parameters are selected .

REFERENCES

[1]. Chiriac, V. (1992) "Influenţa parametrilor de tratament umidotermic asupra stabilităţii dimensionale a materialelor şi produselor vestimentare" *Referat susţinut în cadrul pregătirii prin doctorat.*

[2]. Hoblea, N. (1989) "Stabilirea condiţiilor optime în procesul de termolipire a materialelor textile" *Industria Uşoară nr. 11 / 1989.*

[3]. Mitu, S. (1972) "Absorbţia umidităţii de către produsele de îmbrăcăminte" *Industria Textilă nr. 1 / 1972.*

[4]. Mitu, S. (1992) "Aspecte privind definirea noţiunii de confort vestimentar" *Industria Uşoară nr. 1 / 1992.*

[5]. Mitu, S. (2005) "Bazele tehnologiei confecţiilor textile" Vol I şi II. *Ed Performantica, Iaşi*

[6]. Porav, V. (2007) "Contribuţii teoretice şi experimentale privind analiza comportării noilor tipuri de materiale secundare" *Doctoral Thesis Iasi/ 2007.*

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

INFLUENCE OF PLASMA COATED WOVEN FABRICS YARN'S DENSITY ON ELECTROMAGNETIC SHIELDING EFFECTIVENESS

RĂDULESCU Ion Răzvan[1], SURDU Lilioara[1], VISILEANU Emilia[1], SCARLAT Răzvan[1], CONSTANTIN Cătălin[2], MORARI Cristian[3], MITU Bogdana[2]

[1] INCDTP - Bucharest, Str. L. Patrascanu 16, 030508, Bucharest, Romania, office@incdtp.ro

[2] INFLPR – Magurele, Bucharest, Str. Atomistilor 409, 077125, Bucharest, Romania, mitub@infim.ro

[3] ICPE-CA – Bucharest, Splaiul Unirii 313, 030138, Bucharest, Romania, cristian.morari@icpe-ca.ro

Corresponding author: Rădulescu, Ion Răzvan, E-mail: razvan.radulescu@incdtp.ro

Abstract: *Electromagnetic radiation in our environment means hazards for human's health and interference for electronic equipment. One method of protection according to electromagnetic compatibility is shielding. Conductive textiles represent a modern solution for electromagnetic shielding, due to their specific properties like lightweight, flexibility, mechanical resistance and 3D – shape ability. There are mainly two methods for imparting electric conductive properties on textile materials: insertion of conductive yarns within the fabric structure and coating of the fabric surface with conductive raw materials. This paper presents textile EM shields achieved by combining these methods: woven fabric structures with inserted silver yarns in warp and weft direction with various fabric densities were designed and manufactured and afterwards coated by magnetron plasma with a copper thin film. Electromagnetic Shielding Effectiveness (EMSE) measurements were conducted on these fabrics in the frequency range of 0.1-1000 MHz. Values of EMSE reached 40-55 dB. The main aim of the paper is to show that fabrics with a low yarn density have a better gain of EMSE values after plasma coating with copper. This fact may be explained by an interpenetration of the copper films from one side to the other side within the woven fabric structure for low yarn densities and formation of electrically conductive paths.*

Key words: *textiles, silver, cotton, magnetron, copper*

1. INTRODUCTION

Flexible electromagnetic shields out of textile fabrics represents a solution well documented within the literature. The research studies are focused towards various directions in the inter-disciplinary field of textiles and electromagnetic compatibility [1,2]. As such, research papers tackle first of all new manufacturing methods for achieving EM shields out of textile materials [3-7]. Main aim is to achieve a performant shielding effectiveness (EMSE), by considering cost-effectiveness and resource efficiency. A second priority is to describe new methods for measuring electric properties in case of conductive textiles, such as electric resistivity / conductivity and EMSE [8]. Such scientific contributions have as purpose achieving most precise measurement methods in case of the composite textile materials. Another valuable direction is the modelling of electric properties for textile materials (conductivity, EMSE), followed by subsequent validation of proposed mathematical relations by experimental measurements [9,10]. Main aim is to consider a

mathematical model, simple enough to precisely estimate the experimental evolution of the physical property [11]. Other research contributions tackle resource efficiency and environmental friendliness of the manufacturing technologies, even by LCA studies [12, 13]. The present paper contributes to new manufacturing methods of flexible EM shields, namely magnetron plasma coating and has as main aim a correlation between woven fabric structure (yarn's density) and achieved EMSE properties.

2. MATERIALS

Woven fabrics with inserted conductive yarns and coated in magnetron plasma were used for this study. The woven fabrics consist out of 100% cotton yarns Nm50/2 and conductive yarns out of silver coated polyamide 117/17 dtex (STATEX), inserted in warp and weft direction. Sample F5 had silver yarns inserted only in weft direction. The woven fabrics had plain weave, with various densities (number of yarns per 10 cm). The structural and physical-mechanical properties of the achieved fabric samples are presented in table 1:

Table 1: *Structural and physical-mechanical properties of samples*

Fabric samples / Properties		***F1***	***F2***	***F3***	***F4***	***F5***
Float repeat:	Warp	6:2	6:2	6:2	6:2	1:0
[Basic:conductive yarn]	Weft	3:2	3:2	4:2	5:2	6:1
Density	Warp	160	163	168	168	624
[No. of yarns / 10 cm]	Weft	110	124	140	150	326
Fabric thickness [mm]		0.516	0.495	0.506	0.495	0.490
Specific mass [g/m^2]		98	106	113	118	208

The electrical conductivity of the silver yarns was of σ = 111kS/m. This value was computed by measuring the linear resistance of the yarn and applying the resistivity relation. The relative magnetic permeability and the relative electric permittivity of silver equal to 1. The weaving of combined cotton/silver textiles was conducted to insure 1 silver yarn every 4 mm on both warp and weft direction.

3. EXPERIMENTAL

The woven fabrics samples (F1-F5) were coated by magnetron plasma with copper layers on both sides for improvement of EMSE. EMSE was measured by TEM cell according to standard ASTM ES-07 for initial and coated fabric samples.

3.1. Plasma coating of fabrics

The copper coating of the textile fabrics was performed at INFLPR into a dedicated spherical stainless steel vacuum chamber (K.J. Lesker), pumped out by an assembly of a fore pump and turbomolecular pump (Pfeiffer), which allowed the obtaining of a base pressure down to $3x10^{-5}$ mbar [14]. A constant argon flow (purity 6.0) of 50 sccm was continuously introduced into the chamber by means of a Bronkhorst mass flow controller, which insured to establish the processing pressure around 5 $x10^{-3}$ mbar. The chamber is provisioned with magnetron sputtering gun from K.J. Lesker, accommodating a high purity copper target (99.999%). The discharge was ignited by means of an radio frequency generator (13.56 MHz) provisioned with an automatic matching box for adapting the impedance, and the deposition time was set to insure a coating thickness of 400 nm and

1200 nm on each sides of the textile fabrics. Enhanced deposition uniformity was achieved by rotating the samples during the deposition process (200 rotation/min).

The five woven fabric samples previously described in table 1 were coated on both sides with copper thin films by magnetron sputtering. A number of new five samples with destination electromagnetic shielding resulted (table 2) resulted upon plasma processing.

Table 2: *Plasma coated fabric samples*

Sample code	F6	F7	F8	F9	F10
Coating thickness on both sides [nm]	1200	1200	1200	1200	400

3.2 EM Shielding effectiveness measurement

EMSE measurement was accomplished according to the standard ASTM ES-07, via a Transversal Electric-Magnetic cell (TEM Cell). EMSE is defined as:

$$EMSE = 10\ log_{10}\left(\frac{power\ of\ incident\ signal}{power\ of\ transmitted\ signal}\right) \quad \textbf{(1)}$$

A scheme of the coaxial TEM cell is presented in figure 1 and a picture of the TEM cell in figure 2.

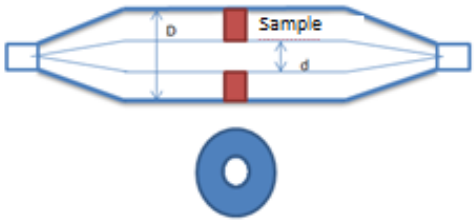


Fig. *1: Scheme of the TEM cell and of the testing woven fabric sample*

Fig. *2: Picture of the TEM cell ICPE-CA*

Tested fabric samples were tailored in annular shape having an outer diameter of 100 mm and an inner diameter of 30 mm and fixed onto the cell by means of colloidal Ag paste. The measurement system included a signal generator E8257D, a Power amplifier model SMX5, the Coaxial TEM cell model 2000 and an Oscilloscope Tektronix model MDO3102. The EMSE measurements were accomplished within the frequency range of 100 kHz to 1 GHz. EMSE was measured for each of the resulted samples (F1 – F10).

4. RESULTS AND DISCUSSION

The five fabric samples with inserted conductive yarns and the same substrates coated by magnetron plasma were investigated regarding EMSE. Figure 3 and figure 4 present EMSE values measured for specific points within the frequency range 100 kHz – 1 GHz.

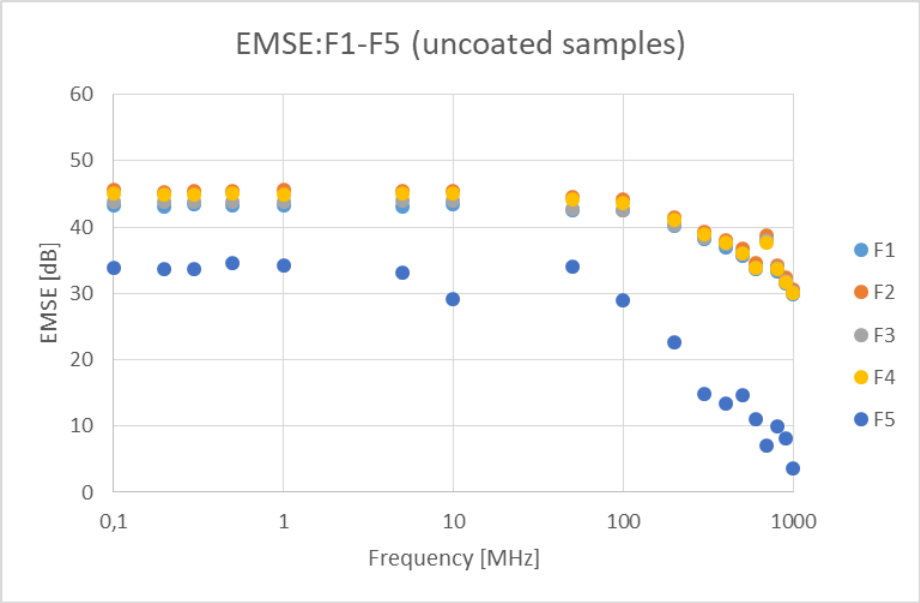


***Fig.** 3: EMSE values for fabric samples F1-F5 (uncoated samples)*

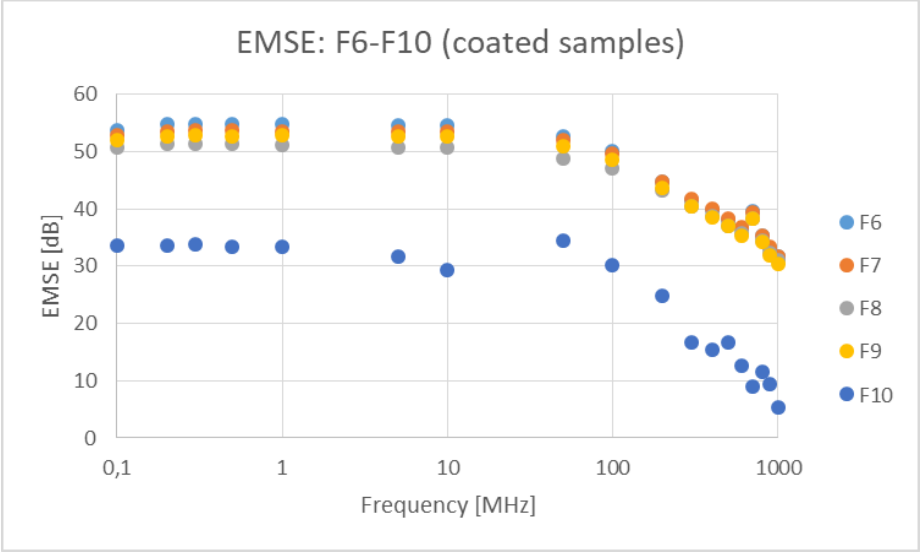


***Fig.** 4: EMSE values for fabric samples F6-F10 (coated samples)*

The measured values of EMSE show that plasma coating renders an increase of 6-12 dB in the frequency range of 100 kHz-100 MHz. Coated textiles are part of the small-aperture metal electromagnetic shields family which can be seen as arrays of waveguides below cutoff. For this type of shielding materials, EMSE is mainly due to reflection loss, absorption and correction factor of multiple reflections having a less significant contribution. When the apertures become a very small fraction of wavelength, the electromagnetic wave "sees" the material as a homogenous media. As the aperture size increase, becoming a larger fraction of wavelength, the electromagnetic wave starts to propagate inside the structure and EMSE drops. This phenomenon explains the decrease in EMSE at frequencies above 100 MHz which can be observed in figures 3 and 4. Moreover, the electrical contact between sample and the test cell becomes very important at high frequencies where

leakages may occur if the contact resistance is low. The sample with high yarn density (F5) shows the smallest EMSE values for the frequency range, for it presents silver yarns only in weft direction. The other four samples have similar EMSE values on the entire frequency range due to similar fabric structures, with single variation of the yarn density. Figure 5 shows explicitly the gain achieved by the copper plasma coating on the five fabric samples. Once again, the fabric with the highest density (F10/F5) shows the smallest gain of up to 2 dB upon Cu coating. Yet, it has to be noted that sample F10 had only 400 nm coating thickness, showing also that the thickness of the coating layer is important to improve EMSE. However, the woven fabric with the low yarn density (F6) shows the highest gain of EMSE of up to 12 dB, followed by F7, which is closely tracked by F8 and F9 with similar EMSE values. These experimental considerations prove the initial premise of the study: fabrics with low yarn density subjected to magnetron plasma coating show better EMSE properties.

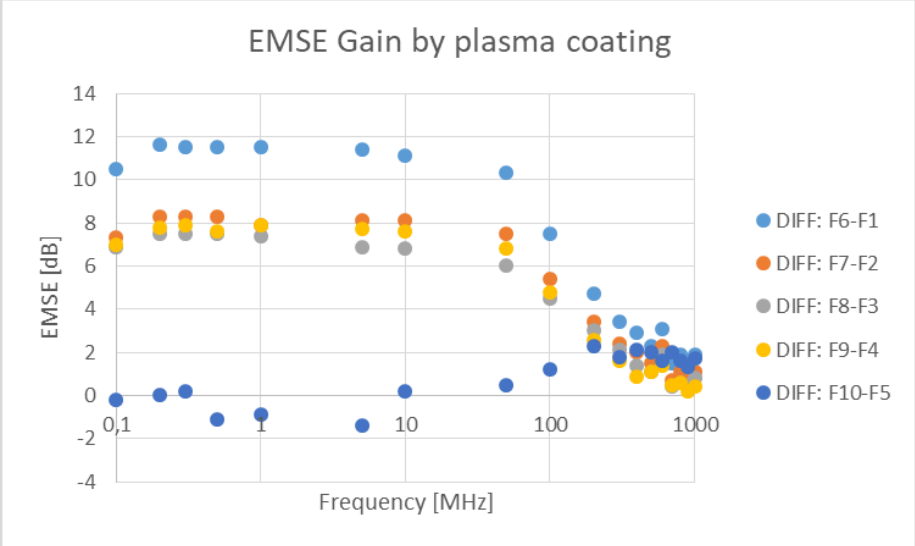


***Fig.** 5: Gain of EMSE on the five woven samples by plasma coating*

This fact may be explained by an interpenetration of the layers on one side to the other one in the existing spaces between the yarns in the weft and warp directions, which is more pronounced in the woven fabrics with low yarn density. This allows the formation of electrically conductive paths inside the fabric that contribute to the overall electromagnetic shielding of the material.

5. CONCLUSIONS

Woven fabric samples with inserted conductive silver yarns and different densities on warp and weft direction were designed and manufactured with destination EM shielding. All fabric samples were subsequently coated by copper magnetron plasma for improvement of EMSE properties. Premise of the study was better electrically conductive and EMSE properties for the coated samples with a low yarn density. Experimental results of EMSE measurement proved this premise. The better electric properties in case of plasma coated fabrics with lower yarn densities may be explained by a better penetration of copper particles inside the fabric structure.

ACKNOWLEDGEMENTS

Research work for this study has been performed within ERA-NET Manunet project Ctr. 28/2018 TexEMFiRe – “Manufacturing textiles with electromagnetic shielding and fire retardant

properties by plasma based methods" and Nucleus project PN19150101 – "Emerging research on lasers, plasma and radiations and their applications in the fields of smart specialization and public interest", while publishing has been funded by Ministry of Research and Innovation, by Program 1 – Development of the national system for research-development, Subprogram 1.2 – Institutional performance – projects for funding excellence in RDI, contract no. 6PFE from 16.10.2018.

REFERENCES

[1] A. Schwab, W. Kuerner, "*Compatibilitate electromagnetica*", AGIR publishing, 2013

[2] C.R. Paul, "*Introduction to Electromagnetic compatibility*", Wiley series in microwave and optical engineering, 2006

[3] B. Moazzenchi, M. Montazer, "*Click electroless plating of nickel nanoparticles on polyester fabric: Electrical conductivity, magnetic and EMI shielding properties*", Colloids and Surfaces A 571 (2019) pp. 110–124

[4] V. P. Anjua, M. Manojb, Pezholil Mohananb, Sunil K. Narayanankuttya, "*A comparative study on electromagnetic interference shielding effectiveness of carbon nanofiber and nanofibrillated cellulose composites*", Synthetic Metals 247 (2019) pp. 285–297

[5] D. Meher, Suman, N. Karna, B.P. Sahoo, „*Development of Poly (vinylidene fluoride) and Polyaniline blend with high dielectric permittivity, excellent electromagnetic shielding effectiveness and Ultra low optical energy band gap: Effect of ionic liquid and temperature*", Polymer 181 (2019) 121759

[6] Hyo-Jun Oha, Reddicherla Umapathi et al., „*Effect of various seed metals on uniformity of Ag layer formed by atmospheric plasma reduction on polyethylene terephthalate substrate: An application to electromagnetic interference shielding effectiveness*", Thin Solid Films 676 (2019) pp. 75–86

[7] J. Ziaja, M. Jaroszewski, "*EMI shielding using composite materials with plasma layers*", InTechOpen, 2011

[8] Morari, C., Patroi, E., Balan, I., "*Composite materials for electromagnetic shielding*", U.P.B. Sci. Bull., Series B, Vol. 78, Iss. 2, 2016

[9] T. Rybicki și S. Brzenski, "*Modelling protective properties of textile shielding grids against electromagnetic radiation*", Fibers and Textiles in Eastern Europe, vol. 21, nr. 1 (97), pp. 78-92, 2013.

[10] M. Neruda, L. Vojtech, "*Electromagnetic Shielding Effectiveness of Woven Fabrics with High Electrical Conductivity: Complete Derivation and Verification of Analytical Model*, *Materials*" 2018, 11, 1657;

[11] K. Velten, "*Mathematical modelling and simulation*", WILEY-VCF Verlag, 2009.

[12] L. Surdu, I.R. Radulescu, I. Barbu, "*Life cycle assessment for medical textiles treated with plasma*", Industria Textila 5/2015, 360-364

[13] I. R. Radulescu, L. Surdu, M. Badic, C. Morari, "*Mathematical modelling of the shielding effectiveness for PES/stainless steel fabrics*", Annals of the University of Oradea, Fascicle of Textiles, Leatherwork – 18th Internatonal Textile Conference Oradea, Romania, 2017

[14] L. Surdu, I.R. Rădulescu, E. Visileanu, C. Stancu, A. Ardeleanu, I. Sandulache, C. Mitran, B. Mitu, *Research regarding the cover factor of magnetron sputtering plasma coated fabrics*, Industria Textila 2/2019, ISSN 1222–5347 2/2019

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

THE EVALUATION OF NOVEL WOUND DRESSINGS BASED ON HYDROGELS

RADULESCU Diana-Elena[1], RADULESCU Denisa-Maria[1], CHIRILA Laura[1], POPESCU Alina[1]

[1] The National Research-Development Institute for Textile and Leather, Textile Chemistry & Environmental Protection Research Department, 16 Lucretiu Patrascanu Street, 030508, Bucharest, Romania, E-Mail: office@incdtp.ro

Corresponding author: Radulescu, Diana-Elena, E-mail: diana.radulescu@incdtp.ro

Abstract: *Wound dressings gained a significant importance in the development of ideal solutions regarding wound healing therapy. The necessity of novel wound dressings in the clinical flied increased over the years due to the constant occurrence of burns or anti-inflammatory lesions. Skin injuries can compromise the integrity and protective function of the cutaneous tissue, resulting in infections. In this regard, numerous studies have been performed to improve the healing process without scarring, by developing suitable wound dressings based on hydrogels. Hydrogel dressings are an essential component in different categories of wound care strategies. The aim of this study was to develop an ideal hydrogel dressing based on carboxymethyl cellulose/pectin/gelatin in order to provide an ideal environment for both cleaning and protecting the wound, but also to offer a suitable permeability to the wound bed. The addition of Common Comfrey (Symphytum officinale) extract and Aloe Vera oil has been accomplished to enhance the healing capacity of the developed wound dressings. Further, woven fabric made of 100% cotton fibers was treated with the synthesized hydrogels through padding method using different concentrations of glycerin (10-20%). The resulted hydrogels were characterized from their morphological and rheological point of view to evaluate their stability and integrity. The treated fabrics were investigated to confirm the successful deposition on the textile material and comfort of the resulted specimens.*

Key words: *hydrogel, textile material, dressing, swelling degree, permeability.*

1. INTRODUCTION

Skin provides a natural barrier against the environment and employs several essential protective functions. When the skin integrity is compromised, the native protective mechanism is disturbed [1]. Wound healing is a dynamic physiological process that consists of four main phases: hemostasis, inflammation, proliferation, and remodeling phase [2]. An ideal skin wound dressing must accomplish the following requirements: provide a physical barrier to prevent further contaminations and injuries, absorb generated metabolites and enhances wound healing capacity by maintaining a moist environment, removes free radicals and improves the antioxidant properties [3].

Hydrogels represent the most suitable choice as wound dressings for their outstanding properties (biocompatibility, high water retention ability and flexibility). Carboxymethyl cellulose (CMC) is one of the most applied polymers for the development of hydrogels due to their abundance, low cost, transparency and film forming ability. Regardless of its beneficial properties, the relatively decreased cell adhesion, inferior antibacterial activity and low water stability of CMC hydrogels limited their applicability as a wound dressing. To overcome the drawbacks, the combination of CMC with other polymeric materials has been preferred to obtain an ideal wound

dressing [4]. Gelatin is an efficient biomaterial for wound dressings, which can absorb wound exudates, provide moist environment that accelerates wound healing and instantaneous hemostasis [5]. Pectin has been widely used in combination with other polymers due to its biocompatibility, strong film forming properties and biodegradability. The high hydrophilicity of these polymers does not maintain their integrity upon exposure to physiologic conditions and therefore, the polymers must be subjected to chemical crosslinking for the improvement of their stability [6].

Furthermore, to enhance the antimicrobial and healing capacity, a combination of bioactive molecules can be incorporated in the developed systems. One of these bioactive molecules is represented by Common Comfrey (*Symphytum officinale*) extract, known for its increased cell proliferation, astringent and anti-inflammatory activity [7]. Another important bioactive substance is Aloe Vera oil, also known for its biological activities (hemostatic, antibacterial and anti-inflammatory), providing an effective solution for the treatment of anti-inflammatory lesions and burns [8]. The main purpose of this study was the development and evaluation of carboxymethyl cellulose/pectin/gelatin hydrogels that incorporate two active substances. Additionally, the obtained hydrogels were further applied on 100% cotton woven fabrics through padding method the treated textile materials being then assessed from the morphological and comfort point of view.

2. MATERIALS AND METHODS

2.1 Materials

For hydrogels synthesis, sodium carboxymethyl cellulose (high viscosity), gelatin (bovine skin ~ 225g Bloom, type B), citrus peel pectin (galacturonic acid ≥74.0%) and glutaraldehyde (50 wt. % in H_2O) were purchased from Sigma Aldrich (Germany). The hydrogel crosslinking was performed using calcium chloride (≥ 93.0%) purchased from Honeywell, (Germany). Vegetable glycerin (99.5% purity) was obtained from SC Herbavit SRL (Romaina). Common Comfrey extract (PlantExtrakt, Romania) and Aloe Vera oil (Mayam, Romania) have been selected as active compounds. For subsequent measurements, the phosphate-buffered saline (PBS) solution (Merck, Germany) has been used.

2.2 Hydrogels Synthesis

The hydrogel films were obtained by preparing 1% (w/v) CMC, gelatin and pectin solutions, under magnetic stirring at 60 ° C. Next, the obtained solutions were cooled and mixed in different concentrations according to Table 1. After complete homogenization, 10-20% (v/v) glycerin was added in the obtained solutions. Furthermore, 1% Common Comfrey extract and 1% Aloe Vera oil were introduced in the obtained solution dropwise and maintained under magnetic stirring for 30 minutes. For crosslinking stage, 0.5% (v/v) glutaraldehyde was used. The developed hydrogels were poured into Petri dishes and kept in the oven for 24 hours at 40 °C. A secondary crosslinking of hydrogels was performed in a 5% (w/v) $CaCl_2$ crosslinking bath, for 24 hours. After crosslinking, the specimens were removed from the Petri dishes, washed and dried at room temperature for 24 hours.

Table 1. *The codification of hydrogels*

Probe	Pectin (%)	Gelatin (%)	CMC (%)	Glycerol (%)	Bioactive substances
F_0-10	1	1	1	10	-
F_0-20	1	1	1	20	-
F_0-10-SA	1	1	1	10	+
F_0-20-SA	1	1	1	20	+

2.3 Functionalization Treatments

For the functionalization treatments, the preparation of hydrogels was repeated. After the homogenization of glutaraldehyde, the hydrogels were cooled and applied on textile fabrics. Simultaneously, the textile materials were sectioned in 20x10 cm variants. Their application was achieved by padding of the selected textile materials with the polymeric solutions under the following conditions: 3 passes through the padder at 2.7 barr and further, the treated textile materials were then dried at 50 ° C for 5 minutes. The secondary crosslinking was performed by the padding the treated fabrics using a $CaCl_2$ crosslinking bath and dryed at 50 ° C for 5 minutes. The treated fabric textiles are presented in Table 2. Additionally, for the evaluation of resulted samples, untreated 100% cotton woven fabric was selected as control (M).

Table 2. *The codification of treated fabrics*

Probe	Pectin (%)	Gelatin (%)	CMC (%)	Glycerol (%)	Bioactive substances	Padding
F-10	1	1	1	10	-	+
F-20	1	1	1	20	-	+
F-10-SA	1	1	1	10	+	+
F-20-SA	1	1	1	20	+	+

2.4 Characterization Methods

2.4.1. Swelling Degree

In order to determine fluid uptake ability, the samples were cut into 2 cm x 2 cm and the initial weight (in dry state) was measured. Each sample was immersed in 25ml PBS (pH= 7.4) at 37°C inside an incubator. Further, samples were gently removed from PBS and the excess fluid was removed with filter paper. Swollen samples were weighted to determine the fluid uptake ability known (swelling degree) by using the following equation:

$$SD\ (\%) = ((W_s - W_d)/W_d) \cdot 100 \quad \textbf{(1)}$$

Where W_s and W_d are the weights of swollen and dry samples respectively. The fluid uptake ability was evaluated for 2h with 15 min time interval.

2.4.2 Water Retention Capacity

For water retention assessment, each sample was immersed in deionized water. Further, the water excess was removed with filter paper and the weight of each probe is determined (W_0). The hydrogels were maintained at room temperature. After 24h, the specimens were taken out and weighted (W_t). This property is defined by the following equation:

$$WR\ (\%) = (W_t/W_0) \cdot 100 \quad \textbf{(2)}$$

2.4.3 Scanning Electron Microscopy (SEM)

SEM analysis was used to investigate the deposition of hydrogels on the fabrics surface by using a FEI Quanta 200 Scanning Electron Microscope with a GSED detector and accelerating voltage of 12.5 Kv – 20 Kv.

2.4.4 Comfort Tests

The treated fabrics were characterized in terms of the main comfort parameters, respectively: water vapor permeability (STAS 9005: 1979) and permeability to air (SR EN ISO 9237: 1999).

3. RESULTS AND DISCUSSION

3.1 Swelling Degree

The swelling degree was determined in order to investigate the absorption capacity (Fig. 1) of the system regarding the released exudate in a predetermined period.

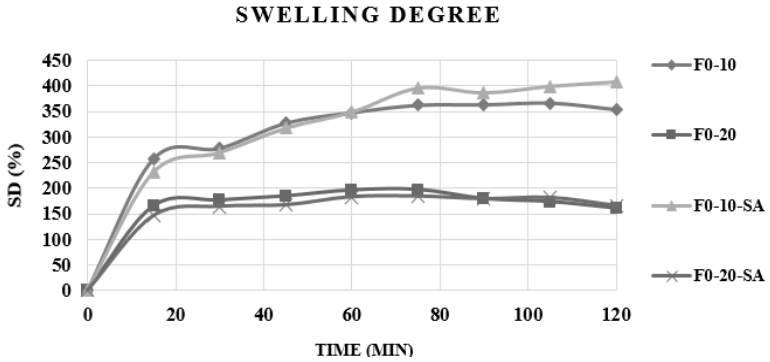


***Fig. 1**: The swelling behaviour of carboxymethyl cellulose/pectin/gelatin hydrogels*

The samples were analyzed in phosphate-buffered saline (PBS) solution, at pH=7.4, similar with the physiological medium. In Fig. 1 it was observed the influence of glycerin in different volume ratios, but also the effect on the encapsulated active substance on the obtained system. The hydrogels with 10% (v / v) glycerin exhibited an increased absorption capacity compared to the sampled with higher glycerin content, which achieved their maximum absorption within a short period of time. Moreover, the entrapment of both active substances does not negatively influenced the stability and integrity of the synthesized hydrogels. Additionally, these polymeric systems exhibited superior swelling degree, ranging between 100 - 400%, an ideal fluid uptake ability that recommends them for wound healing.

3.2 Water Retention Capacity

An ideal wound dressing requires specific properties, such as water retention capacity that is necessary to absorb and maintain the exudate in the polymeric system. This property was assessed by determining the retention capacity as shown in Fig. 2.

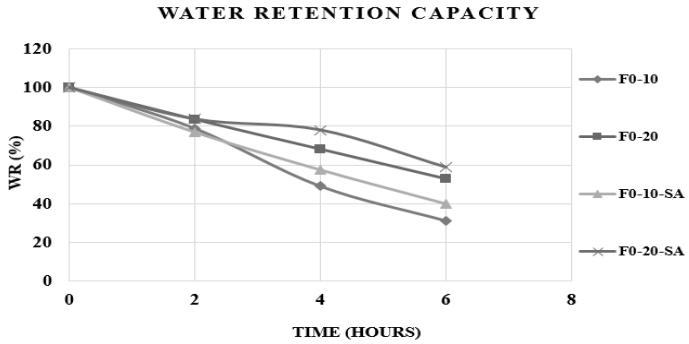


***Fig. 2**: The retention capacity of carboxymethyl cellulose/pectin/gelatin hydrogels*

The increased glycerol content allowed to maintain the absorbed fluid in the hydrogel structure for an increased period (up to 6 hours). Also, the addition of Common Comfrey extract and Aloe Vera oil in the hydrogels does not cause major modifications regarding the retention capacity.

3.3 Scanning Electron Microscopy (SEM)

The morphological evaluation of the obtained wound dressings was accomplished through scanning electron microscopy, as shown in Fig. 3.

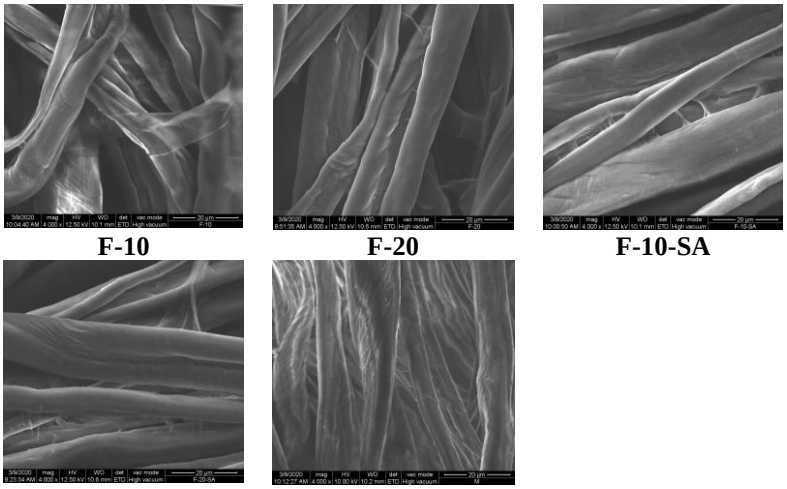
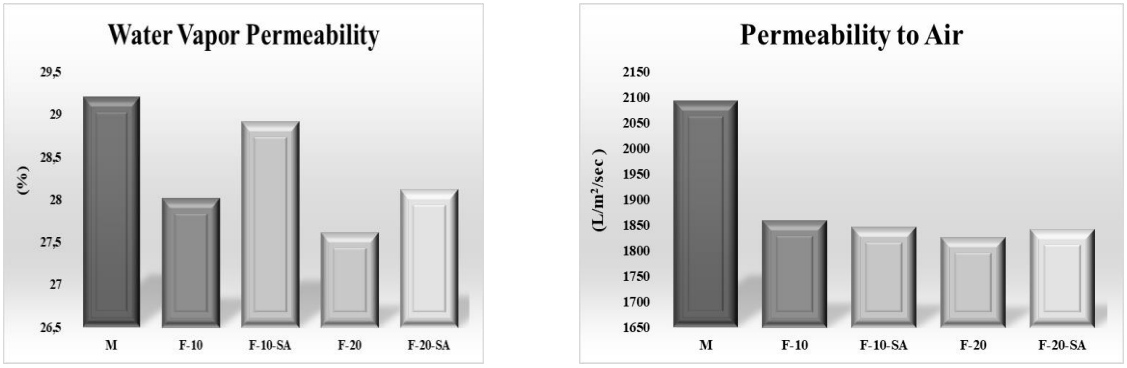


***Fig. 3**: SEM images of the obtained samples*

The SEM images have been recorded at 4000X magnification in order to highlight the successful deposition of hydrogels on the surface of 100% cotton woven fabrics. In all micrographs, the hydrogel film can be observed on the cotton fibers as a thin membrane. Moreover, the incorporation of Common Comfrey extract and Aloe Vera oil does not negatively influence the hydrogel deposition. The developed coatings are presented in a homogeneous slim membrane on the fibers surface suggesting a suitable compatibility between the carboxymethyl cellulose/pectin/gelatin film and cotton fibers.

3.4 Comfort Tests



a) b)

***Fig. 4**: Comfort indices of functionalized fabrics: a) water vapor permeability; b) permeability to air*

Air and water vapor permeability have recorded lower values after functionalization treatment due to the hydrogel deposition on the fabrics surface as a semi-permeable film (Fig. 4).

However, the obtained values are acceptable for the product's destination and does not influence the thermal comfort of end-user, providing proper ventilation for the removal of accumulated exudates.

5. CONCLUSIONS

The developed systems exhibited suitable fluid uptake and water retention capacities, representing a proper solution for wound dressing applications. Moreover, the addition of Aloe Vera oil and Common Comfrey extract has not influenced the main characteristics of hydrogels. Regarding the functionalization treatment, SEM images confirmed the successful deposition of hydrogels on the fabrics surface. Air and water vapor permeability of the treated textile materials decreases after the functionalization treatments, but the obtained values are acceptable for the product's destination. Further research on the potential of hydrogels application as wound dressings must be continued.

ACKNOWLEDGEMENTS

This work was carried out through the Nucleus Programme, with the support of MCI, Project no. 4N / 08.02.2019, PN 19 17 03 01, project title: "Integrated multifunctional systems based on nanocomposites and pharmacodynamic therapeutic agents for different skin conditions - BIOPANTEX"

This scientific paper is funded by the Ministry of Research and Innovation within Program 1 - Development of the national RD system, Subprogram 1.2 - Institutional Performance - RDI excellence funding projects, Contract no. 6 PFE/2018.

REFERENCES

[1] J. Qu, X. Zhao, Y. Liang, Y. Xu, P. X. Ma, B. Guo, "*Degradable conductive injectable hydrogels as novel antibacterial, anti-oxidant wound dressings for wound healing*," Chem. Eng. J., vol. 362, pp. 548-560, 2019.

[2] Y. Zhang, M. Jiang, Y. Zhang, Q. Cao, X. Wang, Y. Han, G. Sun, Y. Li, J. Zhou, *"Novel lignin–chitosan–PVA composite hydrogel for wound dressing, "* Mater. Sci. Eng. C., vol. 104, 2019.

[3] B. Singh, A. Dhiman, *"Design of Acacia Gum–Carbopol–Cross-Linked-Polyvinylimidazole Hydrogel Wound Dressings for Antibiotic/Anesthetic Drug Delivery,"* Ind. Eng. Chem. Res., vol. 55, pp. 9176-9188, 2016.

[4] S. Sadeghi, J. Nourmohammadi, A. Ghaee, N. Soleimani, *"Carboxymethyl cellulose-human hair keratin hydrogel with controlled clindamycin release as antibacterial wound dressing,"* Int. J. Biol. Macromol., vol. 147, 2020.

[5] D. Li, Y. Ye, D. Li, X. Li, C. Mu, *"Biological properties of dialdehyde carboxymethyl cellulose crosslinked gelatin–PEG composite hydrogel fibers for wound dressings,"* Carbohydr. Polym, vol. 137, 2016.

[6] A. Shahzad, A. Khan, Z. Afzal, M. F. Umer, J. Khan, G. M. Khan, *"Formulation development and characterization of cefazolin nanoparticles-loaded cross-linked films of sodium alginate and pectin as wound dressings,"* Int. J. Biol. Macromol., vol. 124, pp. 255-269, 2019.

[7] R. Frost, H. MacPherson, S. O'Meara, *"A critical scoping review of external uses of comfrey (Symphytum spp.),"* Complement. Ther. Med., vol. 21, 2013.

[8] R. Kumar, A. K. Singh, A. Gupta, A. Bishayee, A. K. Pandey, *"Therapeutic potential of Aloe vera—A miracle gift of nature,"* Phytomedicine, vol. 60, 2019.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

GENERAL ASPECTS CONCERNING MULTIFUNCTIONAL FIBER TEXTILES

RARU Aliona[1,3], FLOREA-BURDUJA Elena[2,3], IROVAN Marcela[1], FARÎMA Daniela[3]

[1] Technical University of Moldova, Direction of Academic Management and Quality Assurance, 168 Stefan cel Mare Street, Chisinau MD-2000, Republic of Moldova

[2] Technical University of Moldova, Faculty of Textile and Polygraphy, 4 Sergiu Radautan Street, Chisinau MD-2000, Republic of Moldova

[3] Gheorghe Asachi Technical University of Iasi, Faculty of Industrial Design and Business, 29 Mangeron Street, Iasi 700050, Romania

Corresponding author: Raru Aliona, E-mail: aliona.raru@adm.utm.md

Abstract: *This paperwork analyses the synthesis of literature regarding functional textiles. The actuality of the theme is determined by the overwhelming specialists' interest upon the solution to the problem of elaboration of new generation textiles, and the possibility of these to be worn by the special-needs persons, their number being constantly increasing. This paperwork aims to fundament the theoretical knowledge regarding the classification of the functional materials and establishing their area of use. The main target of this paperwork is also to recommend certain constructive and technical solutions, which shall be taken in consideration while designing clothing products and using innovative textiles. As well we aim to define the field of functional textiles and the field of medical, smart and bioactive textiles. The results of the study will be proven by the chart of classification of functional textiles, and by the solutions given in order to it. The paperwork will present the classification of textiles based on functions, characteristics, areas of use, development stage, types and activity field and the origin of bioactive substance. The medical field of functional textiles is the most important because 2 major directions are presented and both include bioactive materials and smart medical ones. The chart is completed with certain constructive and technical solutions which form their own concepts. The classification chart and the one that determines the area of use are recommended to be taken into consideration in order to facilitate the proccess of textile selection, that are neccessary for functional medical clothing manufacture.*

Key words: Functional textiles, bioactive textiles, medical textiles, smart textiles.

1. INTRODUCTION

Textile fibers are used for designing clothes that maintain medical condition, decrease or cure certain conditions, control several body functions, etc.

The variety of textile materials is constantly renewing. In addition, new characteristics of these materials evolve. The industrial experience showed that choosing materials based on scientific criteria is vital because it prooves: product quality, exterior aspect, shape and dimensional stability, resistance to attrition, light maintenance, and last but not the least- handy and comfortable wearing,

factors that represent a complex state of physiollogical and psychollogical matter. Ensuring these factors to clothing will not disturb the person from persuading his activity or rest.

The problem of new-generation textiles elaboration is actual for proffesionals in the field of light industry. Within this context, global and local concerns are highlighted upon textiles meant for persons with different conditions, which play a major role of maintaining the health rate.

2. GENERAL CONCEPTS AND FUNCTIONAL TEXTILES AREAS OF USE

The field of functional textiles is in constant survey and development. A codification of theoretical information regarding defining, classification and the activity areas of textiles are still not available in speciality literature. In order to facilitate the choosing proccess of materials meant for functional clothing, we consider neccessary to, firstly, establish them.

Multiunctional textile fibers are those fibers to which bioactive properties are attributed or those to which electronic devices are attached and allow the connection between the exterior world and on-going activities. Medical textiles serve as a boundary that prevent, decrease, or even cure some medical conditions. The concept “inteligent materials” has developed in the second half of the XXth century and is associated with significant achievements in physics, chemistry, biochemistry, biophysics, material science, etc. With the help of all those science fields, scientists started to imitate, to copy and to develop diverse useful properties for living matter [1]. Under the term of bioactive textiles, a new concept has arisen, which turns the pasive role of the textile fiber into the active one, for both industry and humankind. It is neccessary to promote the use of raw material with superior hygienic standards, antibacterial and anti-allergic features because they protect the ones that work in risky workplaces [2-5].

Functional textiles share a variety of usability and possess detenction and operating functions, which can be efficiently used in medicine, engineering and fashion. Based on scholars and literature of other connex fields, the areas of use of functional materials may be presented in the light of the following graphic (Figure 1).

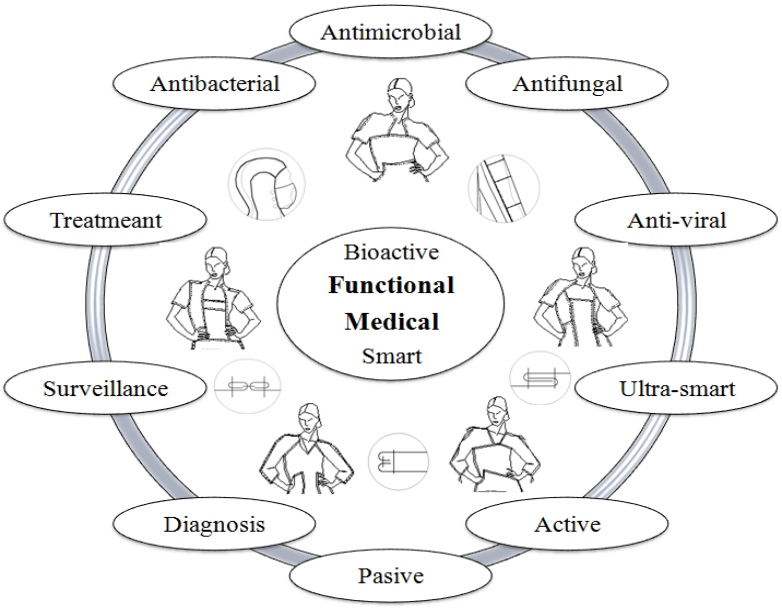


Fig. 1: *Areas of use of medical-functional textiles*

The graphic is completed with multiple constructive and technical products, meant and recommended for persons with diverse chronic illnesses (persons that need permanent health care), shield clothing (antimicrobial, antibacterial, antifungal, antivirucides), and intelligent clothing products.

3. CLASSIFICATION CONCEPT OF FUNCTIONAL TEXTILES

Functions, properties and characteristics of functional textiles require a special classification.

Following, we present chart that classifies the functional textiles, ellaborated as a result of literature research and other connex fields (Figure 2).

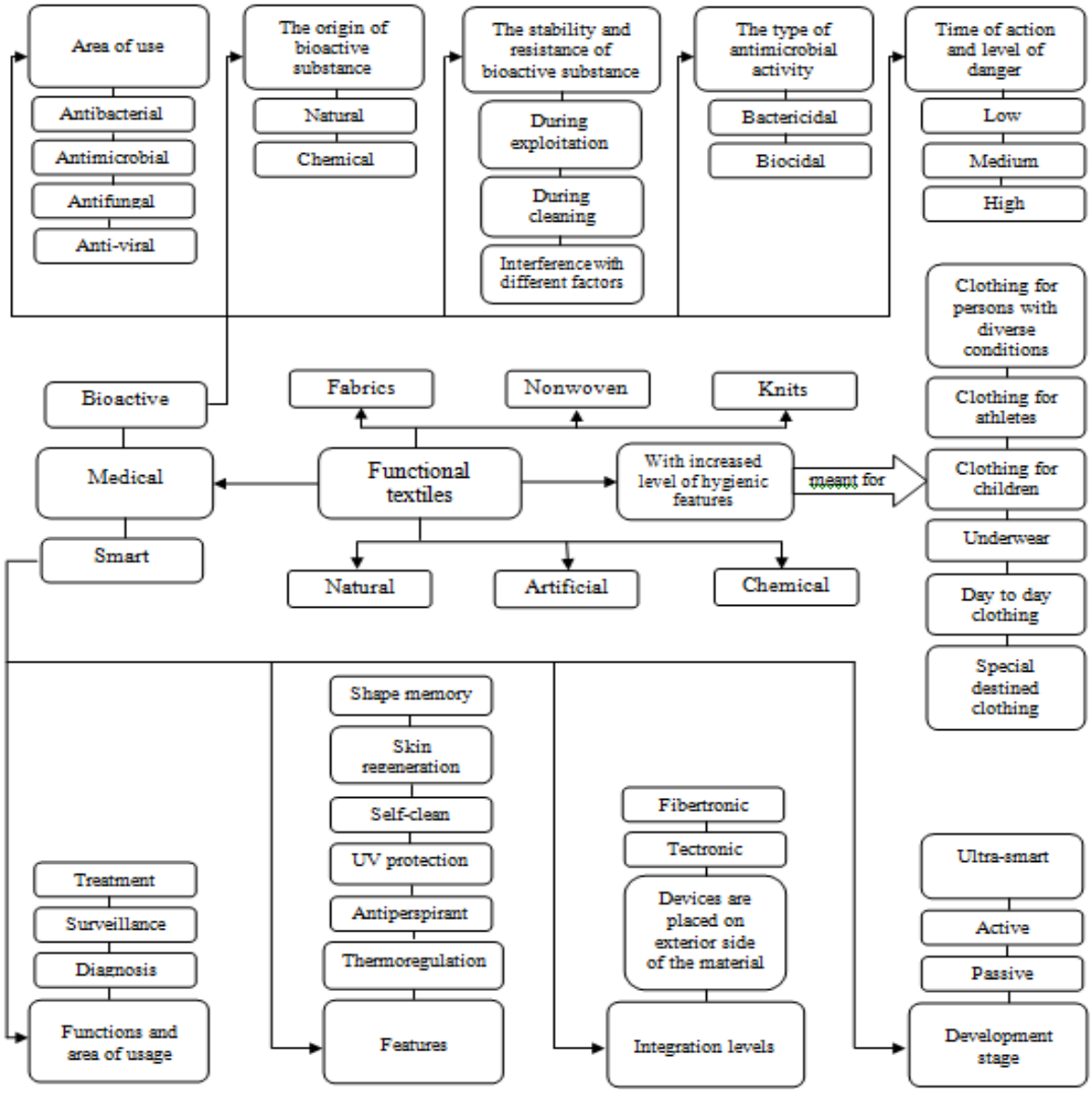


Fig. 2: *Classification of functional fibers*

4. CONCLUSIONS

The future of textile industry belongs to smart textiles which become more and more accessible to other fields, such as medicine, sports, day-to-day industry. Such innovations aim to increase the life quality for persons with special needs.

By using functional textiles, a chain of problems could be solved, for instance: designing clothing products for persons with special needs and medical goods that can supervise the well-being of the patients or even cure them.

The study proccess and the creation one is quite complex and requires the involvement of many specialists, even professionals from other fields.

Because of the diversity and the progressive emerging of texile field, it is recommended the manufacture to be meant for the disabled persons, according to their requirements, functions, properties, imposed by their area of use.

The following chart will facilitate and encourage the proccess of selecting certain textiles for different clothing, especially destined for medical specialty. Constructive and technical solutions are recommended to be taken into consideration while creating experimental models.

In addition, we propose further researches to be done so that would eventually highlight some models of medical gowns and clothes which will reflect the use of functional available textiles.

REFERENCES

[1] G. Krichevskii (2012). «Умный», «интеллектуальный» текстиль и одежда. Учимся у природы [Online]. Available: https://rusnor.org/pubs/reviews/8077.htm

[2] D. Kopitar, B. Rogina-Car, Y. Skenderi (2019). Functional textiles and Clothing: Thermo-Physiological comfort and Microbial Proprieties of different textile raw materials and structures. [Online]. pp. 285-294. Available: https://www.springerprofessional.de

[3] M. Haliullina, A. Galidesina (2014). Использование различных бактерицидных и фунгицидных добавок в полимерах при производстве антимикробных текстильных материалов [Online]. 8, pp. 87-91. Available: https://cyberleninka.ru

[4] F. Pricop, R. Scarlat, A. Popescu, C. Ghiţuleasa (2015). Contribuţii în realizarea de noi sortimente de produse textile tricotate cu proprietăți funcționale bioactive [Online]. 3, pp. 109-113. Available: https://www.tuiasi.ro/ TPMI2.pdf

[5] Sh. Akter, A. Y. M. Anwarul Azim, Medical textiles: Significance and future prospect in Bangladesh (2014). [Online]. 10/12, pp. 488-502. Available: https://www.researchgate.net

[6] G. Krichevskii (2016). Многофункциональный текстиль и умная одежда [Online]. Available: https://rusnor.org/pubs/library/14688.htm

[7] G. Broasca, D. Farîma (2010). Tratamente antimicrobiene pe suprafeţe textile [Online]. 10, pp. 61-66. Available: http://www.revistapielarieincaltaminte.ro

[8] A. Ermurache (2005). Diversificarea constructive-tehnologică a îmbrăcămintei cu effect terapeutic, Teză de magistru, Universitatea Tehnică a Moldovei, Chișinău.

[9] M. Irovan, S. Balan, I. Tutunaru, A. Ermurache (2007). Studies regarding the apparel products with a therapeutic effect, Industria textilă 58/3, pp. 120-132.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

COLOUR FASTNESS ANALYSIS OF PRINTED ELECTRONICS THROUGH THE FLEXOGRAPHY TECHNIQUE ON TEXTILE SUBSTRATES

RODES-CARBONELL Ana M[1], FERRI Josué[1], GARCIA-BREIJO Eduardo[2], BOU-BELDA Eva[3]

[1] Textile Research Institute (AITEX), Alcoy 03801, Spain

[2] Universitat Politècnica de València, Instituto Interuniversitario de Investigación de Reconocimiento Molecular y Desarrollo Tecnológico (IDM), Valencia 46022, Spain

[3] Universitat Politècnica de València, Department of Textile and Paper Engineering, Plaza Ferrándiz y Carbonell s/n. 03801, Alcoy. Spain.

Corresponding author: Rodes, Ana María, E-mail: arodes@aitex.es

Abstract: *The work is framed within Printed Electronics, an emerging technology for the manufacture of flexible electronic products such as electronic textiles. Among the different printing methods, interest on roll-to-roll flexography technique has increased because it allows continuous manufacturing and high productivity at low cost. Nevertheless, the incorporation of the flexography printing technique in the textile field is still very recent due to technical barriers such as of durability and withstanding bending, stretching, abrasion and washing. Specifically, the study is focused on investigating the colour fastness to wash and rubbing of electronic inks printed on textiles through the flexography process. By a comparison of the same ink printed on different flexible substrates it has been concluded that woven and nonwoven fabrics are a suitable option regarding colour fastness to wash instead of thin polymeric and paper substrates that tear at the wash machine. The ink volume transferred to the substrate should be optimized when conductivity and colour fastness to washing are the objectives, still, several coatings could also be applied after the printing. Concerning colour fastness to rubbing where poor results were obtained, a solution for an optimal electronic printing on textiles would be the surface substrates pre-treatment by applying different chemical compounds that increase the adhesion of the ink avoiding its absorption.*

Key words: *e-textiles, wearables, printed-electronics, fastness, flexography.*

1. INTRODUCTION

Printed electronics (PE) refers to the technology that allows the fabrication of electronic devices through a printing process. PE is one of the fastest growing technologies in the world as it provides different printing techniques for fabricating low-cost and large-area flexible electronic devices [1]. In recent years, Flexible electronics has attracted considerable attention as a new technology applicable to wearable devices including flexible displays, flexible batteries and flexible sensors [2] in different areas such as aerospace and automotive, biomedical, robotics, and health applications [3]. Among them, wearable electronic textiles (e-textiles) are of great significance, as they provide better comfortability, durability and lighter weight as well as maintaining the desirable electrical property [4].

The PE printing technique selection shall be according to the type of electronic application (e.g., small, thin, lightweight, flexible and disposable, etc.) to be fabricated, the production cost and volume. Also, the materials (inks/pastes and substrates) must meet certain requirements, depending on the type of printing technology being used and the final application.

PE technologies are divided in contact techniques (e.g., flexography, gravure printing and soft lithography techniques), in which the printing plate is in direct contact with the substrate and, non-contact techniques (e.g., screen printing, aerosol printing, inkjet printing, laser direct writing), where only the inks get in contact with the substrate [5]. Those techniques suitable for roll-to-roll (R2R) processing, such as flexography, are especially attractive as they offer continuous production and high productivity [6].

Flexographic printing is known for depositing a wide range of thicknesses with the same resolution. Impression cylinder, plate cylinder, anilox roller, doctor blade and inking unit are the main parts of the flexographic printing [1]. Variables associated with the flexographic printing process include print speed, print force/engagement, anilox cell volume, anilox force/engagement as well as the ink and substrate properties. [7] Those variables have a direct impact on the prints' morphological and electrical behaviour, as well as the print uniformity has a considerable influence on the final functionality of the device [8]. It must be highlighted in the context of printed electronics on fabrics, the challenge of durability and withstanding bending, stretching, abrasion and washing [9].

Numerous reviews and books have been already published considering printed electronics on substrates that are usually used on electronic devices such as glass, metal, paper or polymers [3,6]. However, the incorporation of the flexography printing technique for printed electronics in the textile field is still very recent and there are not enough studies for its application. As a result, the authors have proposed to analyze this printing methodology for conductive inks on textiles not regarding electronic performance but evaluating the color fastness properties.

2. MATERIALS AND METHODS

2.1 Materials

In addition to polymeric and siliconized paper substrates, which are typical used in printed electronics [3,6], two substrates were also chosen for the study: woven and nonwoven fabric. The four flexible substrates are characterized in Table 1.

Table 1: *Substrates characterization*

Code	Substrate	Material	Structure	Mass per unit area[1]	Color	Protector
SA	Woven fabric	100% Cotton	Plain	300 g/m^2	Greige	No
SB	Spunbonded Nonwoven fabric	100% Polypropylene	Nonwoven	50 g/m^2	White	No
SC	Paper	Siliconized paper	-	140 g/m^2	White	No
SD	Polymeric	100% Thermoplastic Polyurethane	-	94 gr/m^2	Transparent	Yes (white paper)

[1] *Mass per unit area determined according to the standard ISO 3801*

Same aqueous flexo-printable conductive ink, PFI-600 – Silver ink from Novacentrix, has been used in all prints to ensure comparable results. The ink contains silver nanoparticles and has been formulated for high conductivity, fast curing, and improved levelling at lower printing speeds.

2.2 Method

Flexography is a roll-to-roll direct printing technology, where an anilox roller, covered with micro-cavities on its surface, allows the collection of ink, and then is transferred to the printing plate cylinder. At the study, the one-layer flexography printing process has been performed using flexography experimental plants (Flexo VCML Lab from RK and Lambda from Edale) for printing the samples. Different test drawings for the pattern of the printing plate cylinder were designed specifically for the study. The printing process was carried out using 12 cm^3/m^2 of Anilox at 6-22 m/min in all samples except SD fabric, which was performed using 11 cm^3/m^2 at 5 m/min.

Printed layers were dried using an in-line air flow convection dryer with temperatures within 80-150º C.

Once dried, the samples were analyzed regarding color fastness to wash and rubbing (dry and wet) and according to standards methods ISO 105-C10 and ISO 105-X12. After both tests, treated samples were compared with untreated samples visually using grey scale, according to ISO 105-A02 standard.

3. RESULTS AND DISCUSSSION

The grade of color fastness to wash and rubbing of the electronic flexo printed samples were evaluated and presented in the Table 2. Neither the siliconized paper (SC) nor the polymeric substrate (SD) could stand the washing test and were torn at the wash machine. Furthermore, the SD was not capable of withstanding the rubbing test, crashing with the pressure of the crockmeter.

Table 2: *Color fastness to was and rubbing results*

Code	Rubbing				Washing	
	Degradation		Discharge		Degradation	Discharge
	Dry	Wet	Dry	Wet		
SA	4-5	3-4	1	1	4	5
SB	4	1-2	3	2	4	5
SC	2	1	3	1	-	-
SD	-	-	-	-	-	-

The overall results of color fastness to rubbing of samples showed poor fastness properties in terms of discharge, which was harmonious with previous studies of other printing techniques [10]. SA and SB showed an improved grade in the rubbing degradation possibly due to the large amount of ink deposited on the surface although wet rubbing properties are lower than dry. In order to address these challenges, surface pre-treatment onto rough and porous substrates should be done in order to improve the ink adhesion and therefore the electrical behavior [4].

On the other hand, the overall results of color fastness to wash of woven (SA) and nonwoven (SB) fabrics samples were very good to excellent. According to a previous review [11], an increment of ink volume improves the ink coverage, upgrading in this case the conductivity, nevertheless it enhances the ink wash-out effect. For this reason, the ink volume transferred to the substrate should be optimized when conductivity and color fastness to washing are the objectives. In addition, coating and lamination processes could be done in order to ensure the continuous conductive pathway on textiles [9].

4. CONCLUSIONS

By a comparison of the same ink printed on different flexible substrates it has been concluded that woven and nonwoven fabrics are a suitable early option regarding colour fastness to wash instead of thin polymeric and paper substrates that tear at the wash machine. The ink volume transferred to the substrate should be optimized when conductivity and colour fastness to washing are the objectives. Future work will explore several coatings that could also be applied after the printing to protect the circuits and then improve the electronic behaviour after washing.

Concerning colour fastness to rubbing, even better than for thin polymeric and paper substrates, poor results were obtained for woven and nonwoven fabrics. For this reason, future work will be focused on surface pre-treatment onto rough and porous substrates in order to improve the ink adhesion and therefore the electrical behavior.

ACKNOWLEDGMENT

This research is part of HYBRID project that is funded by the Conselleria d'Economia Sostenible, Sectors Productius i Treball, through IVACE. Application No.: IMAMCI/2020/1.

REFERENCES

[1] Avuthu, S.G., Gill, M., Ghalib, N., Sussman, M.R., Wable, G., Richstein, J., Ph., D., & Jabil (2016). "*An introduction to the process of printed electronics*".

[2] Kim, C., Jeon, S.W. & Kim, C.H. "*Reduction of Linearly Varying Term of Register Errors Using a Dancer System in Roll-to-Roll Printing Equipment for Printed Electronics*". Int. J. Precis. Eng. Manuf. 20, 1485–1493 (2019).

[3] Cruz, Sílvia & Rocha, Luis & Viana, Julio. (2018). "*Printing Technologies on Flexible Substrates for Printed Electronics*". 10.5772/intechopen.76161.

[4] Karim, N., Afroj, S., Tan, S. et al. "*All Inkjet-Printed Graphene-Silver Composite Ink on Textiles for Highly Conductive Wearable Electronics Applications*". Sci Rep 9, 8035 (2019).

[5] Cano-Raya, Clara & Denchev, Zlatan & Cruz, Sílvia & Viana, Julio. (2019). "*Chemistry of solid metal-based inks and pastes for printed electronics – A review*". Applied Materials Today. 15. 416-430. 10.1016j.apmt.2019.02.012.

[6] Søndergaard, Roar & Hosel, M. & Krebs, Frederik. (2012). "*Roll to roll fabrication of large area functional organic materials*". Journal of Polymer Science. 51. 16-34.

[7] Mogg, Benjamin & Claypole, Tim & Deganello, Davide & Phillips, C.O.. (2016). "*Flexographic printing of ultra-thin semiconductor polymer layers*". Translational Materials Research. 3. 015001. 10.1088/2053-1613/3/1/015001.

[8] Davide, D. (2019). "*Control of morphological and electrical properties of flexographic printed electronics through tailored ink rheology. Organic Electronics*", 73, pp. 212-218.

[9] Yang, K., Torah, R., Wei, Y., Beeby, S., & Tudor, J. (2013). Waterproof and durable screen printed silver conductive tracks on textiles. Textile Research Journal, 83(19), 2023–2031.

[10] Vasić, Jelena & Kasikovic, Nemanja & Delic, Gordana & Đurđević, Milana. (2018). "*Impact of type of ink and substrate on colorimetric values of inkjet prints*". 365-372. 10.24867/GRID-2018-p44.

[11] Kasikovic, Nemanja & Vladić, Gojko & Milic, Neda & Novaković, Dragoljub & Milošević, Rastko & Dedijer, Sandra. (2018). "*Colour fastness to washing of multi-layered digital prints on textile materials*". Journal of the National Science Foundation of Sri Lanka. 46. 381. 10.4038/jnsfsr.v46i3.8489.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

PRELIMINARY STUDY FROM RICE HUSK EXTRACTS TO FINISH TEXTILE FABRICS

SOLER Andrés[1], GISBERT-PAYÁ Jaime[1], MONTAVA Ignacio[1], BONET-ARACIL Marilés[1]

[1] Departamento de Ingeniería Textil y Papelera, Universitat Politècnica de València
Plaza Ferrándiz y Carbonell s/n, Alcoi, Spain

Corresponding author: Bonet-Aracil, Marilés, E-mail: maboar@txp.upv.es

Abstract: *Nowadays, envoronmental concern is increasing and textile industry is aware of it. Circular economy are two words which are linked together and frequently used nowadays. In this report, we focus the reseach on the rice husk in order to dimish the problem rice waste generates to farmers. Rice husk was treated with some chemicals (HNO_3). The extract was dried and conveniently dissolved to apply it on textile fabrics made of 100 % cotton and 100 % polyester.. The extract was dissolved on NaOH solution and applied by padding on a cotton and polyester fabric at different concentrations. The dried extract was analysed by FTIR and both the extract and fabrics were observed by FESEM-EDX to detect the presence of some particles Results evidence the presence of some particles on the fibres, despite having applied low concentrations FTIR is sensitive enough to detect its presence on fibers. It was expected to observe Si from the extract but FESEM-EDX could not appreciate it. Once the treatment was applied on the fabric yellowing was observed but also water repellence thus with the FTIR spectrum gives the idea that the extract was mainly comprised of lignin. Further studies will be conducted in order to spcecify the new properties conferred to the textiles.*

Key words: *circular economy; rice waste; functionalise; water repellence; cotton; polyester.*

1. INTRODUCTION

Nowadays, envoronmental concern is increasing and textile industry is aware of it. Textile ecological technologies occupy an important place in the research projects developed at national and international levels [1]. Thus, many natural resources are sought, to look for different applications such as natural dyes [2]

Rice husk is a problem for regions such as Comunitat Valenciana in Spain, it cannot be left on the ground as it rots quickly and damages the ground preventing from growing rice the next years. If it is burned CO_2 is a problem. Some researchs are focused on the new products which can be obtained from this waste. This allows to obtain new resources of materials and include the riece husk into circular economy improving the sustainability of rice.

Some researchers mix pieces of rice husk with wood particles in a rotating drum in order to obtian planks of wood-rice [3]. Others [4] by means of high pressure steam, an separate the cellulose from the rice husk, which is its main compound. The difficulty in separating these two components lies in the strong crystalline structure of cellulose and the presence of a lignin. It can be also used to form transparent film from rice nanofibers with cellulose acetate [5].

Swiss botanist A.P. Candolle (1778-1841) used the term "lignin" (derived from the Latin lignum = wood) for the first time. Later in 1865 Schulze et al. They used the term to describe the dissolved part of wood when treated with nitric acid. In the 1960s, with the development of biochemical and organic chemistry analysis tools, more information of interest regarding this biopolymer was accumulated. Since then, research on lignin has grown at a rapid rate, drawing the attention of the paper industries predominantly [7].

Lignin is one of the most abundant biopolymers in plants and together with cellulose and hemicellulose it forms the cell wall of plants in a regulated arrangement at the nano-structural level, resulting in lignin-carbohydrate networks. The composition or distribution of the three components in these networks varies depending on the type of plant. In the case of wood composition, the most commonly found ranges are: Cellulose: 38-50%; Hemicellulose: 23-32% and Lignin: 15-25% [8].

Lignin is present in all vascular plants, and like many other biomass components, it is formed through the photosynthesis reaction. Lignin is considered as an affordable renewable resource with potential industrial use, whose annual production has been estimated in the range of 5-36 x 10^8 tons [7].

Different percentages of ligning can be extracted depending on the vegetable is usaed as raw material, pines are around 27-28% eucaliptus are areound 22%. Rice husk is supposed to offer about 6% of lignin. In this work we will try to obtain rice husk extranct and characterise it. Later on we will apply extract from rice husk onto textile fibres in order to determine whether it modifies some of the fabric properties.

2. MATERIALS AND METHODS

2.1 Materials

Rice husk was collected from Valencia, Spain. HNO_3 and NaOH were purchuased from Panreac.

A 100 % bleached cotton fabric 220 g/m2 was used for the finishing treatment. A 100 % polyester fabric 120 g/m^2 was also used.

2.2 Methods

Rice Husk extraction

Rice husk (100 g) was rinsed with water in order to remove the dust and other particles which can be on the surface. Later on it was placed on a heater at 80º C for 4 hours. 20 grams of the dired husk were placed in an open reactor with 100 mL of HNO_3 and 100 mL of distilled water. The solution was kept at 70º C for 120 minutes. The liquid was filtered and dried at 70º C for 24 hours.

Textil finishing

The dried extraction was dissolved into NaOH 50 Bé. Two concentrations were tested (10 mL and 20 mL) of the dissolved extract were mixed with 40 mL of distilled water and 1 g of fabric was immersed on the final solution (50 mL) (r:b =1:50). Every sample was refrenced as D51 and D61 respectively.

FTIR

FTIR spectra were recorded in order to characterize the fabrics surface. An FT/IR-4700typeA from JASCO wit ATR accessory was used, 16 spectra were recorded with a 4 cm^{-1}resolution.

FESEM

Samples surface was carried out by means of electron microscopy (Scanning Electron Microscopy, SEM) with a FIELD EMISION MICROSCOPE FESEM (ULTRA 55, ZEISS). Each sample is covered with a layer of carbon in order to transform them into conductive by using a Sputter Coater and being able to analyse samples by EDX. The samples were analyzed with the appropriate magnification and with an acceleration voltage of 1 KV.

3. RESULTS

In order to characterize the extract treatment on the fibres some instrumental techniques have been used. Figure 1 shows the FTIR spectra for cotton (Fig. 1) and for polyester (Fig. 2) fabrics. It can be appreciated for both samples (cotton and polyester) that the region between 1800 cm^{-1} to 1500 cm^{-1} shows an significative change on the fibre spectra.

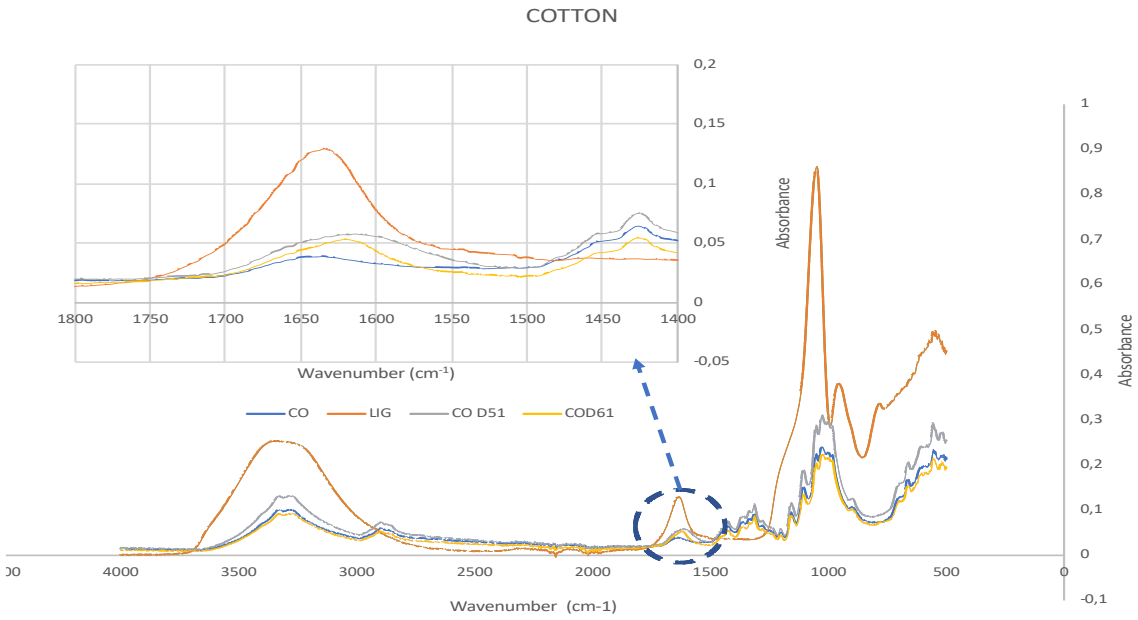


***Fig. 1**: FTIR spectrum of cotton finished with rice husk extract. CO = cotton; LIG = extract, COD51 = cotton treated at concentration 1; COD61 = cotton treated at concentration 2.*

As it can be observed from Figure 1 the pick on cotton fiber (blue line) is centered at 1650 cm^{-1} whereas the pure extract shows the pick centered around 1675 cm^{-1} . Treated cotton (grey and yellow line) shifts towards lower wavenumber due to the treatment with the extract.

Something similar is observed when the treated fabric is polyester. It can be appreciated for both samples (cotton and polyester) that the region between 1800 cm^{-1} to 1500 cm^{-1} shows an significative change on the fibre spectra.

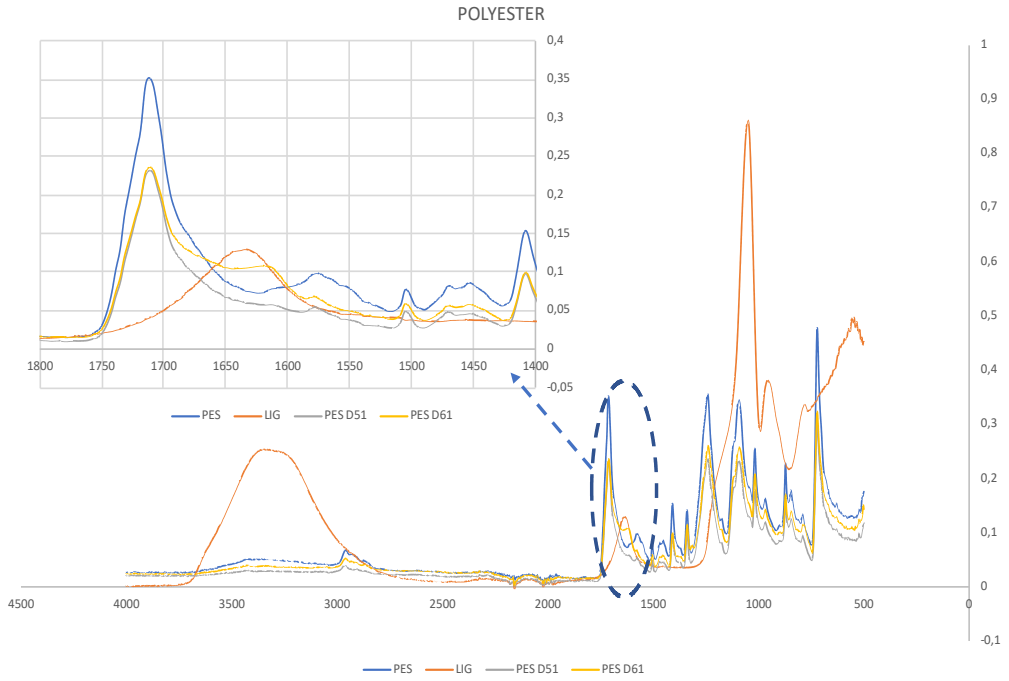


***Fig. 2**: FTIR spectrum of polyester finished with rice husk extract. CO = cotton; LIG = extract, COD51 = cotton treated at concentration 1; COD61 = cotton treated at concentration 2.*

The FESEM images show the presence of some little particles on the fibre surface for both cotton (Fig. 3a) and polyester (Fig. 3b).

According to some references [6] rice husk should contain Silica. FESEM-EDX was performed but results showed no evidence of Si particles on the fabrics surface. The Si absence canbe due to the extraction procedure conditons. In our experiment we worked in open reactor and with temperatures lower than 100º C.

It cannot be observd by FESEM images, but it should be noticed that when fabrics were treated, a yellowish colour is observed for both cotton an polyester fabrics. In order to determine the effect of the extract on the fibres, apprat from the colour variation, some drops of water were placed on every treated fabric (cotton and polyester) and it was compared with the original ones without the finishing treatment applied. Results evidenced an increase on the water repellency (cotton 3 seconds, and treated cotton 10 seconds; polyester 15 seconds and treated polyester 21 second) as the wettability of the fabric was higher for non treated fabrics, considering the time the water drop miss the shape. Further research, with objective tests will be conducted in order to determine if theere is a sensitive difference due to the higher concentration of the extract on fabric.

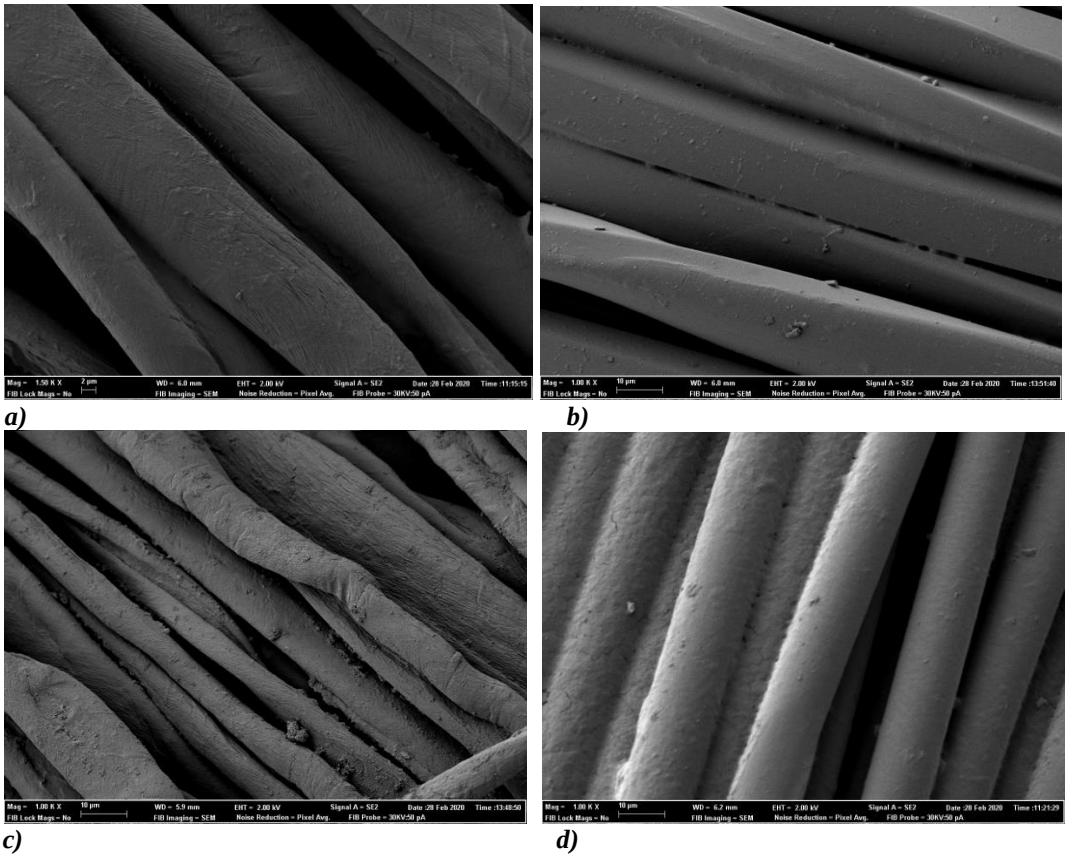


Fig. 3*: FESEM images from fabrics treated with the extract. a) cotton; b) polyester; c) treated cotton; d) treated polyester.*

5. CONCLUSIONS

In this project authors, conscius of the envrinmental problems and aweare of reducing pollution from textil industry, aim to develop a preliminar sutdy to rice husk. The objective was ot obtain a new priduct which could be used as a new functional finish for textile products.

Despite having applied low concentrations of the extract onto the textile fabrics, FTIR demonstrated to be sensitive enough to detect the extract presence on the fibers for both cotton and polyester. It was expected to observe Silica from the extract but FESEM-EDX analysis could not appreciate it, probably due to the fact that the extraction was conducted on open reactor with temperature below 100º C and not at high presure and temperature.

Once the treatment was applied on the fabric, at first sight yellowing was observed but preliminary tests also evidenced water repellence behaviour.

Thus, we can conclude that Silica was not extracted but due to the FTIR spectrum and the water repellency increase, it gives the idea that the extract was mainly comprised of lignin.

Further studies will be conducted in order to spcecify the new properties conferred to the textiles

REFERENCES

[1] M., Dochia, Gavrilaș S. "*Physico-chemical parameters of residual water from different scouring treatments of hemp/cotton fabric"* Annals of the University of Oradea. Fascicle of Textiles, Leatherwork, *2019, 1.41-47.*

[2] M. Bonet-Aracil, P. Díaz-García, E. Bou-Belda, N. Sebastia , A. Montoro, R. Rodrigo. "*Uv protection from cotton fabrics dyed with different tea extracts"*. Dyes and Pigments 2016, 134, 448-452. http://dx.doi.org/10.1016/j.dyepig.2016.07.045

[3] Yang, H. S., Kim, D. J., & Kim, H. J. (2003). "*Rice straw–wood particle composite for sound absorbing wooden construction materials*". Bioresource Technology, *86*(2), 117-121.

[4] Chen, X., Yu, J., Zhang, Z., & Lu, C. (2011). "*Study on structure and thermal stability properties of cellulose fibers from rice straw*". Carbohydrate Polymers, *85*(1), 245-250.

[5] M., Hassan, L., Berglund, R., E., Abou-Zeid, Hassan, W., Abou-Elseoud, & K. Oksman, "*Nanocomposite Film Based on Cellulose Acetate and Lignin-Rich Rice Straw Nanofibers"*. Materials, 2019, *12*(4), 595.

[6] G. M., Tolba, N. A., Barakat, A. M., Bastaweesy, E. A., Ashour, W., Abdelmoez, M. H., El-Newehy,... & H. Y. Kim, "*Effective and highly recyclable nanosilica produced from the rice husk for effective removal of organic dyes*". Journal of Industrial and Engineering Chemistry, 2015, *29*, 134-145.

[7] Marvin Chávez-Sifontes1, Marcelo E.Domine1* lignin, structure and applications: depolymerization methods for obtaining aromatic derivatives of industrial interest. Av. cien. ing.: 4(4), 15-4

[8] Sustainable Forestry for Bioenergy & Bio-based Products (2007). From http://learn.forestbioenergy.net/

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

USING ANFIS FOR MAINTENANCE PLANNING OF TEXTILE MACHINES

ŞUTEU Marius Darius[1], BABAN Marius[2], BABAN Calin Florin[2], DERECICHEI (ŢAP) Alexandra Paula[2]

[1, 3] 1University of Oradea, Faculty of Energy Engineering and Industrial Management, Department Textiles, Leather and Industrial Management, 410058, Oradea, România, E-mail: suteu_marius@yahoo.com

[2] University of Oradea, Faculty of Managerial and Technological Engineering, Department Industrial Engineering, 410087, Oradea, România, E-mail: mbaban@uoradea.ro

Corresponding author: Şuteu Marius Darius, E-mail: suteu_marius@yahoo.com

Abstract: *Considering the complexity of the wear of textile machines, a mathematical modeling of this phenomenon is not available in the existing literature. Based on the advantages of both fuzzy logic and neural networks, a neuro-fuzzy approach seems to be well suited for the prediction of the maintenance activities of textile machines. Therefore, the Adaptive Neuro Fuzzy Inference System (ANFIS) was proposed in this study to plan the maintenance activities of textile machines. The research was performed on the PEGASUS sewing machine at a working speed of 3100 stitches/minute. The sewing material used in the experiments was cotton, while NM 80 sewing needles were employed. The vibrations along the OZ axis and level of noise of the PEGASUS sewing machine were measured with appropriate devices. The ANFIS of the Matlab® software was used to plan the maintenance of textile machines. The amplitude of vibration and level of noise of the needles were used as inputs in the ANFIS system. The output of the ANFIS system was the time to replacement of the needles. The performance of the developed ANFIS system was expressed through the RMSE and MAPE measures. Considering their values, it may be pointed out that the ANFIS prediction system demonstrates good performance.*

Key words: *wear, vibration, noise, ANFIS, replacement*

1. INTRODUCTION

Considering the complexity of the wear of textile machines, a mathematical modeling of this phenomenon is not available in the existing literature [1]. Within this framework, fuzzy logic was employed in the previous studies of the authors for the maintenance modeling of textile machines [1, 2, 3]. However, such approach is relatively difficult, since fuzzy logic does not have learning capabilities. On the other hand, neural networks have such capabilities. Therefore, a neuro-fuzzy approach seems to be well suited for the prediction of the maintenance activities of textile machines. Considering its applicability [4], the Adaptive Neuro Fuzzy Inference System (ANFIS) developed by Jang [5] was proposed in this study for planning the maintenance activities of textile machines.

2. MATERIALS AND METHODS

The research was performed on the PEGASUS sewing machine, at a working speed of 3100 stitches/minute. The sewing material used in the experiments was cotton, while NM 80 sewing needles were employed. The experimental stand used in this study is shown in Figure 1. The Top Lab-GBDT-L device was employed for the measurement of the vibrations along the OZ axis. The level of noise was measured with the Center 322 sonometer.

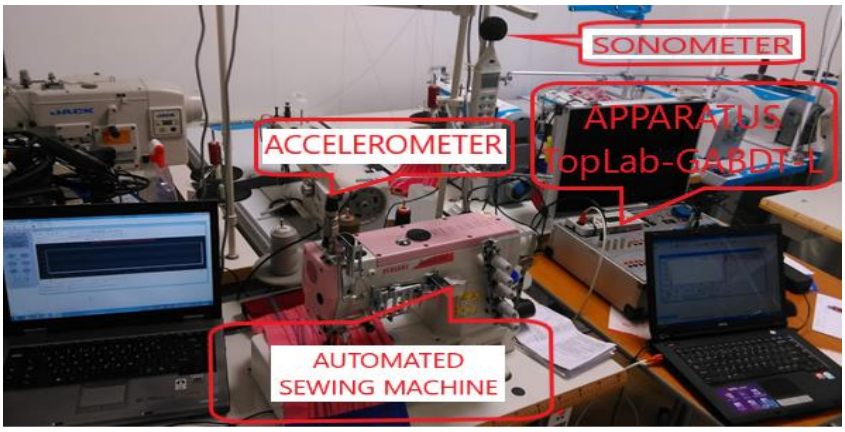
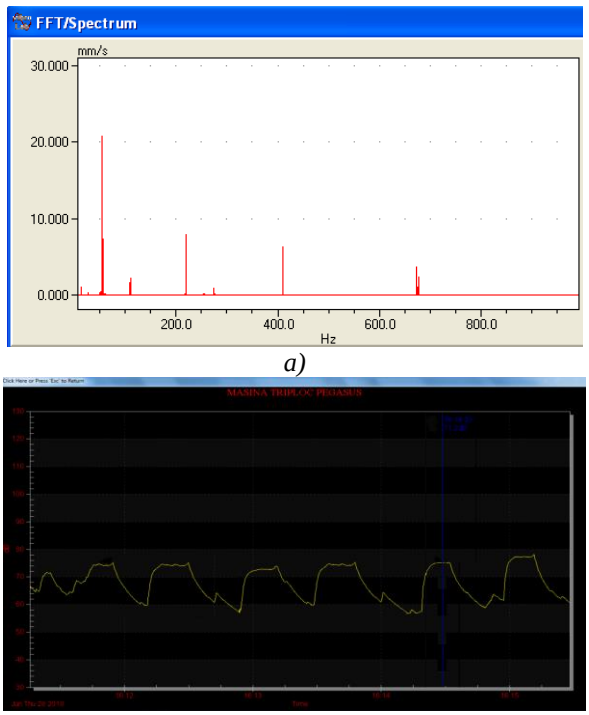


***Fig. 1**: The experimental stand*

The measurement of vibration and noise of a needle are presented in Figure 2.



a)

b)

***Fig. 2:** The measurement of a) amplitude of vibrations and b) level of noise of a needle*

The ANFIS of the Matlab® software was used for the maintenance planning of textile machines.

3. RESULTS

Two inputs were used in the ANFIS system: the amplitude of vibration AV [mm/s] and level of noise LN [db]. The output of the system was the time to replacement of the needles TR [minutes]. The structure of the ANFIS system is depicted in Figure 3.

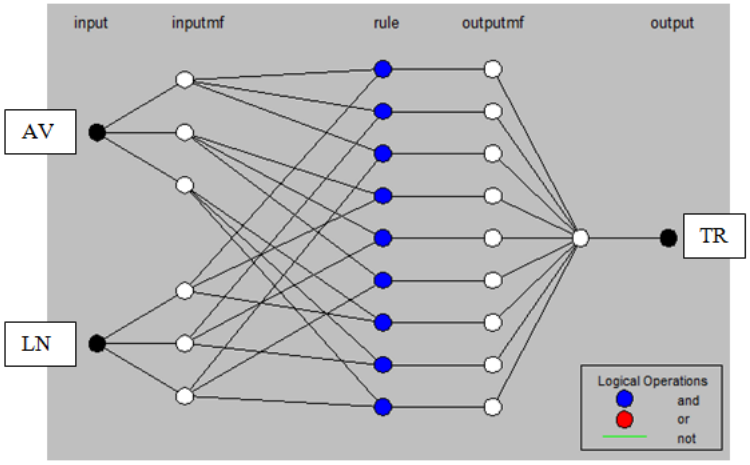


Fig. 3: *The ANFIS system*

A number of 40 experiments were carried out, which were randomly divided into two groups. The first group of data obtained from 32 experiments (80%) was used for training the ANFIS system. The second group of data obtained from 8 experiments (20 %) was employed to check the system. The grid partition was employed to generate the fuzzy inference system based on the first-order Sugeno model for all the eight membership functions implemented in ANFIS. The best results were obtained for the gauss2mf membership function. The training error for this membership function was 0.55203 (Figure 4).

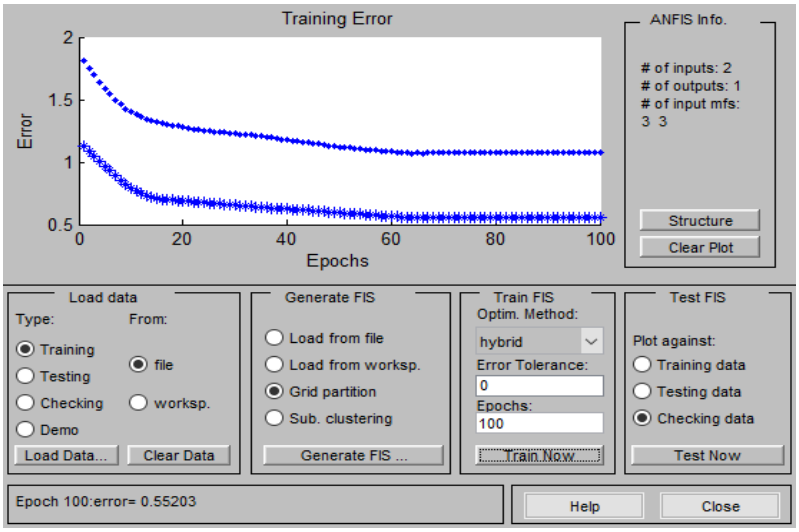


Fig. 4: *The training error*

The performance of the developed ANFIS system was expressed through the RMSE and MAPE measures [6]:

$$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\mathrm{TR}_{p_i} - \mathrm{TR}_{m_i}\right)^2} \quad \textbf{(1)}$$

and

$$\mathrm{MAPE} = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{\mathrm{TR}_{m_i} - \mathrm{TR}_{p_i}}{\mathrm{TR}_{m_i}}\right| \quad \textbf{(2)}$$

where TR_{p_i} and TR_{p_i} are the predicted and measured value of the TR and $i = \overline{1,8}$. The value of RMSE was 1.0564, while the value of MAPE was 5.84%. Based on [7], we may point out that the ANFIS prediction system demonstrates good performance.

5. CONCLUSIONS

In this study, an ANFIS approach was employed for planning the maintenance activities of textile machines. The amplitude of vibration and level of noise of the needles were used as inputs in the ANFIS system. The output of the ANFIS system was the time to replacement of the needles. The performance of the developed ANFIS system was expressed by the RMSE and MAPE measures.

REFERENCES

[1] C.F. Baban, M. Baban, M.D. Suteu, "*Using a fuzzy logic approach for the predictive maintenance of textile machines*", Journal of Intelligent & Fuzzy Systems, 30(2), pp. 999-106, 2016.

[2] M. Baban, C.F. Baban, M.D. Suteu, "*Maintenance Decision-Making Support for Textile Machines: A Knowledge-Based Approach Using Fuzzy Logic and Vibration Monitoring*", IEEE Access, volume7, pp. 83504–83514, 2019.

[3] M.D. Șuteu, C.F. Băban, M. Băban, G. Dragomir, E. Toth (Kiss), "*Predictive maintenance of the automated sewing machines in textile industry*" Annals of the University of Oradea, Fascicle of Textiles-Leatherwork, volume XX, no. 2, pp. 103-106, 2019.

[4] S. Kar, S. Das, P.K. Ghosh, "*Applications of neuro fuzzy systems: A brief review and future outline*", Applied Soft Computing, 15, pp. 243–259, 2014.

[5] J.-S.R. Jang, "*ANFIS: Adaptive-Network-Based Fuzzy Inference System*", IEEE Transactions on Systems Man & Cybernetics, 23, pp.665-685, 1993.

[6] R. Hyndman, A.B. Koehler, "*Another look at measures of forecast accuracy*", International Journal of Forecasting, 22 (4), pp. 679-688, 2006.

[7] C. D. Lewis, "*Industrial and business forecasting methods: A practical guide to exponential smoothing and curve fitting*", London: Butterworth Scientific, 1983.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

THE BEHAVIOUR OF RIB 1:1 AND 2:2 KNITTED COTTON FABRICS DURING DIFFERENT SOLICITATIONS AND TREATMENTS

SZABO Monica[1], DOCHIA Mihaela[2], GAVRILAȘ Simona[3]

[1] "Aurel Vlaicu" University of Arad, Faculty of Engineering, Department of Automation, Industrial, Textile and Transportation Engineering, Postal address, 310330, 2-4 Elena Dragoi Street, Arad, Romania,
E-Mail: szabomonica@yahoo.com

[2] "Aurel Vlaicu" University of Arad, Research Development Innovation in Technical and Natural Science Institute, Postal address, 310330, 2-4 Elena Dragoi Street, Arad, Romania, E-Mail: dochiamihaela@yahoo.com

[3] "Aurel Vlaicu" University of Arad, Faculty of Food Engineering, Tourism and Environmental Protection, Department of Technical and Natural Sciences,
Postal address, 310330, 2-4 Elena Dragoi Street, Arad, Romania, E-Mail: simona2213@yahoo.com

Corresponding author: Dochia, Mihaela, E-mail: dochiamihaela@yahoo.com

Abstract: *The paper presents a study of the behaviour of rib 1:1 and 2:2 knitted fabrics made of 100 % cotton yarns during different solicitations and treatments. The studied knits were grey and finished fabrics obtained on large circular knitting machines in the form of tubular metreage. Grey knitted fabrics were deposited for relaxation, 72 hours in folded condition, in an air-conditioned room in accordance with standard atmosphere parameters. After relaxation, the knits were finished in regular factory parameters and optically brightened. Several aspects were analyzed, namely: vertical density and the mass per square meter; the tesile strength in the direction of the rows of stitches, hydrophilicity and whiteness degree.*
For grey rib 1:1 and 2:2 knitted fabrics, the vertical density after relaxation increases by 60 % compared to the vertical density on the knitting machine. By finishing, the values of vertical density have almost double values compared to the vertical density on the knitting machine. The established vertical density on the knitting machine is decisive for the mass per square meter, the dimensional stability and the shape after several cycles of wear and washing.
The rib 2:2 structures combine elements specific for plain and rib knitted fabrics, which is why they are less balanced in terms of internal tensions. Because of that, this structure behaves differently than rib 1:1 structure during the tensile strength solicitations. The applied Uvitex BLH optical brightener gives to the cotton knitted fabrics an eminent appearance which is called whiter than the whites.

Key words: *rib 1:1 and 2:2 cotton knitted fabrics, grey and finished knitted fabrics, vertical density, tensile strength, hydrophilicity, whiteness degree.*

1. INTRODUCTION

The knitted fabrics are textile structures made of stitches, which are elastic linked. The structures are elastic due to the way they are made on knitting machines and due to the possibility of yarns migrating between the elements of the structure.

After knitting, cotton yarns, try to return to their original state, as unthread loop. This is achieved during relaxation process for 72 hours after knitting. During the relaxation period, the existent internal tensions in knitted fabrics are balanced, tensions that were introduced during the knitting and drawing process, and the loops shape was changed randomly by migrating some quantities of yarn between the elements of the structure. There is no predetermined rule for this modification, the final result being the balancing of the internal tensions in the structure. During the relaxation period, also the vertical density – D_v is modified, this being an essential parameter for the final dimensional stability of the knitwear. The structural elements of a knit that are closely related to both the finishing technology and the dimensional stability obtained are: the yarns fineness, the vertical density and the structure of the knitted fabric [1, 2].

Pre-treatments and finishing operations include steps that have the purpose of removing the natural attendants of the material and technological impurities. A swelling and fixation of the fibre is obtained, as well as modification of the crystalline-amorphous ratio with the arrangement of amorphous areas in the fibre. By removing the non-cellulosic attendants, a better capacity of wetting is conferred to the material [3].

The steps of finishing technological flow for knitted fabrics are:

- Removal of oil stains, made with strong emulsifiers, polyethoxylated fatty alcohols, which have a high emulsifying power and can be used to remove greasy stains;
- Washing step, which in the case of cotton knitwear finishing, has both the purpose of removing the technological impurities, especially the paraffin used for knitting, as well as the maximum swelling of the fibre in order to relax the latent tensions existent in the knitted structure. For dimensional stability, the first washing step is very important, which is why necessary to choose the appropriate washing agents, washing temperature, the duration of the process and mechanical action. The surfactants used in the washing procedure are adsorbed on the surface of the dirt particles, then due to the dispersive and colloid protective character the impurities are passed into the solution and kept there in the dispersed state;
- The alkaline treatment carried out for the removal of hemicelluloses, pectic substances, waxes, fats and for the modification of lignin from the shells of the cotton seeds in a state that allows their rapid removal in the subsequent whitening processes;
- Bleaching for destroying the chromophore of the natural organic pigments of cotton. At the same time, whitening also removes the shells of the cotton seeds that have suffered an advanced swelling during the alkaline treatment process;
- Squeezing, for minimizing the internal tensions introduced into the structure, air blowing system is used, which replaces the classical centrifugation. For proper drying, 3 air passages are used.
- Drying which is done on tunnel type dryers, with tape;
- The last stage of the finishing process is the calendering, operation in which the knit is passed through a frame corresponding to the width of the knitted fabric and among some heated cylinders and afterwards deposited in a folded state for relaxation in air-conditioned rooms with standard atmosphere. To prevent the additional tensions in the fabric, the frames are filled in advance to avoid dragging of the knitted fabric. The parameters of the calendering process are adjusted according to the nature of the yarns and the structure of the knit.

2. EXPERIMANTAL PART

The analyzed knitted fabrics were made on circular knitting machines TERROT and TEXTIMA with large diameter and two needle beds. The technical characteristics of the knitting machines are presented in Table 1.

Table 1: *The technical characteristics of the knitting machines*

No.	Knit structure	The type of knitting machine	Technical specifications			
			Fineness [E]	Diameter [inch]	Number of systems S	Number of needles
1	Rib 1:1	TERROT	18	16	24	2x920
2	Rib 2:2	TEXTIMA	18	20	32	2x1152

The rib 1:1 knitted fabrics were made from 100 % combed cotton yarn with Ne 50/1 yarn count and 12.5 stitches/cm vertical density on the knitting machine. For rib 2:2 structure the same 100 % combed cotton yarn was used but with Ne 40/1 yarn count and 12 stitches/cm vertical density.

The obtained grey knitted fabrics were deposited for relaxation, 72 hours in folded condition, in an air-conditioned room in accordance with standard atmosphere parameters: T = 20 ^{0}C, pressure - P = 760 mm col Hg and relative humidity of air - φ = 60 %. After relaxation, the knits were finished in regular factory parameters and optically brightened. The finishing process was performed according to a preset technological flow so that one of the important parameters like dimensional stability, would be within ± 2%.

The specific reagents used for all steps of finishing technological flow for knitted fabrics were purchase from: CHT Bezema Company (Denimcol Wash RGN – detergent), Huntsman International LLC (Uvitex BLH - optical brightener), Sigma-Aldrich (polyethoxylated fatty alcohol, sodium hydroxide, sodium bisulfite, hydrogen peroxide, sodium carbonate, sodium silicate), and Rotta Company (Sulfolen 148: S-148 alkyl polyglicol ether - wetting agent). The finishing technological flow was consisted of the following operations: washing, alkaline treatment, bleaching and optical brightening, squeezing, drying and calendaring. After drying and conditioning of the samples, a series of analyses were done: vertical density, the mass per square meter, hydrophilicity, tensile strength and elongation at break, whiteness index and yellowness index.

The vertical density of the grey and finished knitted fabrics was done by using a textile magnifying glass. The mass per square meter was determined with an analytical balance Mettler Toledo AB250 according to SR EN 12127-2013 – "*The determination of the mass per unit area on small samples of knitted fabrics*". For structure changes evaluation after finishing, the stereomicroscop Zeiss Stemi 2000 with AxioCam was used. The hydrophilicity evaluation was done according to *AATTCC Test Method 79-2007*. The 5KT testing machine from Tinius Olsen - United States was used to evaluate strength and elongation at break of the raw and finished cotton knitted samples and the values were recorded on the computer by Horizon software. The determinations were done according to ASTM D 5035 – 06 "*Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method)*". The whiteness and yellowness index were measured by a reflectance spectrophotometer (Datacolor 500 from Datacolor Company, USA) and D65 illuminant was considered in all the cases. The samples were folded six times for an opaque view and measured in five different points. The average value was considered. The Whiteness Index (WI) and E313 Yellowness Index were automatically calculated by Datacolor Tools 2.0 software.

3. RESULTS AND DISCUSSIONS

The studied grey and finished knitted fabrics were evaluated by analysing the physical, mechanical and optical properties. Further on will be presented the comparative results obtain for the rib 1:1 and 2:2 grey and finished knitted fabrics. Table 2 presents the vertical density on the knitting machine, after relaxation and after finishing as well as the mass/m^2 for grey and finished knitted fabrics for both types of structures.

Table 2: *Vertical density and mass/m^2 for rib 1:1 and 2:2 grey and finished knitted fabrics*

Structure	D_v on knitting machine [stitches/cm]	$D_{v\ grey}$ [stitches/cm]	$D_{v\ finished}$ [stitches/cm]	m/m^2 grey [g]	m/m^2 finished [g]
Rib 1:1 100 % cotton, Ne 50/1	12.5	21.0	24.0	160.5	192.6
Rib 2:2 100 % cotton, Ne 40/1	12.0	22.0	23.5	232.4	240.7

For a better evaluation of the changes appeared in the structure of knitted fabrics after finishing, the samples were analyzed with a stereomicroscope. Figures 1 and 2 presents the images of rib 1:1 structure for grey and finished knitted fabrics.

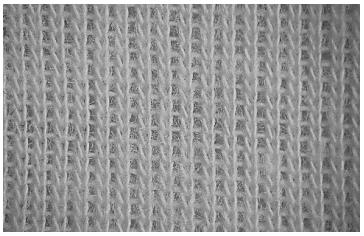


Fig. 1: *Image of rib 1:1 grey knitted fabric*

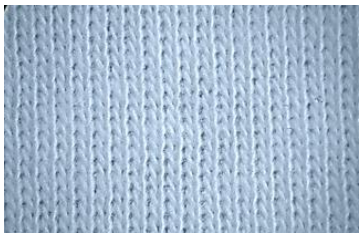


Fig. 2: *Image of rib 1:1 finished knitted fabric*

The rib 1:1 structure has the same appearance on both sides and is one of the most balanced structures due to the arrangement of the sinker loop for rib structure in a different plane from the two planes of the knit. From the images we can see an increase of the knit compactness due to the changes that take place in the fibers and in the knitted structure during the finishing process. The process of finishing is carried out on knitwear in wet condition, at high temperature with controlled and uniform tensions throughout the whole process. Figure 2 highlights the vertical direction of the stitches strings, therefore the minimization of the spiral effect, which shows a technological flow of finishing correctly applied to the knitted fabric. In the bleaching process a swelling of the fibers take place which explains the increase of the vertical density of the knit. By increasing vertical density and knitted compactness, the number of yarn-yarn contact points and the number of contact surfaces between yarns increases, so that, dimensional changes after home laundering are in the accepted limits of ± 2 %.

In figures 3 and 4 are presented the images of rib 2:2 structure for grey and finished knitted fabrics.

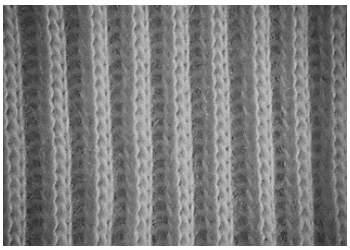


Fig. 3: *Image of rib 2:2 grey knitted fabric*

Fig. 4: *Image of rib 2:2 finished knitted fabric*

The rib 2:2 structure looks the same on both sides but is one of the least balanced structures in terms of internal tensions. This fact is explained by the presence in the structure of both plain and

rib sinker loops. Plain sinker loops are longer than the rib ones, so the yarn-yarn contact surfaces are smaller than in the case of rib 1:1 structures. From figure 4, the same minimization of the spiral effect can be observed, which shows that the technological flow of finishing was correctly applied to the knitted fabric.

The wettability evaluation of cotton knitted samples was made according to AATTCC - Test Method 79-2007. A drop of water was delivered from a burette onto the surface of the fabric. The time required for the water drop to disappear into the fabric was measured and recorded as wetting time. Average values of five determinations on different areas of the fabrics were taken [4]. The average values for all analyzed samples are presented in Table 3.

Table 3: *The hydrophilicity of rib 1:1 and 2:2 grey and finished knitted fabrics*

Sample	Water absorbency [sec.]
Rib 1:1 grey	Does not absorb
Rib 1:1 finished	1 sec.
Rib 2:2 grey	Does not absorb
Rib 2:2 finished	1 sec.

Hydrophilicity values obtained for both finished knitted structures shows a good and effective finishing treatment.

The average values of the tensile strength [N] and of the elongation at break [%] are presented in Figures 5 and 6.

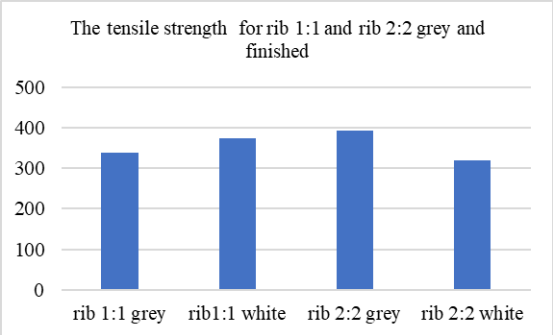


Fig. 5: *Tensile strength of rib 1:1 and 2:2 grey and finished knitted fabric*

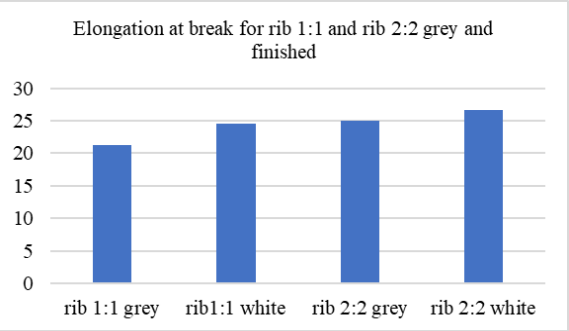


Fig. 5: *Elongation at break of rib 1:1 and 2:2 grey and finished knitted fabric*

By analysing the obtained values, it can be observed that for rib 1:1 structures the breaking force for finished samples is higher than the breaking force for the grey ones. This is explained by the fact that the structure being balanced, the number of points and surfaces of yarn-yarn contact is higher in the finished state than in the grey state. For rib 2: 2 structure the breaking force for the grey knit is higher than for finished one. This fact is explained by that the rib 2:2 structures are the most unbalanced in terms of internal tensions. An advanced waxing of yarn may be another cause of the yarns slippage between the elements of the structure and the increase of the breaking force for the raw state structure. In both cases, for both the rib 1:1 and 2:2, the elongation at break is higher for finished knitted fabric than for raw knitwear. One explanation may be that by washing procedure the paraffin was removed which would allow to the yarns to redistributes between the elements of the structure [5].

An estimated of 15 to 20 % of all textile products are white, the determination and control of whiteness is thus of primary importance to the textile industry [6]. The average values of six measurements for Whiteness and Yellowness Index (CIE/E313) are shown in Table 4.

Table 4: *Whiteness and Yellowness Index (CIE/E313) of rib 1:1 and 2:2 grey and finished knitted fabrics*

Sample	Whiteness CIE/E313	Yellowness E313
Rib 1:1 grey	21.19	26.21
Rib 1:1 finished	178.82	-39.60
Rib 2:2 grey	20.49	29.98
Rib 2:2 finished	177.12	-39.61

The bleaching treatment destroyed the chromophore of the natural organic pigments of cotton and the optical brightener Uvitex BLH increased the apparent reflectance of the article in the blue-violet region of the spectrum. From the above result, it can be seen that the concentration of OBA applied led to a whiteness index over hundred and a negative value for yellowness. Uvitex BLH gives to the cotton knitted fabric an eminent appearance which is called whiter than the whites.

4. CONCLUSIONS

1. For grey, rib 1:1 and 2:2 knitted fabrics made of 100 % cotton yarns, the vertical density after relaxation increases by 60 % compared to the vertical density on the knitting machine. By finishing, the values of vertical density of the rib 1:1 and 2:2 knitted fabrics have almost double values compared to the vertical density on the knitting machine.

2. The vertical density established on the knitting machine is decisive regarding the mass per square meter of the knits, the dimensional stability and the shape after several cycles of wear and washing.

3. The rib 2:2 structures have combined elements specific for plain and rib knitted fabrics, which is why they are less balanced in terms of internal tensions. Because of that, this structure behaves differently than rib 1:1 structure during the tensile strength solicitations.

4. The Uvitex BLH optical brightener gives to the cotton knitted fabric an eminent appearance which is called whiter than the whites.

REFERENCES

[1] L. Ciobanu, D. Ionesi, A. R. Ciobanu, "*Design of fashioning lines in 3D knitted fabrics*", Industria Textila, vol. 64 (4), pp. 198-201, 2011.

[2] D. Ionesi, A. R. Ciobanu, M. Blaga, C. Budulan, "*Knitted preforms for composite materials*", presented at the 7th International Conference – TEXCI, Liberec, Czech Republik, 2010.

[3] M. Ursache, C. Loghin, R. Mureşan, A. Cerempei, A. Mureşan, "*Investigation on the effects of antibacterial finishes on dyed cotton knitted fabrics*", Tekstil Ve Konfeksiyon, vol. 21 (3), pp. 249-256, 2011.

[4] D. Negru, L. Buhu, E. C. Loghin, I. Dulgheriu, A. Buhu, "*Absorption and moisture transfer through knitted fabrics made of natural and man-made fibers*", Industria Textilă, vol. 68 (4), pp. 269-274, 2017.

[5] L. Ciobanu, F. Filipescu, "*Experimental Study of the Mechanical Behaviour of Knitted Fabrics*", FTEE, vol. 20, (2/91), pp. 34-39, 2011.

[6] L. R. Liman, T. Islam, B. Sarker, R. Islam, I. Parveen, "*A comparative study on the application of optical brightening agent on cotton knitted fabric in one bath and two bath exhaust method*", International Journal of Textile Science, vol. 6 (5), pp. 135-142, 2017.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

DEVELOPMENT AND CHARACTERIZATION OF NEW BIOCOMPATIBLE POLYESTER HERNIA MESHES IMPREGNATED WITH CHITOSAN

GRADISTEANU PIRCALABIORU Gratiela[1,2], DOLETE Georgiana[1], TIHAUAN Bianca[1], VISILEANU Emilia[3], AXINIE (BUCOS) Madalina[1]

[1] Research and Development Department of SC Sanimed International Impex SR, Sos. București Măgurele 70F, Bucharest 051434, Romania, E-Mail: gratiela.pircalabioru@bio.unibuc.ro

[2]Research Institute of University of Bucharest (ICUB), University of Bucharest, 91-95 Splaiul Independentei, Bucharest, 050095, Bucharest, Romania

[3] The National Research and Development Institute for Textiles and Leather, 16 Lucretiu Patrascanu, Bucharest Romania, E-Mail: visilean@certex.ro

Corresponding author: Visileanu Emilia, E-mail: e.visileanu@incdtp.ro

Abstract: *Hernias and abdominal wall defects are routinely treated using synthetic and biological meshes. However, complications such as hernia recurrence and seroma and adhesion formation are quite common. So far, various materials have been employed to prevent adhesions while ensuring good mechanical properties. A good hernia mesh should harbor outstanding parietal surface tissue in-growth with minimal visceral surface adhesiveness. A good way to minimize the disadvantages of surgical meshes is to combine synthetic and natural polymers to ensure adequate biomechanical properties, or to design innovative meshes that can replace current hernia meshes. In this study, we have designed polyester (PES) meshes impregnated with chitosan that exhibited increased biocompatibility. These preliminary results pave the way for future ex vivo and in vivo studies.*

Key words: *hernia mesh, chitosan, polyester, abdominal hernia repair, novel textiles*

1. INTRODUCTION

The restoration of defects from surgical incisions requires the use of prosthetic implants, which can cause various long-term complications, such as: rejection/infection of the graft used, fistula formation or hernia relapse [1, 2]. Surgical meshes made of synthetic polymers are the 'gold standard', being used for all types of hernia [3]. The use of these polymer meshes demonstrated a significant reduction in the rate of relapse, pain minimisation, overall improving overall post-operative results. Although a wide range of surgical meshes have been designed and used in hernia healing procedures, no mesh has yet demonstrated a sufficiently strong structure to simultaneously promote the remodeling of the host tissue. In general, non-resorbable synthetic meshes made of polypropylene, polyesters and expanded polytetrafluorethylene are generally used, and resorbable meshes are made of polyglycolic acid and carboxycellulose. In parallel, several models of biological surgical nets derived from bovine pericardium and pig or human acellularized dermis have been

designed [1-6]. Their use is not very well known given the complications arising from the use of xenografts and the extremely high cost of production.

A good way to combat the disadvantages of surgical meshes is to combine synthetic polymers with natural ones to ensure adequate biomechanical properties, or to design innovative hernia meshes that can replace currently available meshes.

An example of material used successfully in the biomedical field is chitosan, derived from chitin, the most widespread natural polymer after cellulose, which is found in the exoskeleton of arthropods or in the cell walls of fungi and yeast. Chitosan is obtained by partial deacetillation of chitin (minimum 50%). The obtained chitosan is a natural, biocompatible, biodegradable polymer, has the property to form films, has a high mechanical strength and is easy to chemically modify [7-9]. In recent years there has been an increased interest in the use of chitosan and chitin, with studies focusing both on the controlled release properties of active substances and on their ability to help regeneration tissues with applications covering a large range in tissue and regenerative engineering.

2. MATERIALS AND METHODS

2.1 Impregnation of polyester and polyamide fabrics with chitosan

The polyester fabrics (with different pore sizes: P1-0.9 mm, P2-1.66mm, P3-1.08mm, P4-1.2mm) were cut into 1x1 cm^2 pieces and hydrolysed in a basic solution in order to modify their surface. The textiles alkalized in a solution of 12% sodium hydroxide for 90 minutes at 60^0C. They were then rinsed with distilled water and acetone to remove any traces of impurities. The materials were then dried in the oven at 80^0C for 10 minutes, and the fiber surface is subsequently modified by immersing the textile materials in 2% chitosan solution, previously dissolved in a 2M acetic acid solution. The immersion stage is followed by a drying at 60^0C for one hour, rinsing with distilled water of the samples and a final drying at 70^0C for 10 minutes. When alkalized polyester fibers are treated with cationic agents, the hydroxyl and carboxyl groups, available on the fiber surface, will participate in the formation of hydrogen or electrostatic bonds with the functional groups of the cationic agent.

The characterization of the obtained material was performed by Fourier transform (FT-IR) infrared spectroscopy. The FT-IR spectra analysis was used to confirm the impregnation of the synthetic fabrics with chitosan. In parallel, a control test was used in order to check if the impregnation steps (alkalization, drying, washing with distilled water and acetone) can affect the structure of the materials.

The materials were analysed before and after the alkalinization of the surfaces to determine whether the fibers undergo changes following hydrolysis treatment in the basic environment. Finally, the fibres coated with chitosan were analyzed to confirm the coating of the fibres with chitosan by the impregnation method. The synthesized materials were characterized after their drying by Fourier transformed infrared spectroscopy using a Nicolet iS50FT-IR spectrophotometer (Thermo Scientific, Massachusetts, USA), equipped with a DTGS detector. The spectra were measured in the spectral range 4000-400 cm-1, with a resolution of 4 cm-1 and 32 scans.

2.2. Biocompatibility assessment

Biocompatibility was analysed using the MTT and LDH tests a spreviously described [10]. MTT assay is a quantitative test which allows evaluation of both cell viability and proliferation. Briefly, HCT-8 epithelial cells were incubated with 1 mg/ml [3-(4.5- dimethylthiazol-2yl)]-2.5-diphenyltetrazolium bromide (MTT) solution for 4 h in the dark, at 37ºC. Formazan crystals were solubilized with HCl-SDS, resulting in purple solution, quantified by spectrophotometry at 570 nm, using FlexStation3 (Molecular Devices, USA).

The LDH test (Tox7 kit, Sigma-Aldrich) was performed according to manufacturer's instructions. Cells that no longer have membrane integrity release lactate dehydrogenase (LDH) into the culture medium. The culture medium was collected and mixed with the kit's components in order to be evaluated 4 days of culture by spectrophotometric readings at 490 nm.
For qualitative analysis of biocompatibility, cells were stained with fluorescein diacetate (FDA) and cell morphology was analysed by microscopy (Carl Zeiss AxioScope, Jena, Germany) and then processed with Zeiss Zen 2010 software. Statistical analysis was performed using Graph Pad Prism 6.0 software, Unpaired t-test. Statistically significant values were considered for $p<0.05$.

3. RESULTS

The FTIR spectra in Figure 1 (left panel) is characteristic of chitosan, being defined by the presence of absorption bands at 3361 and 3291 cm^{-1}, specific to the vibrations of the stretching of the O-H and N-H bonds, as well as the hydrogen bonds in the structure of the chitosan. The two signals at 2921 and 2877 cm ^{1} are generally specific to polysaccharides, which can be attributed to the asymmetric and symmetrical valence vibrations of the sp3C-H bonds. The presence of n-aethylate group residues is confirmed by the absorption bands characteristic of the valence vibrations of the following functional groups: 1656 cm^{-1} for o(C=O) of the primary amides, at 1550 cm, 1 o(N-H) of the secondary amides, respectively at 1254 cm 1 for α(C-N) of tertiary adides. The presence of methylene and methyl groups is confirmed by the signals from 1415 and 1375 cm^{-1} attributed to the deformation vibrations of CH2 and the symmetrical vibrations of the ch3. The absorption band from 1153 cm^{-1} can be attributed to asymmetric vibration movements in the ethereal decks C-O-C, and those at 1060 and 1018 cm^{-1} correspond to the valence vibrations of the functional c-O grouping. The not very intense signal from 1260 cm^{-1} is attributed to the hydroxyl groups present in the chitosan, and finally the absorption band from 1896 cm^{-1} is characteristic of the deformation vibrations outside the plane of the C-H bonds in the pyranosic cycle of the monosaccharides.

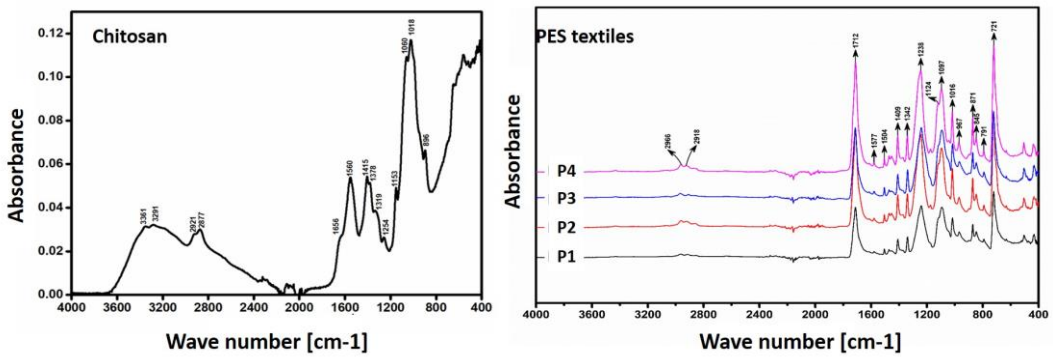


***Fig. 1**: FT-IR spectra for chitosan and PES textiles (PES meshes with different pore sizes*

The characteristic absorption of the spectra of untreated materials (Figure 1, right panel) is based in principle on the absorption band located at 1712 cm^{-1}, characteristic of the valence vibrations of the carbonyl bonds C=O, the absorption bands specific to the asymmetrical and symmetrical elongation of the sp3C-H bonds at 2966 and 2918 cm^{-1} , but also the presence of absorption bands of low intensity, in the range 1600-1500 cm^{-1},characteristic of the valence vibrations of C=C of aromatic compounds. In addition, the fingerprint areas of the region 1400-400 cm 1 confirm typical polyester structures, namely the terephthalate polyethylene: 1409 and 1342 cm^{-1} are specific to the ethylene glycol segment, while 1238 and 1124 cm 1 are specific to the grouping

terephthalate (-OOC-C-H-COO), and the vibrations of the methylene group related to C-O can be identified at 1097 cm-1. The spectra obtained for the four samples (P1-P4) are similar to other spectra in PET-specific literature.

IR spectra of alkaline-activated materials was similar to the untreated ones. They mainly show a attenuation of intensities, a slight change in the strips' gorges or a displacement of the maximum absorption compared to the typical bands of untreated materials (Figure 2).

The impregnation of chitosan on the surfaces of the two types of fibres was successfully carried out according to the spectra obtained from their impregnation. The spectra obtained on the 4 polyester fibre samples (Figure 3(a-d)) can confirm their coating with chitosan by forming the absorption band at approximately 3400 cm 1, which can be attributed to both the existence of the N-H groups in the molecular formula of the chitosan, as well as the formation of hydrogen bonds between polyesters and chitosan. In contrast, in the case of the polyamide sample Figure 13(e), the two spectra are identical. Firstly, it can be confirmed that both polyester fibres and polyamid fibres have not undergone changes following treatment with NaOH 12% solution at 60 °C. After immersion in 2% chitosan solution, polyester fibres demonstrated a good ability to interact with chitosan by forming hydrogen bonds.

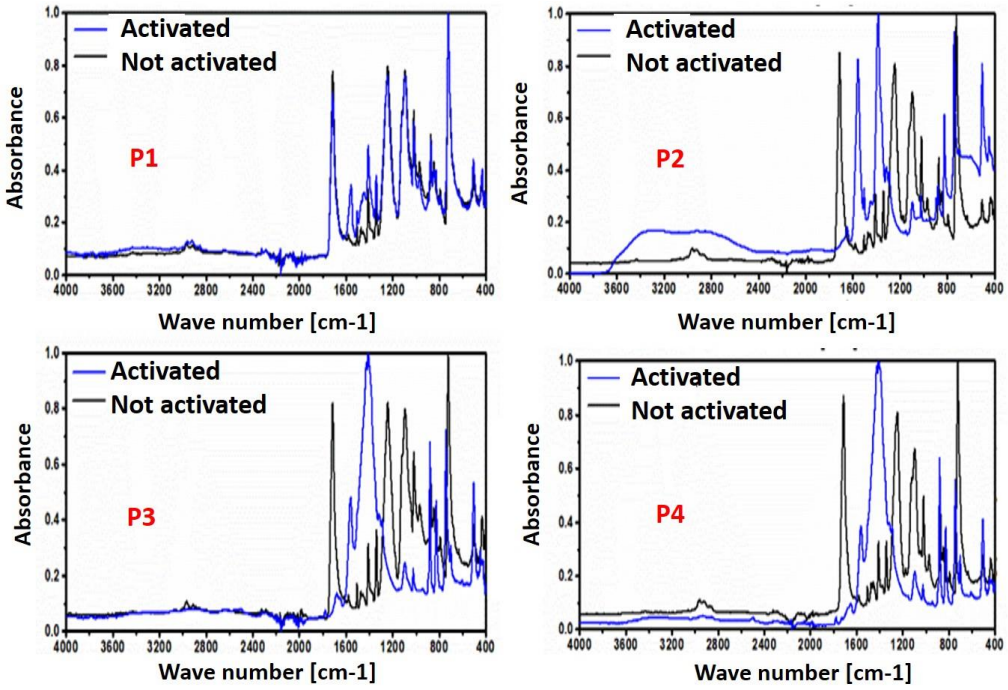


***Fig. 2**: FT-IR spectra for activated samples using alkaline treatment*

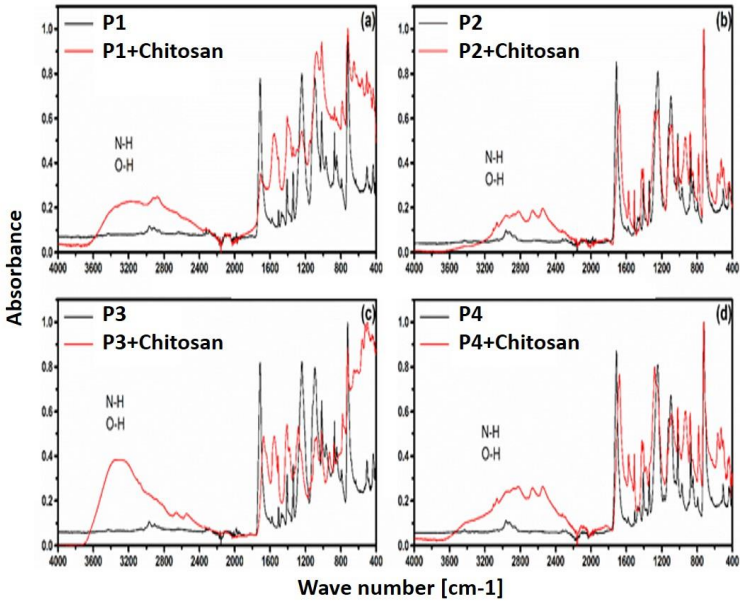


***Fig. 3**: FT-IR spectra for the textiles impreganted with chitosan*

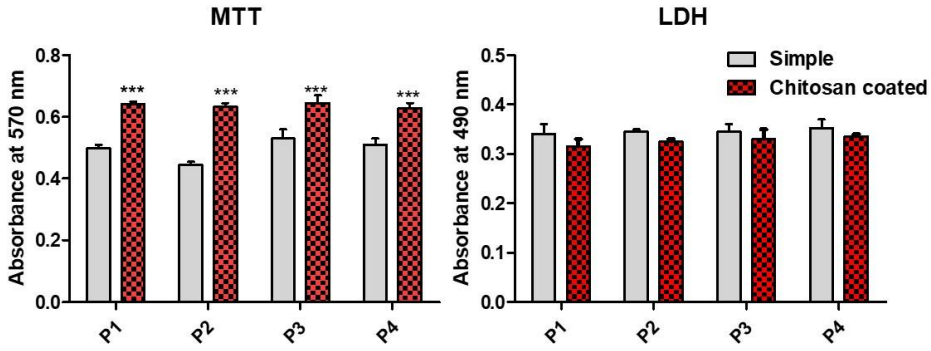


***Fig. 4**: Effect of chitosan coating on the mesh biocompatibility, n=2*

The biocompatibility ananlysis was done using MTT and LDH test. While MTT measures cells proliferation, the LDH test quantifies cytotoxicity. We have observed that chitosan treatment significantly enhanced cell proliferation for all tested samples whereas the cytotoxicity remained unmodified.

4. CONCLUSIONS

Abdominal hernia repair is generally done using surgical meshes made up of various biomaterials. However, no ideal hernia mesh exists and current research efforts are focused on developing meshes with different fiber size and porosity by using a variety of manufacturing methods and implantation procedures. Importantly, surface modification methods are potent areas of opportunity to retain material strength and increase biocompatibility of available meshes. We describe here the development of new PES meshes coated with chitosan aimed for better hernia

repair management. These meshes exhibited good biocompatibility *in vitro* but further *in vivo* studies are required.

Acknowledgements. The authors gratefully acknowledge the financial support of the ManuNet grant PariTex (grant no. 95/2019).

REFERENCES

[1] U. Klinge, B. Klosterhalfen; *Modified classification of surgical meshes for hernia repair based on the analyses of 1,000 explanted meshes*; Hernia (2012) 16:251–258, DOI 10.1007/s1002901209136.

[2] Baylón K, Rodríguez-Camarillo P, Elías-Zúñiga A, Díaz-Elizondo JA, Gilkerson R, Lozano K. Past, Present and Future of Surgical Meshes: A Review. *Membranes (Basel)*. 2017;7(3):47. Published 2017 Aug 22. doi:10.3390/membranes7030047

[3] Bendavid R., Abrahamson J., Arregui M.E., Flament J.B., Phillips E.H. Abdominal Wall Hernias: Principles and Management. 1st ed. Springer; New York, NY, USA: 2001.

[4] Pandit A.S., Henry J.A. Design of surgical meshes—An engineering perspective. Technol. Heal. Care. 2004;12:51–65.

[5] Schumpelick V., Fitzgibbons R.J. Hernia Repair Sequelae. 1st ed. Springer; Berlin/Heidelberg, Germany: 2010.

[6] Cortes R.A., Miranda E., Lee H., Gertner M.E. Biomaterials and the evolution of hernia repair II: Composite meshes. In: Norton J., Barie P.S., Bollinger R.R., Chang A.E., Lowry S., Mulvihill S.J., Pass H.I., Thompson R.W., editors. Surgery. 2nd ed. Volume 11. Springer; New York, NY, USA: 2008. pp. 2305–2315.

[7] Paulo N.M. De Brito e Silva M.S. Moraes A.M. Rodrigues A.P. De Menezes L.B. Miguel M.P., et al. Use of chitosan membrane associated with polypropylene mesh to prevent peritoneal adhesion in rats. J Biomed Mater Res Part B Appl Biomate. 2009; 91:221

[8] Kim I.-Y. Seo S.-J. Moon H.-S. Yoo M.-K. Park I.-Y. Kim B.-C., et al. Chitosan and its derivatives for tissue engineering applications. Biotechnol Adv. 2008; 26:1

[9] VandeVord P. Matthew H. DeSilva S. Mayton L. Wu B. Wooley P. Evaluation of the biocompatibility of a chitosan scaffold in mice. J Biomed Mater Res. 2002; 59:585

[10] Axinie (Bucos) M, Tihauan B, Ivanof A, Pircalabioru GG, Visileanu E, Aydin S, Mihai C, Scarlat R, Vladu A. Development and preliminary characterisation of novel textiles for abdominal hernia repair. Rom Biotechnol Lett. 2019; 24(6): 1090-1096. DOI: 10.25083/rbl/24.6/1090.1096

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

APPLICATION OF THE BENCHMARKING METHOD IN THE PROCESS OF NEW TEXTILE PRODUCT DEVELOPMENT: A LITERATURE REVIEW

UROŠEVIĆ Snežana[1], DOBROSAVLJEVIĆ Andrea[2], VUKOVIĆ Milovan[1]

[1]University of Belgrade, Technical Faculty in Bor, Vojske Jugoslavije 12, Bor, Serbia,

[2] PhD Candidate[1]University of Belgrade, Technical Faculty in Bor, Vojske Jugoslavije 12, Bor, Serbia

Corresponding author: Urošević Snežana, E-mail:snezanaur1@gmail.com

Abstract: *Benchmarking represents a contemporary method which provides opportunityy for learning and change of behaviour based on comparison with the ones best in class. It creates a base for many developmental opportunities for the organizations which are capable to recognize benneffits from practical implementation of this method. Benchmarking has an important place in the development of new product, as well as services, of which a large proportion of small and medium-sized enterprises (SMEs) are still unaware. In initial phase of new product development, in the phase of idea generation, results of benchmarking analysis may affect the projection of success path of following phases of product development. Considering the process of development and marketing of new textile products raises the question of best practice of the process itself, as well as the role and place of benchmarking within the stages of the process of development of new textile products. The paper focuses on looking at modern product innovations marketed by organizations operating within the textile industry and drawing conclusions about the level at which the development of operational performance and the innovation incentive of organizations depends on the implementation of the benchmarking process in the process of developing new textile products.*

Key words: *benchmarking process, new product development process, textile industry, innovations*

1. INTRODUCTION

Benchmarking appears to be the most popular managerial tools around the world, thus it become primary instrument in total quality management (TQM), knowledge management and process improvement efforts of the companies. Better marketing possibilities could be recognized by the implementation of this tool, as well [1]. Through the organizational perspective, benchmarking is viewed as external focus on internal activities, functions or operations with the aim to reach continuous improvements [2]. Benchmarking is used within many organizations as a mean for gathering of valuable knowledge about certain business activities, products, processes etc. Therefore, it can be said that it is widely accepted initiative for improvement of business [3]. Although there is an opinion in the practice that organizational benchmarking seeks to imitate or copy the activities and/or products of its competitors it actually represents the process in which organizations overlook outside its borders for the purpose of learning. Innovation stimulation manifests itself as a learning outcome in this process [4]. Organizations face an ongoing effort to improve competitiveness in a changing business environment that carries a high degree of uncertainty and risk, so new challenges

that organizations face require organization problems to be addressed in a new way [5]. In the literature about benchmarking can be found that organizations strive to be the best, in the sense of „best-in-class “, leading brand in the market and everything else that makes them stand out as unique in the eyes of customers, and differs them in comparison to competitors [6]. Implementation of best practice encourages the wave of continuous improvements within the organization [7]. Practice of new product development can be defined as common performance that implements ideas and policies that lead to the launch of new products and services. Best practice would, then, be the one which results with best business outcomes, so taking into account the new product development practice the best practice would be the one that promotes greater success in development and launch of new products and services [8].

Process of new product development within textile industry receives new dimension in contemporary business circumstances, where innovation is recognized as a vital source of competitive advantages of organizations [9], whereby organizations' struggle for competitive advantage is strengthened and benchmarking is a continuous activity [10] of comparison with best in class receives special role in this process. Therefore, the main considerations in the paper are to look at contemporary product innovations marketed by organizations operating within the textile industry and to draw conclusions about the level in which the development of operational performance and innovation incentive for organizations depends on the implementation of benchmarking processes in the process of developing new textile products through identification the place and role of benchmarking within the various stages of the new product development process.

2. PROCESS OF NEW TEXTILE AND CLOTHING PRODUCT DEVELOPMENT

Market globalization created an arena of competitiveness in which the organizations are forced to continuously develop new successful products in order to survive [11]. The term „ new product development “, refers to the process of development of individual products and overall new production program of one organization. The success of new product development is dependent of the understanding of customers’ needs and desires which are being reviewed very early in the new product development process [12]. According to that, new product development shows its strategic characteristic [13]. The development of a new product is actually a process consisting of a number of successive stages, and this series of stages can also be considered as a series of activities aimed at collecting and evaluating information [14]. Shih et al. [15] point out that what makes the development of textile and apparel products so different from the development of other products is that this process involves a constant seasonal change in demand, production opportunities, technical application of materials. The development of textile and apparel products may vary because its characteristics are significantly influenced by seasonal plans and technical knowledge. These are driven by the trends that prevail over a short period of time. Incorporating a large amount of different ideas and knowledge into the process of developing a new product should have an impact to it, and result with enhancement of the process. The enhancement should be visible in adequate meeting the needs and desires of consumers. Within the research conducted by these authors, the focus is on the most important participants in the open innovation process, namely on customers and consumers. Consumers opinion is valuable. That is why various improvements can be generated by involvement of customers in the process of new product development. These improvements can be in product quality, risk reduction and increase of market acceptance of textile product [16]. In development of the procedure for the development of a new product or process within the SMEs, Šenk et al [17] list five successive and overlapping stages. Kowang & Rasli [18] state a standard flow of the new product development process, which contains five stages in their research about new

product development in multi-location R&D organizations. Durmuşoğlu & Barczak [19] explore the use of information technology tools in the stages of new product development, outlining three stages of this process. Nepal et al [20] state "stage-gate", Noting that this process was first developed and implemented in the US industry in the late 1980s and early 1990s, and consists of discrete phases from planning to product placement, with key decision points at the end of each phase determining direction for further product development. Ebarefimia [21] states seven phases of new product development process. The phases presented by different authors mentioned in text are listed in table 1.

Table 1: *Overview of the stages of the product development process based on research of different authors*

Authors	Product development process phases
Šenk et al (2010)	Idea generation → evaluation and selection of the best idea → development of the product construction concept → testing of entrepreneurial idea → technical implementation and commercialization of product
Kowang & Rasli (2011)	Identification of chances → concept development → product design → process design → product commercialization
Nepal et al (2011)	Identifying needs → gate 1 → design specification → gate 2 → concept development → gate 3 → detail design → gate 4 → testing and improvements → gate 5 → production → gate 6 → marketing
Durmuşoğlu & Barczak (2011)	Discovery → development → commercialization
Ebarefimia (2014)	Idea generation → screening of ideas → concept development and testing → development of marketing strategy → business analysis → test marketing → commercialization

Source: [17,18,19,20,21]

Figure 1 illustrates an example of the process of developing new textile and clothing products.

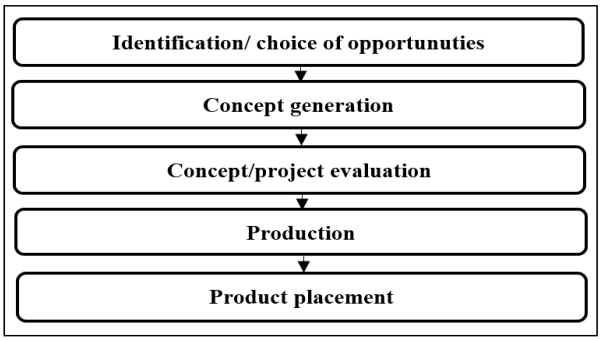


Fig. 1: *Example of new textile and clothing products development [15]*

3. BENCHMARKING IN DIFFERENT PHASES OF PRODUCT DEVELOPMENT

Successful companies use right methods at the right time. Great number of methods, such as method for support in decision making like AHP (Analytic Hierarchy Process), risk analysis, simulation and optimization methods, can be applied within the new product development process [22]. Benchmarking appears to be one of the methods that can contribute in new product development process. It is an approach that can be used to facilitate the implementation of improvements in new product development phases [23]. Within the research [24] the

implementation of specific types of methods by specifically successful companies has been investigated. Benchmarking is, thus, listed among cross-functional methods. In this group of method are listed the SWOT analysis, techniques of creative thinking and scenario planning as well.

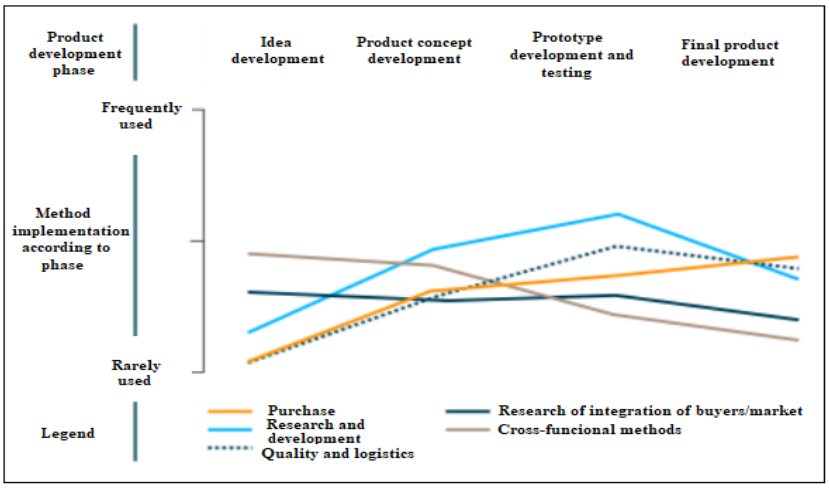


Fig. 2: *Methods used in different product development phases [29]*

From conducted research it is concluded that the implementation of the correct combination of methods is the key of success of product, and that companies that combine methods have 15% more success with their new products in comparison to ones that use single method practice [24]. As process of new product or service generation starts with idea generation and concept development every idea generation should be started with the respect to the customers demands and needs. Within this phase benchmarking process lets us understand the potential opportunities on the market in order to conclude what is necessary to do to take advantage of recognized opportunities. Based on the research represented in the figure 2, we can say that the implementation of the benchmarking as one of cross-functional methods is highlighted in initial phase of new product development process. It is still implemented in the phase of concept development, but its frequency slightly reduces with advancement through the following phases. Benchmarking implementation in these phases results in identification of necessary improvements in products, based on product performance gaps [25, 26]. Testing the reliability, completeness, flexibility, contemporary design of competing products and collecting other relevant information related to the placement and sale of products, significant information can be obtained that can assist the manufacturer in the initial stages [27]. Powell & Cassill [28] note that benchmarking of competitive products may form a base for development of new textile products, but also to contribute by forming appropriate strategies concerning features of new products and new market entry strategies. New idea generation that results from the application of benchmarking, especially contributes to the initial stages of development of a new textile product [29].

4. CONCLUSIONS

New product development appears with the desire of the organization to achieve the success on the market, according to which it requires creativity, design, research and development, implementation of marketing strategies and investments in order to gain benefits. Without new product development organizations wouldn’t be able to maintain their products suitable for the

market, neither would they be able to adopt new ways of production and placement of new products. Considering the contemporary innovations within the textile industry and the width of application of these products, it can be concluded that different world organizations in the field of textile products are encouraged to innovate and work to develop operational performance. Benchmarking is found to be a beneficial tool especially in initial phase of new product development. Idea generation that results from benchmarking application establishes a solid base for following new product development phases. Further research in this area should focus on examining the extent to which the benchmarking method is applied at the various stages of new product development in local small and medium-sized textile enterprises, as well as the level at which domestic textile companies are making efforts to develop operational performance through the application of management methods. On the basis of these data, it would then be possible to draw a parallel between the results obtained at the level of local enterprises and the results of foreign research.

ACKNOWLEDGEMENTS

Paper prepared as part of the project TR 34020, supported by the Ministry of science and technological development of the Republic of Serbia.

REFERENCES

[1] A. Lahat, A., A. Shoham, „*Benchmark the Marketing and Operation Capabilities for International Firms Export Performance*“, Procedia-Social and Behavioral Sciences, vol. 109, pp. 998- 1000, 2014.

[2] J. Moriarty, C. Smallman, „*En route to theory of benchmarking*“, Benchmarking: An International Journal, vol. 16, no. 4, pp. 484-503, 2009.

[3] M. Zairi, *„Benchmarking for Best Practice“,* Routledge, 2010.

[4] R. Huggins, *„Regional competitive intelligence: Benchmarking and policy-making“*, Regional Studies, vol. 44, no 5, pp. 639-658, 2010.

[5] B. Wellstein, A. Kieser, „*Trading-best practices - a good practice?“,* Industrial and Corporate Change, vol. 20, no 3, pp. 683-719, 2011.

[6] G. Francis, J. Holloway, „*What have we learned? Themes from the literature on best-practice benchmarking“.* International Journal of Management Reviews, vol. 9, no 3, pp. 171-189, 2007.

[7] M. Paunović, G. Čolović, S. Borić, *„Benčmarking proizvodnog procesa*“, Tekstilna industrija“, vol. 64, no 4, pp. 52-55, 2016.

[8] K. B. Kahn, G. Barczak, J. Nicholas, A. Ledwith, H. Perks, *„An examination of new product development best practice“.* Journal of Product Innovation Management, vol. 29, no 2, pp. 180-192, 2012.

[9] S. Salomo, J. Weise, H. G. Gemünden, *„NPD planning activities and innovation performance: the mediating role of process management and the moderating effect of product innovativeness“*. Journal of Product Innovation Management, vol. 24, no 4, pp. 285-302, 2007.

[10] M. Hinton, G. Francis, J. Holloway, „*Best practice benchmarking in the UK“.* Benchmarking: An International Journal, vol.7, no 1, pp. 52-61, 2000.

[11] A. Balbontin, B. B. Yazdani, R. Cooper, W. E. Souder, „*New product development practices in American and British firms“.* Technovation, vol. 20, no 5, pp. 257-274, 2000.

[12] G. Gresham, J. Hafer, E. Markowski, „*Inter-functional market orientation between marketing departments and technical departments in the management of the new product development process“.* Journal of Behavioral and Applied Management, vol.8, no 1, pp. 43, 2006.

[13] B. Nadia, G. Gregory, T. Vince, „*Engineering change request management in a new product development process".* European Journal of Innovation Management, vol. 9, no 1, pp. 5-19, 2006.

[14] W. Y. C. Shih, K. Agrafiotes, P. Sinha, „New product development by a textile and apparel manufacturer: a case study from Taiwan". The Journal of The Textile Institute, vol. 105, no 9, pp. 905-919, 2014.

[15] N. Bhuiyan, *„A framework for successful new product development"*. Journal of Industrial Engineering and Management, vol. 4, no 4, pp. 746-770, 2011.

[16] F. T. Piller, D. Walcher, „*Toolkits for idea competitions: a novel method to integrate users in new product development".* R&d Management, vol. 36, no 3, 307-318, 2006.

[17] M. Šenk, P. Metlikovič, M. Maletič, B. Gomišček, „*Development of new product/process development procedure for SMEs".* Organizacija, vol. 43, no 2, pp. 76-86, 2010.

[18] T. O. Kowang, A. Rasli, „*New product development in multi-location R&D organization: a concurrent engineering approach".* African Journal of Business Management, vol. 5, no 6, pp. 2264, 2011.

[19] S. S. Durmuşoğlu, G. Barczak, „*The use of information technology tools in new product development phases: Analysis of effects on new product innovativeness, quality, and market performance".* Industrial Marketing Management, vol. 40, no 2, pp. 321-330, 2011.

[20] B .P. Nepal, O. P. Yadav, R. Solanki, „*Improving the NPD process by applying lean principles: A case study".* Engineering Management Journal, vol. 23, no 1, pp. 52-68, 2011.

[21] U. S. Ebarefimia, „*New product development process and its impact on business performance in Nigeria".* The Business & Management Review, vol. 4, no 4, pp. 25, 2014.

[22] J. Wind, V. Mahajan, „*Issues and opportunities in new product development: An introduction to the special issue".* Journal of Marketing Research, vol. 34, no 1, pp. 1-12, 1997.

[23] M. Senanayake, T. Little, "*Measures for new product development*". Journal of Textile and Apparel, Technology and Management, vol.1, no. 3, 1-14, 2001.

[24] Best Practices in New Product Development, *Using Effective Methods to Boost Success* (2013)https://www.rolandberger.com/en/Publications/pub_best_practices_in_new_product_development.html dostupno: 10.02.2020

[25] A. Kumar, J. Antony, T. S. Dhakar, *„Integrating quality function deployment and benchmarking to achieve greater profitability"*, Benchmarking: An International Journal, vol.13, no. 3, pp. 290 – 310, 2006.

[26] M. Kozak, *"Destination benchmarking",* Annals of Tourism Research, vol 29, no. 2, pp. 497-519, 2002.

[27] M. Paunović, Lj. Radovanović, N. Đalić, S. Borić, "Benčmarking kao deo strategije kvaliteta održavanja pri razvoju modnog proizvoda", Tekstilna Industrija, vol. 66, no. 3, pp. 39-46, 2018.

[28] N. B. Powell, N. L. Cassill, *"New textile product development: Processes, practices, and products"*. Journal of the Textile Institute, vol. 97, no. 2, pp. 155-166, 2006.

[29] T. Asrofah, S. Zailani, Y. Fernando, "Best practices for the effectiveness of benchmarking in the Indonesian manufacturing companies", Benchmarking: An International Journal, vol. 17, no. 1, pp. 115-143, 2010.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

A COMPARATIVE STUDY ON THE CONCENTRATIONS OF TCMTB BASED FUNGICIDES IN LEATHER AND THEIR EFFECT ON MOULD RESISTANCE

POLATDEMIR Erdogan Can[1], ZENGIN ADIGUZEL Arife Candas[1], MUTLU Mehmet Mete[1]

[1] Ege University, Engineering Faculty, Department of Leather Engineering, 35100, Bornova, Izmir, Turkey

Corresponding author: Mutlu, Mehmet Mete, E-mail: mete.mutlu@ege.edu.tr

Abstract: *TCMTB (2-(thiocyanomethylthio)-benzothiazole), as a broad spectrum antifungal agent, has found a wide spread usage in processing of pickled, wet-blue and crust leathers and became one of the most used fungicides in leather although it suffered some drawbacks related to its toxicity and handling hazards. Monitoring TCMTB usage and the amounts in leather while keeping the antifungal effectiveness has become a necessity. In this study; 5 different TCMTB based fungicides with similar concentrations sold under different trade names were applied to wet-blue sheep skins. Then the leathers and baths were evaluated for their TCMTB content by using UV Spectrophotometer and HPLC methods to determine the concentration of the active content in fungicides and residue in leather. Meanwhile the effect of the biocides on the fungal resistance of leathers was tested by the use of two methods: tropical chamber and ASTM D4576.*

Key words: TCMTB, Biocide, Fungicide, HPLC, UV Spectrophotometer, fungal resistance

1. INTRODUCTION

As a result of the hydrolytic degradation caused by the mould grow on leather, it can cause irregularities in dyeing and finishing processes, and in the later stages, more serious and irreversible faults on the grain, and may affect the various physical properties of the leather negatively. When appropriate conditions come into existence, mould may also develop in the final product, causing unpleasant appearance and even odours. Although precautions taken for storage conditions can slow down or prevent mould growth, the precise solution can be achieved by using commercial preparations containing active substances called antifungal agents or fungicides.

Some of the earliest products to be used as fungicides were organo mercury compounds (eg. phenyl mercuric acetate aka PMA) and chlorinated phenols (eg. penta chloro phenol aka PCP). These products were effective in degradation of fungi but they were also very toxic to other living organisms, including humans. The use of organo mercury compounds and chlorinated phenols eventually became restricted, starting in the 1970s [1].

Nowadays, only a few fungicides dominate the leather industry usage. The big four fungicides are commonly known by their abbreviations, for example, PCMC (para-chlor-meta-cresol), OIT (2-n-octylisothiazolin-3-one), OPP (ortho-phenylphenol), TCMTB (2-(thiocyano-methylthio) benzothiazole) [2]. These fungicides are also hold under microscope for their toxicity and hazards. The Environmental Protection Agency (EPA) has reviewed risk assessments for

TCMTB and the Reregistration Eligibility Decision (RED) for TCMTB was approved on August 1, 2006 [3].

Ecolabelling is a worldwide voluntary or mandatory labelling system for consumer products, designed to help costumers to select and encourage manufacturers to make products with low environmental impact [4]. The Ecolabel, "Der blaue Engel" (the blue angel), gives recommendations for allowable limits in leather of the active fungicide components: PCMC < 300 mg/kg, OIT < 100 mg/kg, OPP < 500 mg/kg and TCMTB < 500 mg/kg [5].

In this study, the determination and comparison of TCMTB amounts bound in the leather and remaining in the process bath by using UV spectrophotometry and HPLC methods were investigated by using five different TCMTB based commercial fungicides with same active matter. The fungal resistance of the leathers was also evaluated with tropical chamber and ASTM D4575 test method.

2. MATERIAL AND METHOD

2.1 Material

Three wet-blue domestic sheep skins processed without any fungicides were used as leather samples. Five different fungicides that have 30% TCMTB were suplied from the market and coded as T1, T2, T3, T4, T5.

2.2 Method

50 pieces of 7 cm x 11 cm size were cut from various places of wet-blue leathers and separated in groups of 10 for each fungicide. The weight of each group was adjusted to 150±0.1 g.

1 gram of fungicide was added to 1000 ml water. 1/1000 fungicide solutions were applied to the leather samples in 2000 ml flasks for 2 hours at 30°C in a shaking incubator at 150 rpm.

2.2.1 Determination of exhaustion values by UV Spectrophotometer

The leather samples processed with fungicides were ground after drying and the obtained leather powders were washed in distilled water for 6 hours in an orbital shaker. Relative exhaustion values were found by determining the ratio of fungicide removed by washing and comparing the with the stock fungicide solutions by using UV spectrophotometer.

The amount of TCMTB (%) removed by washing (W%) and remained in the leather (B%) were calculated using the following equations (1) and (2).

$$W\% = (Abs.E / Abs.I) \times 100 \quad \textbf{(1)}$$

$$B\% = 100 - W \quad \textbf{(2)}$$

W	The amount of removal by washing in %
Abs.E	Peak absorbance value for washing solution
Abs.I	Peak absorbance value for Stock Solution
B	Binding amount in%

2.2.2 Determination of TCMTB content in leather by HPLC

Leather samples taken according to ISO 2418 were ground according to ISO 4044. 1±0.001 gr of ground leather was weighed and placed in a 100ml beaker, and then 20ml acetonitrile was added. The extraction was performed at room temperature for 1 hour in 80% power ultrasonic bath. Following the extraction, the solution was filtered to for the use of HPLC. HPLC allows the rapid,

sensitive and highly specific determination of fungicide preservatives in leather [6].

CC250 / 4 nucleosil 100-5 C18 HD separator column and appropriate precolumn were used for the HPLC analysis. After isocratic with 60% acetonitrile at the flow rate of 0.8 ml/min, at 30°C column temperature for the first 6 minutes, then 99.7% TCMTB (in acetonitrile) was calibrated in 95% pure water for 9 minutes with 0.02ml injection volume, at UV detection frequency of 275 nm and measurements were conducted under the same conditions.

2.2.3 Standard Test Method for Mould Growth Resistance of Leather - ASTM D4576

The ASTM D4576 method [7] stipulates the using of a series of leather samples checking both grain and flesh side, having the surface of 1 $inch^2$ each inoculated with *Aspergillus niger* and examined after 3, 7 and 14 days. In our study the interval of time was extended to 21 days to get more distinguishable results. The test samples were placed in the center of Petri vessels and then the growing medium (*potato dextrose agar*-PDA), was filled up to the upper level of leather samples. The Petri vessel was incubated for three weeks at the temperature of 27°C. Visual assessment was performed according to the micelle percent on the leather surface at 3, 7, 14 and 21 days. Assessment marks were given depending on this percent, as follows: (0)- mould absent on the surface of sample, (0.5)- less than 12% of sample surface is covered with micelle, (1)- 25% of sample surface is covered with micelle, (2)- 50% of sample surface is covered with micelle, (3)- 75% of sample surface is covered with micelle, (4)- 100% of sample surface is covered with micelle

2.2.4 Tropical Chamber Test

Tropical Chamber test is based on ASTM D3273-00 [8] test method and performed in an insulated cabin whose internal environment is kept at 95-100% humidity and 27-30°C temperature for 4 weeks (28 days). The tropical chamber is infused with the spores of various types of fungi, which are frequently observed in leather and with the help of the air circulation, ideal humidity and temperature these spores affect the leather much faster than normal environment. The evaluation is made by scoring the % surface area covered with mould over 100. Samples scoring 20 and below at the end of each week are considered to have successfully completed the test. Samples showing mould growth below the limit value at the end of the 4^{th} week are considered to have long-lasting mould resistance. Week 3 refers to medium-term and week 2 indicates short-term mould resistance.

In our study, leather samples cut in size of 7 cm x 10 cm were placed on hangers in the cabin. The chamber was infused with *Aspergillus niger* spores and the samples were examined every week. Besides for each test, a piece of leather without fungicides (blank sample) was hung to check if the tropical chamber was working by getting over 20 points at the end of the first week. The mould growth was evaluated for 8 weeks to get distinguishable results for our study.

3. RESULTS AND DISCUSSIONS

When the results of washing and binding ratios of TCMTB based fungicides are examined, it can be seen that there are considerable differences between the binding ratios of the fungicides which have the same benzothiazole active substance (Table 1). The sample of T2 showed the best binding capacity while the sample of T5 had the lowest value. The degree of binding between T3 and T2 samples were found similar. The differences in the binding degree of the samples indicate that the amount of TCMTB bound to leather is affected by other ingredients in the composition of the product.

When the data related to determination of TCMTB content in the leather samples is evaluated, the amount of TCMTB found in the leather sample treated with T3 was found higher than

the others (Table 2). The sample of T5 was the leather with the least TCMTB content. T3 and T2 samples showed similar values.

Table 1 *Washing and binding ratios of TCMTB based fungicides*

Fungicide	Measurement (nm)	Initial Abs.	Final Abs.	Washing Degree (%)	Binding Degree (%)
T1	221	0.79	0.23	28.49	71.51
T2	218.4	1.58	0.34	21.49	78.54
T3	221	1.12	0.25	22.01	77.99
T4	218.2	0.95	0.22	23.68	76.32
T5	221	0.28	0.12	42.84	57.16

Table 2 *The TCMTB contents of the leathers determined by HPLC*

Fungicide	TCMTB amount in Leather Sample (mg/kg, HPLC)	TCMTB (g/Kg)	TCMTB (%)
T1	2635.56	276.40	27.64
T2	3195.65	305.16	30.51
T3	3412.63	328.19	32.82
T4	1732.31	170.24	17.02
T5	1566.05	205.48	20.55

When the mould growth resistance of the samples was tested according to ASTM D4576, it can be seen that all fungicides can provide sufficient antifungal protection against *Aspergillus niger*, graded as "0", at the end of the 21st day. This result was not included in the table because it would be better to give the inhibition zone diameters to compare the effectiveness of the fungicides (Table 3). When evaluated according to the average preserved diameters (Table 3), better fungicidal performances are listed as T1, T3, T2, T4 and T5 in descending order. While T3 and T4 leather samples performed better antifungal activity on the suede side, T1 and T2 had higher antifungal performance on the grain side. T5 sample provided the least protection in both suede and grain side compared to other samples.

The fact that these fungicides, which are produced using the same active substance as benzothiazole, showed different performances on the grain and suede sides of the leathers indicates that the differences that may occur in the auxiliary ingredients used for dissolution, emulsion stability of TCMTB and also the penetration of the fungicide to leather may lead to different results in practice.

Table 3 *Mould Growth Resistance of the Leathers - ASTM D4576*

Fungicide	Mould Resistance Assessment							
	Day 3*		Day 7*		Day 14*		Day 21*	
	Grain Side	Flesh Side	Grain Side	Flesh Side	Grain Side	Flesh Side	Grain Side	Flesh Side
T1	4.27	4.00	4.22	3.97	4.27	4.07	4.27	4.03
T2	4.55	4.10	4.25	3.83	4.22	3.40	4.25	3.40
T3	4.34	4.60	4.12	4.30	4.10	4.10	4.03	4.10
T4	4.02	4.17	3.79	4.07	3.47	4.07	3.47	4.07
T5	3.75	3.63	3.53	3.27	3.22	2.97	3.33	3.03
Blank	2.9		2.27		2.3		2.2	

* Inhibition zone diameter in cm.

According to the results of the first four-week tropical circle test, all leather samples showed that they had long-term mould resistance by scoring below 20 at the end of the 4th week. Starting from the 5th week, an increase in mould growth on the leather samples shows that the fungicide applications of the study were found compatible with the ideal usage rates in real tannery conditions. At the end of the 6th week, T4 fungicide, which remained from the tropical circle test with 30 points, showed the lowest performance among the 5 fungicides applied. The T5 fungicide remained from the test at the end of the 7th week and the T1 fungicide at the end of the 8th week. T2 and T3 fungicides, which scored 20 or less in the tropical chamber test at the end of the 8th week, showed that they provided better protection than the other fungicides. T2 fungicide was slightly more successful than T3 fungicide with an average of 15. (Table 4)

Table 4 *Mould Growth Resistance of Leathers according to Tropical Chamber test*

Fungicide	Mould Resistance Assessment							
	Week1	Week2	Week3	Week4	Week5	Week6	Week7	Week8
T1	0	0	0	0	0	5	15	30
T2	0	0	0	0	0	5	15	15
T3	0	0	0	0	0	5	10	20
T4	0	0	0	5	15	30	40	45
T5	0	0	0	5	10	20	35	50
Blank	40	85	100	100	100	100	100	100

Table 5 gives us opportunity to summarize all findings and make a comparison with TCMTB content of fungicide samples, their binding percentage, bound TCMTB in leather and mould resistance results. According to ASTM D4576 and tropical chamber test results, all fungicides were able to provide adequate protection to the leathers during the standard testing time. In the extended process, the development of mould was started to be observed in leather samples with less TCMTB content. It was concluded that mould resistance is directly relevant to the bound TCMTB in leather. However, the binding % is not always related to the concentration of fungicide as seen T3 and T4. The findings indicate that, while evaluating the performance of fungicides, their ability to bind TCMTB to the leather is important as well as their TCMTB content. Another finding was that TCMTB concentrations of fungicide samples varied in a wide range although they are marketed as similar products. This is another point that consumers should take into consideration.

Table 5: *Comparison of fungal resistance and TCMTB contents*

Fungicide	**TCMTB (%)**	**Binding (%)**	**TCMTB in leather (mg/kg leather)** (HPLC)	**Avg. inhibition zone diameter (cm)** (ASTM D4576)	**Avg. area covered with mould (%)** (Tropical Chamber)
T1	27.64	71.51	2635.56	4.19	30
T2	30.52	78.54	3195.65	4.00	15
T3	32.82	77.99	3412.63	4.05	20
T4	17.02	76.32	1732.31	3.68	45
T5	20.55	57.16	1566.05	3.23	50
Blank	-	-	-	2.20	100

4. CONCLUSIONS

Among the fungicides used in the leather industry, TCMTB has come to the fore with its wide spectrum and compatibility with operating conditions and has found wide usage. It is produced

and marketed under different names by many manufacturers. It is seen that these products, each of which have the same active ingredient and produced with the claim of providing the best protection, are different in many ways and can result different mould resistance to leathers. These differences should be known by the user; arranging the process in accordance with the product character will prevent unnecessary consumption and ensure optimum antifungal protection.

In this study, the binding ability of TCMTB to leather, which is one of the product characteristics that should be considered during the use of fungicide, was determined for each product, and the results were examined comparatively with 2 different antifungal resistance tests. According to the results, TCMTB concentrations for each fungicide, TCMTB binding percentages to the leather, TCMTB amounts in the leather samples and the relationship between this TCMTB amount and the fungal resistance of the leather were revealed. The results showed that the amount of use and product efficiency for each fungicide can be optimally utilized in industrial conditions.

As other fungucides, TCMTB based fungucides are also put under the scope for their environmental impacts. Limitations to their usage and concentrations in leather are discussed. In order to continue using TCMTB-based fungicides in the leather industry, studies on optimizing the usage amounts and developing fungicides with high TCMTB binding ability should be developed.

ACKNOWLEDGEMENTS

The authors wish to acknowledge to Odak Chemical Ltd for supplying fungicides, to Zenith Industrial Chemicals Ltd for conducting tropical chamber tests and to Turkish Prime Ministry State Planning Organization (Project Number: 2007-DPT-001) for their support of instrumental analysis devices.

REFERENCES

[1] D. L. Dalton, "*Green fungicide technologies*", in International Leather Maker, May-June 2015, [Online], Available: https://internationalleathermaker.com/news/fullstory.php/aid/1984/Zenith_pioneers_green_leather_fungicides.html

[2] TFL, "*Restricted substances in leather*" [Online], Available: https://www.tfl.com/media/03-tfl.com-and-intranet/salesfolder/sf_tfl_eco_tec_restricted_substances_in_leather_glo_en.pdf

[3] United States Environmental Protection Agency, "*Reregistration Eligibility Decision for 2-(Thiocyanomethylthio)- benzothiazole (TCMTB)*", EPA739-R-05-003, 2006.

[4] I. I. Bucişcanu, "*Ecolabels for leather and leather products*", Annals of the University of Oradea Fascicle of Textiles, Leatherwork, p:149-154, 2017.

[5] Blue Angel The German Ecolabel, "Basic Award Criteria, Leather", [Online], Available: https://produktinfo.blauer-engel.de/uploads/criteriafile/en/DE-UZ%20148-201503-en%20criteria.pdf

[6] J. Font, M. Reyes, S. Cuadros, A. Bacardit, A. Marsal, "Determination of TCMTB and other fungicides in leather", Journal of American Leather Chemists Association, p:341-348, 2011.

[7]ASTMD 4576 – 86 (Reapproved 1996), "*Standard Test Method for Mold Growth Resistance of Blue Stock (Leather)*".

[8] ASTM D3273 – 00, "*Standard Test Method for Resistance to Growth of Mold on the Surface of Interior Coatings in an Environmental Chamber*"

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

INNOVATIVE CLEANER PRODUCTION TECHNOLOGIES AND TREATMENT OF SEGREGATED STREAMS FOR RECOVERY OF QUALITY SALT & WATER FOR REUSE

Dr. S. RAJAMANI

Chairman-Asian International Union of Environment (AIUE) Commission,
Chennai-600028, India, Mobile: +91 9840063210, E-mail: dr.s.rajamani@gmail.com

Abstract: *The conventional treatment system adopted by Indian and Global Tanneries consist of (i) Segregation of Spent Chrome Stream and discharge of supernatant for combined treatment along with effluent from all sectional operations starting from soaking to finishing, (ii) Conventional physiochemical and biological treatment for reduction of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), etc., (iii) Ultra-filtration and Reverse Osmosis (RO) system for recovery of water and Multiple Effect Evaporator (MEE) for the evaporation of RO reject stream and generation of mixed salt in case of Zero Liquid Discharge (ZLD) system and (iv) Storage of mixed salt recovered from the MEE system for which no viable disposal system is found.*

Establishment of treatment system for the mixed stream results in poor performance of biological treatment units, increases the O&M cost, and accumulation of recovered mixed salt in case of ZLD system. It is estimated that, more than 8-10 tons of mixed salt is generated during the treatment of 1.0 MLD effluent under ZLD system. To address this serious environmental problem, an innovative approach of segregation of saline streams such as soak liquor and chrome liquor are planned to be collected separately with the feasibility of recovering reusable quality salt and chromium in the form cake for regeneration and use in the form of Basic Chromium Sulphate (BCS) by the tanneries. This innovative treatment concept has been developed and is being implemented in many CETPs in India. This will become the first of its kind in Global Leather World. This developmental scheme is in accordance with the guidelines and recommendations of UNIDO in terms of sustainability of ZLD system for the leather sector.

The technological developments on cleaner productions, centralized chrome recovery reuse system, segregation of saline soak water for separate treatment with recovery of water and quality salt are dealt in this technical paper.

Keywords: *Combined Treatment, Segregation of saline stream, Chromium, Quality water, ZLD.*

1. INTRODUCTION

The tanneries in World Leather Sector process about 17million tones of hides & skins per year. Only less than 20% of fresh hides and skins are processed without applying salt and more than 8-10million tones of salt mainly in the form of sodium chloride is applied for curing. They are transported, stored, and processed in a period of 2-6 months. The entire salt applied is discharged as waste in the effluent as dissolved solids, causes environmental challenges due to increase in salinity and depletion of quality water resources, etc.

With a view address the environmental challenges, technological developments such as (i) Segregation of Spent chrome stream and adoption of improved chrome recovery system by recovering chromium in the form of cake, (ii) Advanced process control and cleaner production, (iii) Segregation of saline stream with high TDS around 20000mg/L from soak liquor, separate treatment and recovery of quality salt and water for reuse by adopting ZLD system[1], (iv) Improved biological treatment system with mild chemical usage for reduced sludge generation, (iv) Advanced tertiary treatment systems, etc. for the application of single or multiple stage Reverse Osmosis (RO) system for recovery of water. Recent applied R&D on sustainable development in cleaner leather

production, environmental protection techniques with focus on saving energy and chemical by converting the physiochemical treatment into total biological treatment, water-recovery for reuse, quality salt recovery for reuse, etc. are detailed in this technical paper.

2. SEGREGATION OF STREAMS AND SEPARATE TREATMENT FOR RECOVERY OF CHROME, QUALITY SALT AND WATER

Due to the inherent quality of industrial wastewater such as textile dyeing units, tanneries etc., the conventional treatment plants are unable to meet the prescribed TDS level of 2100 mg/l in the treated effluent. In addition to TDS management the control of volatile solids in hazardous category sludge is also becoming a necessity. For control of salinity, chromium, sludge and viable management of TDS with the recovery of quality water from wastewater, the required treatment steps are (i) Cleaner production and other viable process control in tanneries[2], (ii) Segregation of streams such as saline soak liquor, spent chrome liquor for separate treatment, recovery of chromium, Sodium chloride salt and quality water for reuse, (iii) Upgradation of biological treatment systems with better efficiency in BOD and COD removal, (iv) Minimum usage of chemicals in the treatment process and reduction in sludge generation, (v) Reduction in TDS level in the mixed stream and (vi) Tertiary treatment of the low saline mixed stream and integration of treated tannery effluent with treated domestic sewage wherever feasible for TDS management[3].

The availability of domestic sewage is limited in many locations for dilution/mixing with treated tannery effluent for TDS management. The viable plan of segregation of soak liquor, separate treatment, and recovery of quality salt will be helpful in reduce the TDS level in the mixed stream and scope for adoption of dilution / mixing with available treated domestic sewage.

The segregated soak liquor is taken to the CETPs through separate pipe line and after primary and secondary treatment units, the membrane system is adopted for recovery of water and quality of saline stream for reuse in pickling. The balance treated saline stream is evaporated and quality salt (98% purity) is recovered for reuse without any difficulty. In addition to recovery and reuse of quality water by the industry, the additional benefits are savings in chemical usage in the tanning process and reduction in pollution load in the effluent.

The segregated chrome stream is taken for Centralized Chrome Recovery System (CCRS) for recovery of chromium in the form of chromium cake. In the improved chrome recovery system, the time required in the chrome recovery process is reduced from 16 hrs to less than 8 hrs. By avoiding the soak stream and supernatant from the CCRS to the main composite stream, the TDS level will be reduced from the level of about 15000mg/l to 8000mg/l.

The process flow diagram of segregation and collection of three streams viz. (i) Saline Soak liquor, (ii) Spent Chrome liquor and (ii) Composite stream with low TDS and separate treatment is shown below:

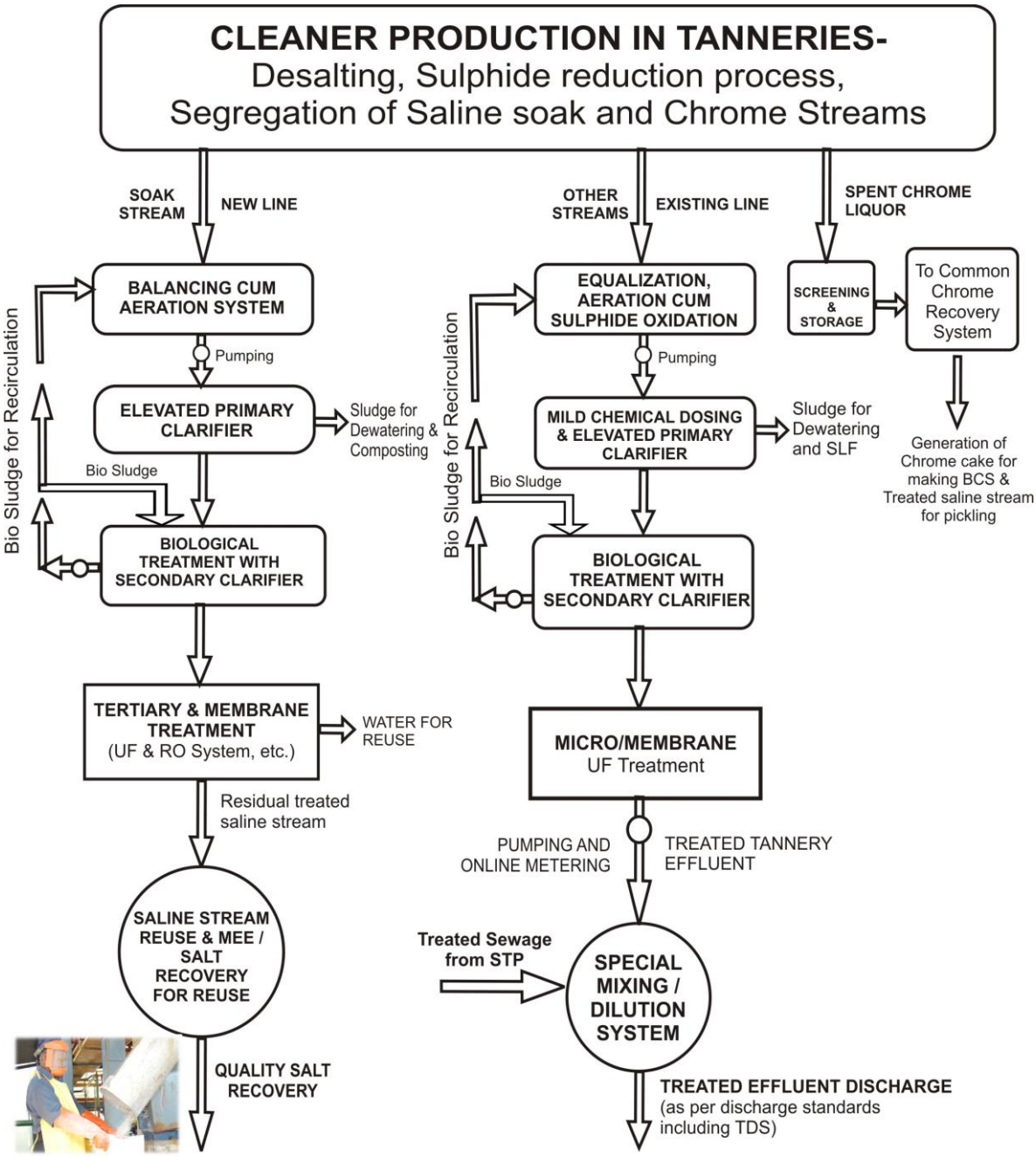


Fig.1: *Segregation and treatment process of Soak saline stream, Spent chrome stream and Composite low saline stream*

3. SUSTAINABLE CLEANER PRODUCTION AND EFFLUENT TREATMENT

Due to the segregation of soak liquor and chrome stream for separate treatment and reuse, the TDS level in the main combined stream taken to the CETP is reduced by 50% and it has become viable to convert the entire CETP to the total biological treatment system and scope for mixing the treated effluent with treated domestic sewage for overall TDS management and disposal by meeting all the discharge parameters without the necessity of multiple stage evaporator for the mixed stream with low TDS.

4. INTEGRATION OF EQUALIZATION CUM MIXING SYSTEM WITH BIOLOGICAL TREATMENT FOR SULPHIDE OXIDATION

The effluent is collected in equalization cum mixing system, pumped to the primary clarifier, mixed with high dosing of chemicals such as lime alum, etc. The conventional system adopted in most of the CETPs in India could not reduce the sulphide level in the physiochemical treatment and the sludge accumulation in the equalization tank is one of the major problems. The COD reduction to the prescribed level (i.e. 250mg/l) in the final treated effluent could not be met by some of the CETPs adopting conventional physicochemical and biological treatment. The performances of the aerobic biological treatment system with limited detention time are not satisfactory and unable to produce the required quality effluent.

With a view to oxidize the sulphide present in the effluent, control the sludge settling in the equalization tank and to minimize the chemical usage the equalization system has been upgraded with increased detention time, increased depth and usage of new type of aspirators integrated with a compressor. The residual excess biosludge from the secondary clarifier is pumped to the equalization tank which is helpful in biological oxidation process and to reduce the chemical dosage in the first stage clarifier [4]. The upgradation of equalization cum mixing system into aerobic biological oxidation using residual/excess biosludge and adopted in one of the CETPs in India is shown below:

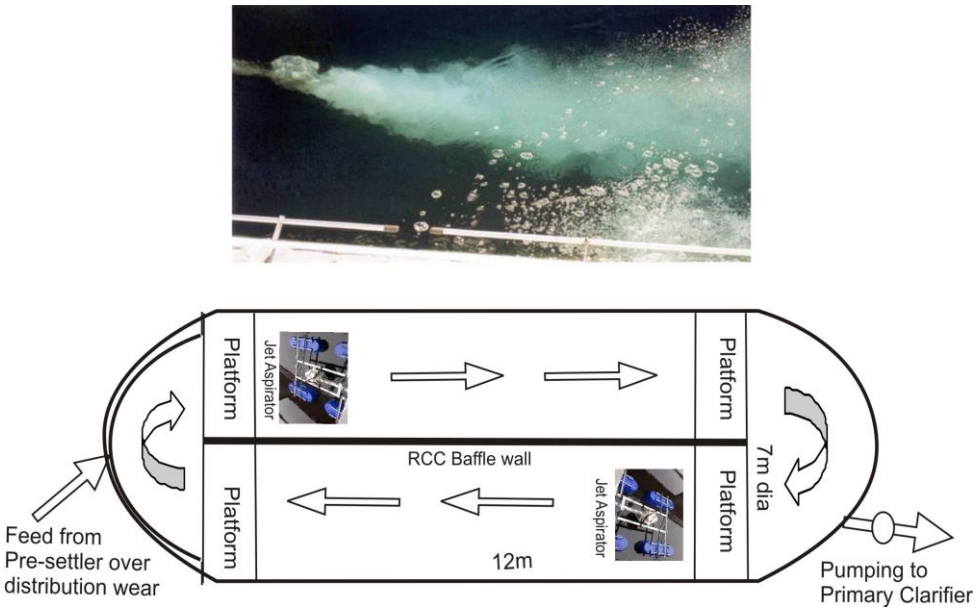


Fig.2: *Improved Collection cum Equalization cum Sulphide Oxidation System*

The primary clarifier units are also upgraded by providing elevated clarifiers with minimum required chemical dosing. This improved system is performing better in terms of sludge settling, withdrawal, and dewatering.

The improved aeration system with jet aspirator has been successfully adopted in many CETPs in Tamilnadu and proposed to be implemented in more CETPs. The sustainable alternatives to the total ZLD system for a single combined stream have been developed and are being introduced in upgradation of CETPs in Uttar Pradesh and other States[5]. It is also estimated that nearly 80% capacity of the wastewater from the Indian Leather Sector will be treated by adopting cleaner technologies, segregation of streams and separate treatment, integration with treated domestic sewage, etc. In this circumstance for long term sustainability of the CETPs which adopted ZLD for single combined streams, the concept of separate treatment of saline streams with recovery of quality reusable salt, cleaner productions, etc. may have to be followed. UNIDO in its recent technical publications on environment and effluent treatment for the World Leather sector clarifies the limitations of ZLD system and emphasizes the segregated stream treatment aspects[6].

5. CONCLUSION

The conventional effluent treatment systems are being upgraded by segregating the saline soak stream with separate treatment, adoption of UF & RO, and Multiple Effect Evaporators (MEE) with recovery of quality salt for reuse. About 200kg of quality salt (sodium chloride) is recovered from the effluent discharged during the process of each & every tone of hides & skins. The physiochemical treatment is converted into a total biological treatment system to reduce sludge generation by 50%, achieving the pollution control discharge standards and clarity in treated effluent. Upgradation of CETPs with Improved Cleaner Production Process, Centralized Chrome Recovery and Reuse systems, Integrated treatment with treated domestic sewage for sustainable TDS management with financial support from National and International organizations in India and other countries. These technological developments and upgradation of CETPs are being implemented in many locations covering more than 700 tanneries in India with a financial outlay of more than 150 million US dollars.

ACKNOWLEDGEMENT

Contributions of National Mission for Clean Ganga (NMCG), Department for Promotion of Industry and Internal Trade (DPIIT), National Green Tribunal (NGT), Banthar Industrial Pollution Control Company (BIPCC), Unnao Tanneries Pollution Control Company (UTPCC), IL&FS Cluster Development Company, Asian International Union Environment (AIUE) Commission, Asian International Forum and others commission members from various countries, IULTCS, UNIDO, European Union including Italy, Spain, Netherlands and other countries such as China, Romania, Turkey, and Russian Federation, New Zealand are acknowledged. Leather Industry Associations and Common Effluent Treatment Plants (CETP) specifically Pallavaram, Dindigul, Madhavaram, Jajmau CETPs in India are acknowledged.

REFERENCES

[1] S.Rajamani, *Sustainable ZLD System by Adopting Centralized Treatment of Segregated Streams for Recovery of Reusable Quality Chemical, Salt & Water – First of its kind in India & Asia* – Article published in Leather News India Journal, 2020.

[2] S.Rajamani , *Innovative Technologies on Cleaner Production and Waste Management in Tanneries* – Paper presented in International Leather Engineering Congress Innovative Aspects for Leather Industry, Izmir, Turkey, 2019.

[3] S.Rajamani , *Sustainable Environmental Technologies Integrated with Cleaner Production – Recent developments in World Leather Sector* – Paper presented in XIVth International Scientific-Practical Conference, Ulan-Ude, Russia, 2018.

[4] S.Rajamani , *Innovative Environmental Technologies including Water Recovery for Reuse from Tannery and Industrial Wastewater - Indian and Asian Scenario*, Paper presented in 6th International Conference on Advanced Materials and Systems (ICAMS 2016), Bucharest, Romania, 2016.

[5] S. Rajamani , *Noval Industrial Wastewater Treatment Integrated with Recovery of Water and Salt under Zero Liquid Discharge Concept,* Paper presented in The Pacific Basin Consortium for Environment and Health, University of Indonesia, City of Depok, West Java, 2015.

[6] S. Rajamani , *Growth of Leather Sector and Recent Environmental Development in Asian Countries,* Paper presented in 10th Asian International Conference on Leather Science & Technology, Okayama, Japan, 2014.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

ASPECTS REGARDING THE DESIGN OF THE TECHNOLOGICAL PROCESS FOR MAKING THE UPPER SHOE ASSEMBLY

SECAN Cristina[1]

[1] University of Oradea, Faculty of Energy Engineering, Department of Textiles-Leather and Industrial Management, B.St.Delavrancea str., No. 4, 410087, Oradea, Romania

Corresponding author: Cristina SECAN, E-mail: cris_secan@yahoo.com

Abstract: *This paper presents the technological process of manufacturing a men sports shoe product, in the IL system. The paper begins with the presentation of the technological process of manufacturing the product as an assembly, followed by detailing in a case study the specific operations, but also the common ones, which are carried out during the process. In the case of this model, the order of operation of the technological process is given by the method of joining the top with the upper but also by the type of the linings.*
The technological process presents the method of assembling the component parts of the upper assembly, the equipment used, the time norm and the production norm. In conclusion, we can say that a special role in obtaining a production both qualitative and quantitative represents the way the production is organized, the maintenance of the machines, the optimal use of the production capacity, so as to ensure a continuous flow of production. The production launch is made according to the adopted manufacturing program, and this is done in correlation with the production capacity and the quantity of the finished product that will reach the beneficiary.

Key words: footwear, cutting, technological process, operation, flux

1. INTRODUCTION

The technological process of making a shoe product is structured, for the classic technologies, on three distinct segments: cutting of component parts, processing and assembling them and finishing the products.

The technological peculiarities, for a particular product depend on the confectining system adopted, the existing technical endowment and the technological characteristics of the product to be made [1].

The design of the technological process of processing and assembling the component parts of the upper assembly (upper parts and linings) is of particular importance in the manufacture of footwear products, which subsequently combines with the lower assembly, resulting in the finished product [2-3].

In the technological process, the order of the stitching operations of the parts of the faces and linings is imposed by the model variant and the way of combining the faces with the linings [4].

The paper highlights another form of presentation of the technological process in the preparation-sewing workshop. Thus, the component parts of the product and the processing-assembly of parts are presented. This presentation is very useful for the practical realization of the prototype. When making the drawings the Autocad program was used.

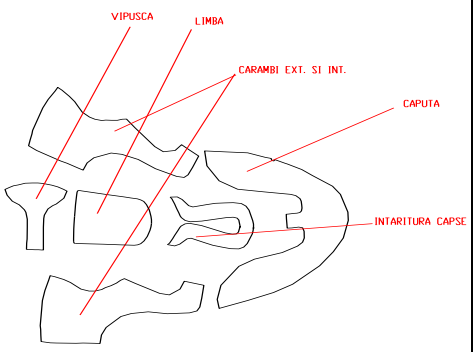
2. CASE STUDY:

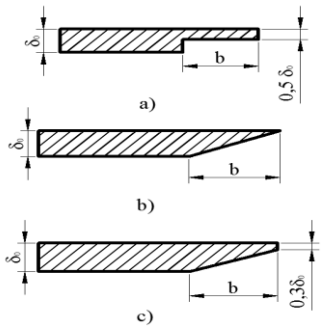
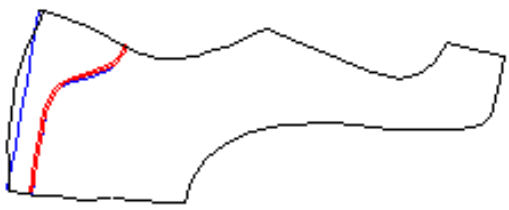
In the present paper, we present the design of the technological process of processing - sewing for a sports shoe type product for men, in IL system, made of natural leather în the front part combined with corrected front and outer linings out of lining leather, fig.1

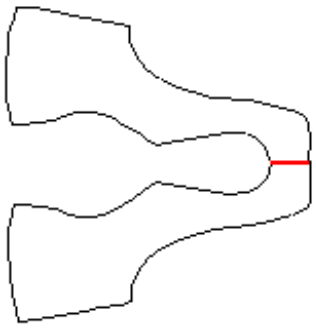
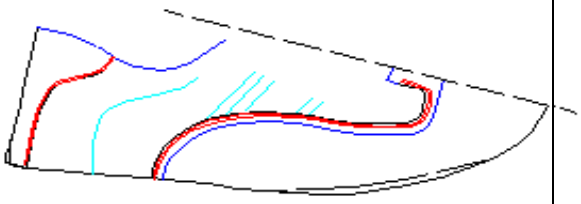
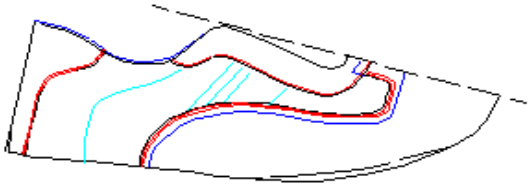
Fig. 1: *Men's shoe*

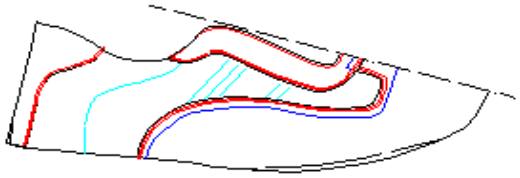
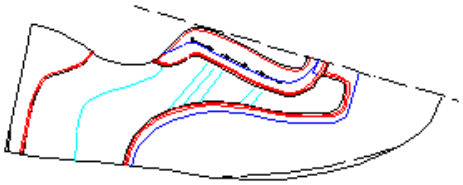
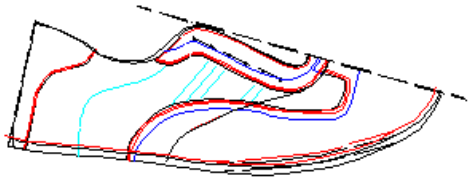
Thus, within the technological process of processing - assembling the upper apart of the product, it is presented the method of assembling the component parts with all the operations[5,6] that the component parts of this assembly contain, the execution mode of the operation [7], the equipment used, the time and production norms. The time norm consists of the preparation-closing time, the operative time, the service time at the workplace and the time of regulated interruptions. These times were practically determined by timing the manufacturing process, throughout its development.The production norm will be calculated on the basis of the time norm, taking into account the fact that it represents the quantity of products realized in a working shift.

Table 1: Presentation of the technological process

	Name of the operation	Mode of operation	N_T [min*om/per]	N_P [min*om/per]
1.	Tailoring the uppers parts: top, leggings, tongue, braid, staples and padding reinforcement	-lmechanic: electro-hydraulic punching tool with folding arm 	2.981	161.01
2.	Equalizing the marks of the uppers and the lining	-mechanic: flexible marks equalizing sewing machine	0.8	600

3.	Thinning the margings of the marks	-mechanic: flexible marks equalizing sewing machine  a) – right thinning b) – oblique thinning up to zero size c) – oblique thinning up to finite size.	1.64	293
4.	Sewing the lining	-mechanic: sewing machine with flat table 	1.4	342
5.	Sewing the ornament on the legging	-mechanic: sewing machine with flat table 	2.98	161
6.	Sewing the heel counter stiffener on the legging	-mechanic: sewing machine with flat table 	2.2	280
7.	Sewing the legging at the back	-mechanic: sewing machine with flat table	1.1	436

8.	Sewing the legging at the front	--mechanic: sewing machine with flat table 	0.3	1600
9.	Sewing the top on the legging	-mechanic: pillar type sewing machine 	2.20	218
10.	Sewing the tongue with lining	-mechanic: sewing machine with flat table 	0.78	615
11.	Greasing and lining the tongue	- manual: working table	0.6	800
12.	Sewing the tongue all around	-mechanic: sewing machine with flat table	0.5	960
13.	Cutting all the surplus lining	-mechanical: spare cleaning machine	0.,8	600
14.	Sewing the staple reinforcement on the upper parts	-mechanic: pillar type sewing machine with 2 threads 	1.4	342
15	Sewing the upper parts with lining	-mechanic: pillar type sewing machine	1,5	320
16.	Greasing and lining the	--manual: working table	1,5	320

	uppers			
17.	Sewing all around the uppers	-mechanic: pillar type sewing machine 	2,5	192
18.	Cutting the surplus lining	-mechanical: spare cleaning machine	1,3	369
19.	Applying the toecap	-mechanical: machine to apply thermo-adhesive toecap	0,8	600
20.	Greainsg and lining the top	-manual: working table	1	480
21.	Perforating the tops for shoe lacing	-mechanic: machine for perforating and encasing staples 	0.8	600
22.	Shoe lacing with rope of the tops	-manual: working table	0.5	960
23.	Preforming the semi-finished product in the heel counter stiffener area	-mechanic: punching machine for the heel counter stiffener	1.5	320
24.	Sewing the uppers in the pulling reserve area	-mechanic: simple pillar type sewing machine 	1.4	342
25.	Removing the ends of threads and cleaning the semi-finished product	-manual: working table	1.57	305
26.	Control, transport of errans in the regrouping warehouse	-manual: working table	1.5	320

3. CONCLUSIONS

In order to obtain a quantitative but also qualitative production, we must consider the organization of the workplace.Thus the sewing machines must be in good working condition, being maintained regularly by lubrication on time and by cleaning.The work place must be supplied with needles and thread depending on the color of the upper parts and the thickness of the material. The

lighting of the workplace is particularly important and must be ensured both by controlling the illuminator but also by replacing them.

In the production units, in order to obtain an optimum quantity of the products, the following will be taken into account: optimal use of the production capacity, launch of the flow production within the manufacturing programs and errands, ensuring the match between the size of the program and the volume of production on the shift, etc.

4. REFERENCES

[1]. Harnagea, F. (2002). *Tehnologia articolelor de marochinărie*, Editura Performantica, Iaşi.

[2]. Secan C, Dorsonszky L. (2011). *Lucrări practice şi de proiect la disciplina ''Procese de fabricaţie în pielărie''*, Editura Universităţii din Oradea, ISBN 978-606-10-0525-3.

[3]. Secan C.,Harnagea F. (2013). *Aspects of the technological process of manufacturing-sewing a footwear product for women, type shoe,* Annals of the Oradea University,"Fascicle of Textile - Leatherwork", The International scientific conference, "Innovative solutions for sustainable development of textiles industry", vol XIV, Ed.Universităţii din Oradea, ISSN 1843-813X, pp 99.

[4]. Secan C., Dorsonszky L. (2014)**.** *Aspects regarding the setting of time standards for the production and sewing operations* , Annals of the Oradea University,"Fascicle of Textile - Leatherwork", The International scientific conference, "Innovative solutions for sustainable development of textiles industry", vol XV, Ed.Universităţii din Oradea, ISSN 1843-813X, pp 151.

[5]. Volocariu S. R. (1999). *Procese de fabricaţie în industria produselor din piele şi înlocuitori*, Editura Gh. Asachi, Iaşi.

[6]. Volocariu R. S., Mărcuş L. (2007). *Îndrumar de laborator pentru procese de fabricaţie în industria confecţiilor din piele*, Editura Pim, Iaşi.

[7].Croitoru D. F. (1987). *Utilaje şi automatizări pentru industria confecţiilor din piele şi înlocuitori,* Rotaprint I.P.Iaşi.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

NEW LUBRICATING NATURAL POLYMER FOR WATER-REPELLENT UPPER LEATHER PRODUCTION

YORGANCIOGLU Ali[1], ONEM Ersin[1]

[1] Department of Leather Engineering, Faculty of Engineering, Ege University, 35100 Bornova-Izmir, Turkey,
E-Mail: ali.yorgancioglu@ege.edu.tr, ersin.onem@ege.edu.tr

Corresponding author: Yorgancioglu Ali, E-Mail: ali.yorgancioglu@ege.edu.tr

Abstract: *In this study, collagen hydrolysate from bovine shaving wastes of leather production with the alkali hydrolysis reaction was emulsified with amino functional silicone oils to prepare lubricating natural polymer (LNP). Particle size and zeta potential of the LNP were measured. Prepared LNP was used in the fatliquoring step of chromium tanned bovine leathers. Contact angle of the leather surfaces with water were employed to study hydrophobicity of treated leather. The water absorption behavior of leather was determined by dynamic water resistance (penetrometer test) and static water resistance tests (kubelka water up-take). Performance characterizations of leathers were carried out with tensile strength, tear strength, filling efficiency and water vapour permeability (WVP) analyses. The contact angle measurements showed that the hydrophilic property of leather surface decreased after LNP treatment. Both dynamic and static water absorption behaviour was lowered while the WVP of leathers was not significantly affected negatively except of 20% LNP. Only 20% LNP application slightly decreased the WVP of leathers. Moreover, new lubricating agent provided satisfactory strength performance and good filling effect on leathers.*

Key words: Leather, waterproof, collagen hydrolysate, lubricating agent, fatliquoring.

1. INTRODUCTION

The onset of the 21st century has marked great developments in technology and science. However, these developments have come with a price, one of which is aggravated global warming, leading to sudden climatic changes. In order to survive and be productive in such conditions, there is a need for appropriate apparel and shoes for people specifically working in outdoor environments. Waterproof products are engineered with the aim of protecting the wearer from weather conditions like wind, snow and rain as well as preventing excessive loss of body heat [1].

Under normal conditions, the leather has a natural fiber weave structure, so it absorbs water by absorbing certain amount of water. For this reason, leather products used especially in winter get wet when exposed to humid environment. The water absorption feature should be limited in order for the leather to maintain its strength and its shape. For these reasons, the water resistance properties of leathers under dynamic and static conditions are important for the protection of usage hygiene and physiology [2]. During its production, leather is hydrophobed in various ways to meet customer demands [3]. To achieve the required specifications, it is necessary to use an optimized combination of hydrophobic and hydrophilic components in the applications [4]. Lubricants used in leather production are one of the main factors in obtaining hydrophobic leather and reducing the water absorption of leather [5]. Since the production of hydrophobic leather is also done in an aqueous environment, the chemicals used must somehow be dissolved in water, that is, they must contain hydrophilic groups that are compatible with water. At the same time, the chemicals used

must have hydrophobic groups because we want to reduce the water absorption rate of the leather [6]. The lubrication emulsions are bounded to the skin with their reactive groups, allowing a certain amount of water to be absorbed into the skin. The oil-in-water emulsion is penetrated into the skin and takes the form of water-in-oil emulsion. The oils cover the leather fibers with a hydrophobic layer with very low surface tension. Water vapor can enter between the fibers; however, hydrophilic water droplets have high surface tension and do not spread to the hydrophobic fiber surface and only wet the inner surface [7]. For these purposes different types of oils, natural and petroleum derivative fatliquors are being used in fatliquoring process [8]. On the other hand, lubricating polymers are a good alternative to provide water-repellent properties to leather as well as their filling effect with softening and retanning features [9].

In recent years there has been an increasing interest in the design of natural polymers for various applications in many industries [10]. Gelatinous products are the subgroups obtained from collagen which is one of the most interesting degradable polymers [11]. Collagen hydrolysates are new forms yielded by hydrolysis of native collagen having lower molecular weight fragments than original structure and including a wide range of sub-categories with differentiated functionalities. Collagen hydrolysates as natural biopolymer exhibits superior properties such as higher enthalpy, the greater network structure of fibrils and strong reactive complex in the leather production [12].

In the present study, it was aimed to develop a novel lubricating emulsion with functional properties using for leather industry by evaluating the waste protein from leather wastes. Collagen hydrolysate emulsified with amino functional silicone oils was investigated for the water-repellent leather production on the way of sustainability of leather industry.

2. EXPERIMENTAL PART

2.1. Materials

In this study, collagen hydrolysate was obtained from low grade by-product of gelatin manufacturing process of bovine shaving wastes with the KOH hydrolysis reaction (Halavet Gelatin Company). Span 60 were purchased from Merck. Amino functional silicone oil was provided from United Chemicals Company, Turkey and LIPSOL LA was provided from Schill+Seilacher GmbH.

2.2. Emulsification with collagen hydrolysate

In the emulsion; amino functional silicone oil and Span 60 were mixed at 90 ^{o}C. At the same time collagen hydrolysates and water were heated in a separate vessel to about 50 ^{o}C. Then, the continuous phase was added to dispersion phase while mixing. After adding this mixture, emulsion was stirred for 4 h at 80 °C. pH of the emulsions have been adjusted to 6.5 during homogenization. At the end of the reaction time, the emulsion was cooled to room temperature.

2.3. Particle size of lubricating polymer

Particle size and zeta potential of emulsions were determined with a Malvern Zeta Sizer Nano ZS analyzer. For the analysis, sample were prepared as 0.1 mg/mL concentration by diluting with the ultrapure water. The measurement size range of the instrument was 0.1-10000 nm.

2.4. Application of lubricating natural polymer in fatliquoring process

The process recipe was given in Table 1. The total amount of lubricating natural polymer (given as * in Tables) was 10%, 15%, 20% used in the recipe. For comparison, the one piece was treated with lubricating agent and the other piece was not.

Table 1: *Leather production recipe*

Process	%	Chemicals	Temperature	Time	Remarks
Neutralization	100	Water	30 °C		
	1	Sodium formate		30 min	
	1	Sodium bicarbonate		60 min	pH:5, drain
Washing x 3	200	Water	30 °C	10 min	Drain
Fatliquoring- Dyeing	100	Water	40 °C		
	4	Lipsol LA (modified lecithin)	55 °C		
	*	LNP		90 min	
	2	Dyeing auxiliary		30 min	
	4	Dye		60 min	
	2.5	Formic acid		60 min	pH:4.1,drain
Washing-Drying					

2.5. Determination of water-repellence properties

Keyence VHX-1000 digital microscope was used to measure the water contact angles on leather. A droplet of deionized water (0.3 ul) was dripped on the leather surface. In order to demonstrate the water-repellent properties of leathers, the dynamic water resistance of the leathers was examined using the Bally Penetrometer 5316 test device according to TS 8541 EN ISO 5403 standard. Determination of the static water absorption of leathers was carried out in the kubelka apparatus according to the TS 4123 EN ISO 2417 method. The amount of water absorbed during immersion of leathers was determined at the end of 30 minutes, 1 hour and 24 hours.

2.6. Pyhsical properties of leather treated with lubricating protein filler

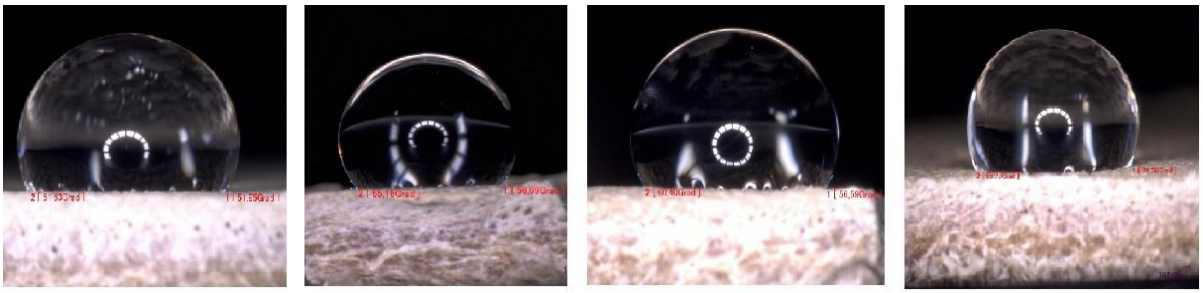
Prior to the tests all leathers were conditioned according to the standard of EN ISO 2419:2012. The tensile strength and tear strength properties of leather was determined according to the standards of TS 4119 EN ISO 3376:2011 and TS 4118-2 EN ISO 3377-2. For the tests, the measurement of the thickness of the samples was performed in accordance with EN ISO 2589:2002. The water vapor permeability analysis was carried out with the Satra STM 473 test device as specified in TS EN ISO 14268. The method was performed in a conditioning room with 20±2 °C temperature and 65±2% relative humidity. The results were calculated in milligrams of water vapor per square centimeter (mg/cm^2.h) according to the formula WVP= m/πr^2.h.

3. RESULTS AND DISCUSSION

Average particle size and zeta potential are important parameters in assessing the stability of emulsions and determining the lubrication efficiency in leather production. As the particle size of the emulsions decreases, there is more surface area in the unit volume of the fatliquors. The increase in the surface area promotes chemical reactions and increases the binding of the fatliquor. If their size exceeds the size of the pores of the leather, their penetration into the leather would become difficult [13]. The average particle size of the emulsion was 1285.3 nm with high stability (ζ= -49.3 mV). During collagen production, a few microfibrils form a fibril with a diameter of 0.2-0.5 μm. Together with the fibrils, a 3 μm diameter collagen strand is formed [14]. When the particle sizes of the emulsions were examined, it was thought that emulsion would penetrate into the collagen matrix.

Contact angle measurement helps in deriving the wettability of the surface. The higher the angle between the surface and water, the higher the water resistance and the lower the wettability. It was observed that the drop of water would seep into the control leather in 5-10 seconds. Hence it was very difficult to measure the contact angle, control leather showed 51.63 contact angle. As

shown Fig. 1, after the application of the LNP there was significant increase in the contact angle of the treated leather as 55.16, 60.40 and 67.93, respectively.



(A) (B) (C) (D)

Fig. 1. *The contact angle results of leather: (A) control; (B) 10% LNP; (C) 15% LNP; (D) 20% LNP*

Water repellence properties are achieved by repellent lubricating natural polymer with reducing the free energy at fibre surface. If the adhesive forces between a fibre and a liquid drop are greater than internal cohesive forces in between the liquids, the drop will spread. However, if the adhesive forces between a fibre and liquid drop are less than internal cohesive forces in between the liquids, the drop will not spread [15].

Determination of water resistance properties in dynamic conditions is vital for determining the water absorption properties of leather goods, especially for an out-door walking shoes during usage because the mechanical action during measurement simulates the mechanical action during walking in water. Dynamic and static water absorption of leathers were given in Table 2.

Table 2: *Dynamic and static water absorption behaviour of leathers*

Leather samples	Dynamic water absorption (%)	Static water absorption (%) in 30 minutes	Static water absorption (%) in 60 minutes	Static water absorption (%) in 24 hour
Control	152.1	122.4	131.3	135.32
10% LNP treated	101.4	67.75	87.77	89.52
15% LNP treated	73.03	48.11	57.84	74.19
20% LNP treated	56.24	22.14	33.65	57.97

With the increase in the ratio of LNP used in leather production, it is seen that the water absorption characteristics of leathers decreased significantly under dynamic conditions. While the water absorption rates of the control group samples were given as 152.1%, it was observed that this ratio decreased to 56.24% in the leather treated with 20% LNP.

A significant decrease in static water absorption was observed for the experimental leathers after 10, 15 and 20 percent of LNP treatment. Whithout LNP application in control groups, static water absorption ratios were 122.4, 131.3 and 135.32 with the increased duration (30 min to 24 h), respectively. On the other hand, the ratios decreased from 122.4 to 22.14, from 131.3 to 33.65 and from 135.32 to 57.97 after 20% LNP treatment. Furthermore, decreases in absorptions were almost two times more when LNP treatments increased from 10% to 20% for 30 min and 60 min applications. Decreases were comparatively slower when the time reached to 24 h.

Various physical analyses of the leathers were carried out as per standard method. Analyses results were presented in Table 3.

Table 3: *Properties of leather treated with lubricating natural polymer*

Leather samples	Tensile strength (N/mm^2)	Tear strength (N)	Filling coefficiency (%)	Water vapour permeability ($mg/cm^2.h$)
Control	17.82	83.21	3.13	12.46
10% LNP treated	20.26	92.13	8.27	12.24
15% LNP treated	22.97	107.24	12.31	11.78
20% LNP treated	23.42	122.28	14.14	9.56

From the results given in Table 3, it can be seen that mechanical properties of leathers treated by LNP were higher than control groups. It was observed that the increase in the tensile strength of the leather with the increase of the emulsion in the process. The strength value was observed in control group as 17.82 N/mm^2, while the highest strength value was obtained in leathers treated with 20% emulsion with 23.42 N/mm^2. When the tear strength results were examined, there was a significant increase from 83.21 N to 122.28 N. Moreover, LNP emulsion application improved the thickness of skin up to 14.14% when compared to control samples. In the leather production, chemicals with high nitrogen, carbon and amino acid content are highly demanded beacause of the forming crosslink between the leather fiber network [12]. When we evaluate the properties of the LNP, it was thought that collagen hydrolysates in the emulsion can make additional bond to the leather fibers which increase the mechanical properties and the thickness of the leather.

Water vapour permeability or breathability of the materials is one of the key factor in comfort properties of leather. The term “breathable” refers to the ability of materials to diffuse water vapour while preventing the penetration of water. It is important that the products help in passage of sweat from body to atmosphere. This is because, if a person is in a cold climate performing high activity wearing non-breathable clothing, he may suffer from hypothermia, and if he is in a hot, he may suffer from heat stress [16]. From Table 3, it was determined that the increase in the rate of LNP in the production slightly decreased the WVP. WVP and waterproofness are two contrasting abilities. WVP allows the flow of air and water vapour, while waterproof abilities restrict the transfer of water from outside to the inside, protecting the wearer from getting wet. It is therefore a challenge to develop materials that allow the transfer of water vapour from the inside of the materials to the outside and simultaneously restrict the passage of water from the outside to the inside [17]. When the results of the analyses are evaluated, it is determined that when using 20% LNP, the WVP rates of the leathers decreased by approximately 24% compared to control groups. However, it is thought that the significant reduction can be tolerated with the 15% of LNP treatment by providing a 5% decrease.

4. CONCLUSIONS

Demands for products that can impart hydrophobic qualities have increased greatly over the years as their application has become more prevalent in many industries. Water repellency and water vapour permeability of products used in outerwear are of major importance and influence to human comfort. This study focuses on the evaluation of collagen hydrolysates derived from solid tannery waste to produce lubricating natural polymer for processing of leather that would be both water repellent and breathable. Lubricating emulsions have shown that it can be used as a good waterproofing agent in leather production with ensuring lower water absorption rate brought to the leathers with minimal changing of the WVP. In accordance with the proteinic ingredients collagen hyrolysate was used as filler in lubricating agent in order to ensure fullness and some performance characteristics. This study may help to realize a clean, new, renewable leather chemical option from tannery solid waste as an alternative solution to current leather waterproof fatliquoring chemicals.

REFERENCES

[1] S. Kumar, "*Waterproof breathable textiles (WBT) market share, Growth to 2020*", 2015.

[2] B. Basaran, B. O. Bitlisli, A. Zengin, A. Aslan, "*The effect of shoe creams on dynamic water resistance and static water absorption characteristics of shoe upper leathers*", Ege Üniv. Ziraat Fak. Derg., vol. 40(2), pp. 145-151, 2003.

[3] R. M. Silva, V. V. Pinto, F. Freitas, M. J. Ferreira, "*Characterization of barrier effects in footwear*", In: Multifuctional Barries for Flexible Structures (S. Duquesne, C. Magniez, G. Camino, eds.), Springer, vol. 292, pp. 229–268, 2007.

[4] D. A. Holmes, "*Waterproof breathable fabrics*", In A. R. Horrocks & S. C. Anand (Eds.), Handbook of Technical Textiles, Boca Raton and Cambridge: Woodhead Publishing Ltd and CRC Press LLC, pp. 282-315, 2000.

[5] R. A. Palop, A. Marsal, "*Factors influencing the waterproofing behaviour of retanning-fatliquoring polymers-Part I*", Journal of the American Leather Chemists Association, vol. 99(10), pp. 409–415, 2004.

[6] A. Yorgancioglu, E. E. Bayramoglu, M. Renner, "*Preparation of antibacterial fatliquoring agents containing zinc oxide nanoparticles for leather industry*", The Journal of the American Leather Chemists Association, vol. 114(5), pp. 171-179, 2019.

[7] V. Jankauskaite, I. Jiyembetova, A. Gulbinienė, J. Širvaitytė, K. Beleška, V. Urbelis, "*Comparable evaluation of leather waterproofing behaviour upon hide quality. I. Influence of retanning and fatliqouring agents on leather structure and properties*", Materials Science, vol. 18, pp. 150-157, 2012.

[8] A. G. El A'mma, J. J. Hodder, G. J. Ward, "*Lubricating acrylic syntans. A review of the technology and practical applications*", Journal of the American Leather Chemists Association, vol. 91, pp. 237-245, 1996.

[9] A. Afsar, H. Ozgunay, O. Yilmaz, A. C. A. Zengin, G. Zengin, "*Applicability of lubricating acrilic syntans in vegetable tanned saddlery leathers*", Journal of Textiles and Engineer, vol. 20, pp. 21-27, 2013.

[10] A. Yorgancioglu, E. E. Bayramoglu, 2013, "*Production of cosmetic purpose collagen containing antimicrobial emulsion with certain essential oils*", Industrial Crops and Products, vol. 44, pp. 378-382, 2013.

[11] S. Scopel, C. Baldasso, A. Dettmer, R. Santana, "*Hydrolysis of chromium tanned leather waste: Turning waste into valuable materials – A review*", Journal of the American Leather Chemists Association, vol. 113, pp. 96-133, 2018.

[12] A. Aslan, G. Gulumser, "*Evaluation of chrome-tanned leather solid wastes as lubricating filler agents*", Tekstil ve Konfeksiyon, vol. 21, pp. 405-409, 2011.

[13] B. Sahu, B. Aravindhan, M. A. Javid, "*Application of calophyllum inophyllum oil as antifungal fat-liquor for leather industry*", Industrial Crops and Products, vol. 105, pp. 104-112, 2017.

[14] G. Reich, "*The structural changes of collagen during the leather making process*", Journal of the Society of Leather Technologists and Chemists, vol. 83, pp. 63-79, 1999.

[15] N. A. Patankar, "*On the modeling of hydrophobic contact angles on rough surfaces*", Langmuir, vol. 19, pp. 1249-1253, 2003.

[16] A. K. Sen, "*Coated textiles - Principals and applications*", (2 ed.). Boca Raton: CRC Press, Taylor & Francis Group, LLC, 2008.

[17] J. Fan, L. Hunter, "*Engineering apparel fabrics and garments*", Cambridge and Boca Raton: Woodhead Publishing Company and CRC Press LLC, 2009.

ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

CONTENTS

			[3] "Aurel Vlaicu" University of Arad, Faculty of Engineering, Department of Automation, Industrial, Textile and Transportation Engineering, Postal address, 310330, 2-4 Elena Dragoi Street, Arad, Romania	
5	**CHARACTERISATION OF CARBON TAILORED FIBRE PLACEMENT REINFORCED COMPOSITES**	**DOMENECH-PASTOR Jorge[1], GONGA Eloi[1], CAMPOS Juan[1], DIAZ-GARCÍA Pablo[2], GARCIA Daniel[3]**	[1] Asociación de Investigación de la Industria Textile – AITEX, Smart Textiles Research Group, Postal address, ES03801 Alcoy, Spain [2] Universitat Politècnica de València (UPV), Escuela Politécnica Superior de Alcoy, Ingeniería Textil y Papelera (DITEXPA), Plaza Ferrándiz y Carbonell 1, 03801, Alcoy, Spain [3] Universitat Politècnica de València (UPV), Escuela Politécnica Superior de Alcoy, Instituto de Tecnología de Materiales (ITM), Plaza Ferrándiz y Carbonell 1, 03801, Alcoy, Spain	**27**
6	**EVOLUTION AND SOCIAL NECESSITY ASPECTS IN FUNCTIONAL CLOTHING PRODUCTS**	**FLOREA-BURDUJA Elena[1,3], RARU Aliona[2,3], IROVAN Marcela[1], FARÎMA Daniela[3]**	[1] Technical University of Moldova, Faculty of Textile and Polygraphy, 4 Sergiu Radautan Street, Chisinau MD-2000, Republic of Moldova [2] Technical University of Moldova, Direction of Academic Management and Quality Assurance, 168 Stefan cel Mare Street, Chisinau MD-2000, Republic of Moldova [3] Gheorghe Asachi Technical University of Iasi, Faculty of Industrial Design and Business, 29 Mangeron Street, Iasi 700050, Romania	**33**
7	**EFFECT OF FULLERENES**	**GOCEK Ikilem[1],**	[1] Istanbul Technical	**37**

		Cornelia[1], IORDACHE Ovidiu[1], PERDUM[1] Elena	030508, Bucharest, Romania [2] Politehnica University of Bucharest, Faculty of Applied Chemistry and Materials Science, 1-7 Gheorghe Polizu Street, 011061, Bucharest, Romania	
12	**STUDY OF THE EFFECT OF THE CONCENTRATION OF HYDROTALCITE IN THE RECOVERY OF COLORANTS IN TEXTILE WASTEWATER**	**LÓPEZ Daniel [1], MICÓ-VICENT Bàrbara [2,3], BONET-ARACIL Mariles [1], BOU-BELDA Eva [1]**	Universitat Politècnica de València, epartamento de Ingeniería Textil y Papelera, Plaza Ferrándiz y Carbonell s/n, Alcoi, Spain [2]Universitat Politècnica de València, Departamento de Estadística e Investigación Operativa Aplicadas y Calidad, Plaza Ferrándiz y Carbonell s/n, Alcoi, Spain [3] Departamento Óptica Farmacología y Anatomía, Universidad de Alicante Carretera de San Vicente del Raspeig s/n, Spain	**61**
13	**INVESTIGATION OF THE BENDING BEHAVIOUR OF WOVEN SPACER FABRICS**	**SADOUGHI Mahlagha[1], ASAYESH Azita[2], EZAZSHAHABI Nazanin[3], HAMZEH Saeed[4]**	[1, 2, 3,4] Amirkabir University of Technology, Textile Engineering Faculty, 424 Hafez Ave, 15875-4413, Tehran, Iran	**65**
14	**RECONCEPTION OF WOMEN'S BLOUSE BASED ON FUNCTIONAL ANALYSIS**	**MALCOCI Marina[1], POPA Parascovia[2]**	[1, 2] Tehnical University of Moldova, Faculty of Textiles and Polygraphy, Bd. Ștefan cel Mare 168, Chișinău, R. of. Moldova	**71**
15	**EFFECT OF MISS STITCH ON THE TENSILE STRESS RELAXATIONOF RIB WEFT KNITTED FABRICS**	**MIRAKHORLI Sara ASAYESH Azita[2]**	[1, 2] Amirkabir University of Technology, Department of Textile Engineering, Textile Excellence & Research Centers, 424 Hafez Ave, 15875-4413, Tehran, Iran	**77**
16	**ANALYSIS OF THE EFFECT OF FABRIC STRUCTURE AND APPLIED VOLTAGE ON THE HEAT FLUX OF THE THREE-LAYER HEATING FABRICS**	**NAZEM BOUSHEHI Arash[1], EZAZSHAHABI Nazanin[2], AMANI TEHRAN Mohammad[3]**	[1, 2, 3] Amirkabir University of Technology, Textile Engineering Faculty, 424 Hafez Ave, 15875-4413, Tehran, Iran	**83**
17	**CALCULATING THREAD CONSUMPTION IN THE CASE OF ASSEMBLY BY SEWING OF ADHESIVE-BACKED MATERIALS**	**PORAV Viorica**	University of Oradea, Faculty of Energy Engineering and Industrial Management, Departement of Textiles Leather and	**89**

	ANALYSIS OF PRINTED ELECTRONICS THROUGH THE FLEXOGRAPHY TECHNIQUE ON TEXTILE SUBSTRATES	**CARBONELL Ana M[1], FERRI Josué[1], GARCIA-BREIJO Eduardo[2], BOU-BELDA Eva[3]**	(AITEX), Alcoy 03801, Spain [2] Universitat Politècnica de València, Instituto Interuniversitario de Investigación de Reconocimiento Molecular y Desarrollo Tecnológico (IDM), Valencia 46022, Spain [3] Universitat Politècnica de València, Department of Textile and Paper Engineering, Plaza Ferrándiz y Carbonell s/n. 03801, Alcoy. Spain	
23	**PRELIMINARY STUDY FROM RICE HUSK EXTRACTS TO FINISH TEXTILE FABRICS**	**SOLER Andrés[1], GISBERT-PAYÁ Jaime[1], MONTAVA Ignacio[1], BONET-ARACIL Marilés[1]**	[1] Departamento de Ingeniería Textil y Papelera, Universitat Politècnica de València Plaza Ferrándiz y Carbonell s/n, Alcoi, Spain	**117**
24	**USING ANFIS FOR MAINTENANCE PLANNING OF TEXTILE MACHINES**	**ŞUTEU Marius Darius[1], BABAN Marius[2], BABAN Calin Florin[2], DERECICHEI (ŢAP) Alexandra Paula[2]**	[1, 3] 1University of Oradea, Faculty of Energy Engineering and Industrial Management, Department Textiles, Leather and Industrial Management, 410058, Oradea, România [2] University of Oradea, Faculty of Managerial and Technological Engineering, Department Industrial Engineering, 410087, Oradea, România	**123**
25	**THE BEHAVIOUR OF RIB 1:1 AND 2:2 KNITTED COTTON FABRICS DURING DIFFERENT SOLICITATIONS AND TREATMENTS**	**SZABO Monica[1], DOCHIA Mihaela[2], GAVRILAŞ Simona[3]**	[1] "Aurel Vlaicu" University of Arad, Faculty of Engineering, Department of Automation, Industrial, Textile and Transportation Engineering, Postal address, 310330, 2-4 Elena Dragoi Street, Arad, Romania, [2] "Aurel Vlaicu" University of Arad, Research Development Innovation in Technical and Natural Science Institute, Postal address, 310330, 2-4 Elena Dragoi Street, Arad,	**127**

	THE DESIGN OF THE TECHNOLOGICAL PROCESS FOR MAKING THE UPPER SHOE ASSEMBLY		Faculty of Energy Engineering, Department of Textiles-Leather and Industrial Management, B.St.Delavrancea str., No. 4, 410087, Oradea, Romania	
31	**NEW LUBRICATING NATURAL POLYMER FOR WATER-REPELLENT UPPER LEATHER PRODUCTION**	**YORGANCIOGLU Ali[1], ONEM Ersin[1]**	[1] Department of Leather Engineering, Faculty of Engineering, Ege University, 35100 Bornova-Izmir, Turkey	**163**