VLÁKNA a TEXTIL

2

Volume **27.**
June
2020

FIBRES AND TEXTILES

STU FCHPT

TECHNICAL UNIVERSITY OF LIBEREC
Faculty of Textile Engineering

Trenčianska univerzita Alexandra Dubčeka v Trenčíne
Fakulta priemyselných technológií v Púchove

VÚCHV

VÚTCH CHEMITEX

Spoločnosť priemyselnej chémie ZSVTS

CHEMOSVIT FIBROCHEM

Indexed in:
SCOPUS
Chemical Abstracts
World Textiles

ISSN 1335-0617
print version

ISSN 2585-8890
online version

Fibres and Textiles
Vlákna a textil

Published by	***Vydáva***
Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology	Slovenská technická univerzita v Bratislave, Fakulta chemickej a potravinárskej technológie
Technical University of Liberec, Faculty of Textile Engineering	Technická univerzita v Liberci, Fakulta textilní
Alexander Dubček University of Trenčín, Faculty of Industrial Technologies	Trenčianska univerzita Alexandra Dubčeka v Trenčíne, Fakulta priemyselných technológií
Slovak Society of Industrial Chemistry, Bratislava	Slovenská spoločnosť priemyselnej chémie, Bratislava
Research Institute of Man-Made Fibres, JSC, Svit	Výskumný ústav chemických vlákien, a.s. Svit
VÚTCH – CHEMITEX, Ltd., Žilina	VÚTCH – CHEMITEX, spol. s r.o., Žilina
Chemosvit Fibrochem, JSC, Svit	Chemosvit Fibrochem, a.s., Svit

Editor in chief *(Šéfredaktor)*: Anna Ujhelyiová

Executive editor *(Výkonný redaktor)*: Marcela Hricová

http://www.vat.ft.tul.cz

Editorial office and distribution of the journal
(Redakcia a distribúcia časopisu)

Ústav prírodných a syntetických polymérov
Fakulta chemickej a potravinárskej technológie
Slovenská technická univerzita v Bratislave
Radlinského 9, 812 37 Bratislava, SK
Tel: 00 421 2 59 325 575
e-mail: marcela.hricova@stuba.sk

Order and advertisement of the journal
(Objednávka a inzercia časopisu)

Slovenská spoločnosť priemyselnej chémie,
člen Zväzu vedecko-technických spoločností
Radlinského 9, 812 37 Bratislava, SK
Tel: 00 421 2 59 325 575
e-mail: marcela.hricova@stuba.sk

Order of the journal from abroad – excepting Czech Republic
Objednávka časopisu zo zahraničia – okrem Českej Republiky

SLOVART G.T.G, s.r.o. EXPORT-IMPORT
Krupinská 4, P.O.Box 152, 852 99 Bratislava, SK
Tel: 00421 2 839 471-3, Fax: 00421 2 839 485
e-mail: info@slovart-gtg.sk

Typeset and printing *(Sadzba a tlač)*

FOART, s.r.o., Bratislava

Journal is published 4x per year
Subscription 60 EUR

Časopis vychádza 4x ročne
Ročné predplatné 60 EUR

Evidenčné číslo MKCR SR Bratislava EV 4006/10

IČO vydavateľa 00 397 687

Fibres and Textiles (2) 2020
Vlákna a textil (2) 2020
June 2020

Content

MATHEMATICAL MODELING OF THE THERMO-MECHANICAL FUSING PROCESS

Snezhina Angelova Andonova

Faculty of Engineering, South-West University "Neofit Rilski", 66 Ivan Mihailov Str., 2700 Blagoevgrad, Bulgaria

andonova_sn@swu.bg

Abstract: *Nowadays with the introduction of microprocessor systems and other ways of automation means the development of the industrial technologies has outstripped the scientific base of many technological processes in the sewing industry. Investigating and analyzing these processes helps to solve some theoretical problems of the automation. Such scientific researches contribute to reducing the cost characteristics of the machinery and the equipment used and to improving the quality of the sewing products. One major technological process in the sewing industry is the thermo-mechanical fusing (TMF). Manual performed operations or a set of them have been automated in the process of thermo-mechanical fusing. A number of automated systems have been created that ensure synchronization in the operation of the mechanisms of conducting the TMF process. However, the automatic process control (maintaining certain levels of factors for a certain time) is accomplished by pre-setting the technological mode (i.e., pre-entering the levels of these factors) by the technologist. This creates persecutes for influence of subjective factor on quality. Therefore, the choice of appropriate levels of factors should be made on a scientific basis. In the context of the foregoing, the purpose of the present work is to derive a mathematical model of the TMF process through research and analysis with the help of modern control and measuring equipment.*

Keywords: *mathematical modeling; thermo-mechanical fusing process.*

1 INTRODUCTION

Nowadays with the introduction of microprocessor systems and other automation means the development of the industrial technologies has outstripped the scientific base of many technological processes in the sewing industry. Investigating and analyzing these processes helps to solve some theoretical problems of automation [1]. Such scientific researches contribute for reducing the cost characteristics of the machinery and the equipment used and to improving the quality of the sewing products [2-4]. One major technological process in the sewing industry is the process of thermo-mechanical fusing (TMF). Manual performed operations or a set of them have been automated in the process of thermo-mechanical fusing. A number of automated systems have been created that ensure synchronization in the operation of the mechanisms for conducting the TMF process. However, the automatic process control (maintaining certain levels of factors for a certain time) is accomplished by pre-setting the technological mode (i.e., pre-entering the levels of these factors) by the technologist. This creates conditions for influence by the subjective factor on quality.

On the other hand, the intervals of possible values of the controllable /manageable/ factors in the TMF process are usually given by the manufacturers of the respective additional material /interlining/. It must be pointed out that these intervals are relatively wide. The choice of specific value for the respective factor is made by the operator of the machine or the technologist. This choice is made on the basis of numerous preliminary experiments and the experience and sense of the worker concerned. This also creates conditions for influence by the subjective factor on the quality and productivity of TMF.

Therefore, the choice of the appropriate levels of factors should be made on a scientific basis.

From the conducted study, it can be summarized that some investigations were made to determine the effect of individual parameters on the TMF process [5, 6]. However, the combined influence of the controllable factors, such as satisfying the quality and performance criteria, has not been sufficiently studied. This lag in the development of technology compared to the capabilities of automation is due to the fact that the technological process under consideration is very complex [7, 8]. Each of its stages proceeds according to different laws and depends on many factors. In addition, the TMF process runs by closed pressing plates, and the control and management of the condition of the processed textile materials (TM) leads to additional difficulties. Globally, many elite companies have conducted research in this area, but their studies are commercial or confidential.

In the context of the foregoing, the purpose of the present work is to derive a mathematical model of the TMF process through research and analysis with the help of modern control and measuring equipment.

Mathematical modeling has been applied in a number of scientific works [9-14]. In this way, the relevant problem is posed on a scientific basis. The derivation of a mathematical model creates the conditions for optimization of the studied process [15-17].

2 EXPERIMENTAL WORK

In order to achieve optimal quality indicators for TMF with energy and time saving, it is necessary to create a mathematical model of the function connecting the output parameter *Y* with the input factors *x*. This requires conducting experiments by varying of the factors studied. For the purpose of this study, an active experiment was used that was achieved through full factorial experiment (FFE) [9, 10].

2.1 Methods

To formulate the conditions and methods for conducting the experiment, principles of the morphological method for analysis and synthesis of methods are applied [18].

The FFE method is used because it realizes all possible combinations on two levels of the factors. The number of these combinations for *n* factors is *N*:

$$N = 2^n \tag{1}$$

For FFE, the expected mathematical model is [9, 10]:

$$Y_C = b_o + \sum_{i=1}^{N} b_i x_i + \sum_{i \le j}^{C_n^2} b_{ij} x_i x_j + \sum_{i \le j \le k}^{C_n^3} b_{ijk} x_i x_j x_k \ldots + b_{123\ldots n} x_1 x_2 x_{3\ldots n} \tag{2}$$

where: Y_C - the calculated output parameter, b_i - regression coefficients; x_i - factors.

The main elements that are determined according to the methodology for compiling a mathematical model through FFE [9, 10] are:

- determination the variance of the output parameter for each test according to (2):

$$S_j^2(Y) = \frac{1}{m-1} \sum_{u=1}^{m} \left(Y_{ju} - \overline{Y}_j \right)^2 \tag{3}$$

where: *m* - the number of repetitions of the j^{th} test ($j=1 \div N$);

- checking the variances uniformity according to the methodology described in [9, 19];
- determination of variance of reproducibility:

$$S_R^2 = \frac{1}{N} \sum_{j=1}^{N} S_j^2(Y) \tag{4}$$

- calculation of the regression coefficients:

$$b_o = \frac{1}{N} \sum_{j=1}^{N} \overline{Y}_j \tag{5}$$

$$b_i = \frac{1}{N} \sum_{j=1}^{N} x_{ij} \overline{Y}_j \tag{6}$$

$$b_{ik} = \frac{1}{N} \sum_{j=1}^{N} x_{ij} x_{kj} \overline{Y}_j \tag{7}$$

$$b_{ikl} = \frac{1}{N} \sum_{j=1}^{N} x_{ij} x_{kj} x_{lj} \overline{Y}_j \tag{8}$$

where: *x* - coded values of the levels of the factors with serial numbers *i, k, l* etc. in the j^{th} order from the design of the experiment, $\overline{Y}_j$ - the mean values from the results measured for each combination of input factors;

- verification the significance of calculated regression coefficients.

After an analysis of the modern mathematical methods, Student's t-test was used in the present work.

Only those coefficients are significant for which the following is valid [9, 10]:

$$t_C > t_T \tag{9}$$

where: t_C - calculated coefficient; t_T - the tabular value of Student's distribution by selected significance level r = 0.05 and degree of freedom

$$f = N\,(m-1) \tag{10}$$

$$t_C = \frac{|B_i|}{S_{(B_i)}} \tag{11}$$

$$S_{(Bi)}^2 = \frac{S_{(Y)}^2}{N(m-1)} \tag{12}$$

where $S_{(Bi)}^2$ - variance of regression coefficients.

- verification the adequacy of the model:

The verification is carried out using the Fisher's F-test [9, 10]:

$$F_C = \frac{S_{ad.}^2}{S_{(Y)}^2} \tag{13}$$

where: $S_{ad.}^2$ - adequacy variance;

For this experiment, the variance of adequacy is:

$$S_{ad.}^2 = \frac{m}{f} \sum_{j=1}^{N} \left(\overline{Y}_j - Y_{jC} \right)^2 \tag{14}$$

$$f = N - M \tag{15}$$

where: Y_{jC} - the value calculated according to the mathematical model; *M* - number of significant regression coefficients.

F_T is defined by statistical probability P = 0.95 for degrees of freedom f_1 and f_2.

$$f_1 = N\text{-}M; \quad f_2 = N(m\text{-}1) \quad (16)$$

The hypothesis that the mathematical model derived is adequate is assumed at the selected level of significance if [9, 10]:

$$F_C < F_T \quad (17)$$

2.2 Experimental conditions

In order to determine the conditions for conducting the experiment, it is necessary to select the optimization criteria (the output parameters) and the controllable factors. They can be quality criteria or performance ones. In the present work, the time to complete the TMF process (the output parameter Y) is selected as the optimization criterion. It is a basic one for productivity. For controllable factors were selected: X_1 - pressure, P [N/cm^2]; X_2 - temperature of the pressing plates, T [°C]; X_3 - fabric mass per unit area of the basic TM, M [g/m^2]. The main levels of the factors and the intervals of variation (in natural and coded values) are given in Table 1. The temperature between the basic and the auxiliary TM (interlining) is T_M (material temperature). It is measured at point 1 given in Figure 1, where position "2" indicates the basic TM, position "3" indicates the auxiliary TM (interlining), position "4" indicates the lower plate of the press, position "5" indicates the top plate of the press.

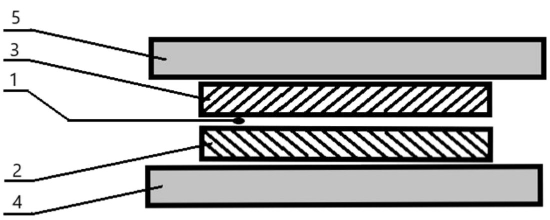


Figure 1 Experimental scheme

After conducting a number of preliminary studies, the following conditions for performing the experiments were selected:

- a fusing machine ATLAS - I. BALA - 4-93 - stationary press type "drawer";
- the TM temperature recorded with a computer integrated measurement system [20].

The T_M temperature at which a sufficiently secure connection is made between the basic and the additional TM (interlining) is established after conducting a number of preliminary experiments [21].

For this purpose, the quality criterion is the strength of the connection between the basic and the auxiliary TM (interlining). If attempting to separate the basic TM from the interlining the integrity of the auxiliary TM (interlining) becomes disrupted, that means that the strength of the bond is made greater than the tearing strength of the interlining.

In the present work, this criterion is taken as a proof that the TMF process is sufficiently reliable and efficient. The application of this criterion is relatively quick and easy. This is the reason why it was proposed to be used as a method of work in conducting this research.

The temperature T_Q is assumed to be required for quality fusing when working with the textile materials described.

The fusing process is finalized upon reaching T_M to T_Q. After numerous preliminary experiments, it was found that T_Q = 112°C for the studied TM.

2.3 Materials

Materials produced by the company NITEX-50 - Sofia were used for basic textile materials.

They are 100% wool fabrics:

- article EKSELSIOR, mass per unit area 173 g/m^2, warp threads count 52/2 Nm, weft threads count 37/1 Nm, warp threads density 122 pcs/10 cm, weft threads density 230 pcs/10 cm;
- article RITZ, mass per unit area 193 g/m^2, warp threads count 52/2 Nm, weft threads count 37/1 Nm, warp threads density 175 pcs/10 cm, weft threads density 263 pcs/10 cm;
- article KARDINAL, mass per unit area 213 g/m^2, warp threads count 52/2 Nm, weft threads count 37/1 Nm, warp threads density 370 pcs/10 cm, weft threads density 232 pcs/10 cm.

Material produced by the company Kufner-B121N77 was used for an auxiliary TM /interlining/. The auxiliary TM is fabric, with mass per unit area 63 g/m^2, warp threads 100% PES, weft threads 100% PES.

Table 1 Levels of factors

Factors	X_1 Pressure P [N/cm^2]		X_2 Temperature of the pressing plates T [°C]		X_3 Mass per unit area of the basic textile materials M [g/m^2]	
Levels	***Natural***	***Coded***	***Natural***	***Coded***	***Natural***	***Coded***
$X_{oi} + J_i$	40	+1	150	+1	213	+1
X_{oi}	25	0	135	0	193	0
$X_{oi} - J_i$	10	-1	120	-1	173	-1
J_i	15		15		20	

Table 2 Design of the experiment, measured values of the output parameter, calculated regression coefficients and calculated output parameter

№	X_0	X_1	X_2	X_3	X_1X_2	X_1X_3	X_2X_3	$X_1X_2X_3$	Y_{1j}	Y_{2j}	$\bar{Y}_j$	S_j^2	Y_C
1	+	-	-	-	+	+	+	-	20	21	20.5	0.5	20.938
2	+	+	-	-	-	-	+	+	18	19	18.5	0.5	18.063
3	+	-	+	-	-	+	-	+	12	13	12.5	0.5	12.938
4	+	+	+	-	+	-	-	-	10	11	10.5	0.5	10.063
5	+	-	-	+	+	-	-	+	40	38	39	2.0	38.438
6	+	+	-	+	-	+	-	-	34	36	35	2.0	35.563
7	+	-	+	+	-	-	+	-	23	24	23.5	0.5	23.188
8	+	+	+	+	+	+	+	+	21	19	20	2.0	20.313
	b_0	b_1	b_2	b_3	b_{12}	b_{13}	b_{23}	b_{123}					
	22.4375	-1.4375	-5.8125	6.9375	0.0625	-0.4375	-1.8125	0.0625					

3 RESULTS AND DISCUSSION

3.1 Experimental results

The design of this experiment is presented in Table 2. The number of the factors is 3, consequently *N* = 8 and *m* = 2.

The mean values from the results measured for each combination of input factors are given in Table 2.

3.2 Discussion of experimental results

The value calculated according to the mathematical model is given in Table 2. The obtained experimental data for the full factor experiment for the function *Y* - the duration of the TMF process are processed.

The calculations performed are according to equations (1) to (17). It is necessary to carry out a process reproducibility check, which is reduced [9, 19] to an outlying variances check (by Cochran's C test).

The results for the calculated and tabulated value of the Cochran's C test are:

$$G_T = 0.6798$$

$$G_C = 0.2353$$

Therefore, the intra-group variance does not differ statistically and the process is reproducible. The regression coefficients are determined by the formulae (5) ÷ (8). The calculated coefficients are given in Table 2.

The following important characteristics were defined:

- -variance of the output parameter – according to (4): $S_R^2 = 1.0625$
- -variances of regression coefficients and significance of the regression coefficients, using (9) ÷ (12):

$$S^2_{(B_i)} = 0.1328$$

$$t_{C(B_0)} = 61.57; \quad t_{C(B_1)} = 3.94$$

$$t_{C(B_2)} = 15.95; \quad t_{C(B_3)} = 19.04; \quad t_{C(B_{12})} = 0.17$$

$$t_{C(B_{13})} = 1.2; \quad t_{C(B_{23})} = 4.97; \quad t_{C(B_{123})} = 0.17$$

The value of Student's t-distribution is defined according (10): $t_T = 2.31$.

Insignificant are only coefficients b_{12} and b_{13}, the absolute value of which is smaller than the critical one.

After elimination of the insignificant coefficients, the model becomes the following form:

$$Y_C = 22{,}4375 - 1{,}4375.x_1 - 5{,}8125.x_2 + \\ + 6{,}9375.x_3 - 1{,}8125.x_2.x_3 \qquad (18)$$

Verification of the model adequacy:

- -the adequacy variance was established (14): $S^2_{ad.} = 1.0625$
- -the expected Fisher's F - test was calculated according to (13): $F_C = 1.00$;
- -the tabulated value of Fisher's distribution (16) is F_T $(r=0.05,\ f_1=3,\ f_2=8) = 4.07$.

As $F_C = 1.00 < 4.07 = F_T$, the model is adequate.

Therefore, the hypothesis that the mathematical model (18) is adequate can be accepted with confidence level $P=0.95$.

4 CONCLUSIONS

After a thorough analysis of the nature and characteristics of the technological process TMF of a fusing machine (stationary press type "drawer"), a full factorial experiment was designed to derive a mathematical model of the process.

The necessary tests were made to perform a full factor experiment of type 2^3. The time for completing the TMF process was selected as optimization criterion. By applying the methods of mathematical modeling, a mathematical model of the TMF process for the respective fusing machine type was derived. This model describes the influence of the pressure *P* [N/cm^2], the temperature of the pressing plates *T* [°C] and the mass per unit area of the basic textile materials *M* [g/m^2] on the duration of the TMF process. The hypothesis of the adequacy of the mathematical model was proved. Obtaining an adequate mathematical model of the process creates real prerequisites for its optimization.

5 REFERENCES

1. Gries T., Lutz V., Niebel V., Saggiomo M., Simonis K.: 14: Automation in quality monitoring of fabrics and garment seams, Automation in Garment Manufacturing, 2018, pp. 353-376, https://doi.org/10.1016/B978-0-08-101211-6.00014-8
2. Wu L., Yick K.I., Ng S.P., Yip J., Kong K.H.: Parametric design and process parameter optimization for bra cup molding via response surface methodology, Expert Systems with Applications 39(1), 2012, pp. 162-171, https://doi.org/10.1016/j.eswa.2011.07.003
3. Watcharapanyawong K., Sirisoponsilp S., Sophatsathit P.: A model of mass customization for engineering production system development in textile and apparel industries in Thailand, Systems Engineering Procedia 2, 2011, pp. 382-397, https://doi.org/10.1016/j.sepro.2011.10.052
4. Colovic G.: *3:* Determining time of technological operations in clothing production, Management of Technology Systems in Garment Industry, 2011, pp. 43-79, https://doi.org/10.1533/9780857094049.43
5. Andonova S.: Analysis of factors influencing the process of thermos-mechanical sticking in the sewing industry, Journal of Multidisciplinary Engineering Science and Technology 6(10), 2019, pp. 10884-10887, ISSN: 2458-9403
6. Petrov H.: Research on the creation of high-performance technologies and equipment for the sticking of textiles, Edited by TU Sofija - University Press, Sofia, Bulgaria, Dissertation, 1991
7. Motejl V.: Machines and equipment in clothing production, SNTL, Praha, 1984
8. Havkin V., Vajscheslavcev G.: Robotization of technological equipment of light industry, Moscow: Legprombıtizdat, 1987
9. Damyanov G.: Mathematical methods for the planning of an experiment in the research in the textile industry, IOT: Sofia, 1977
10. Damyanov G., Germanova-Krasteva D.: Textile Processes: Quality Control and Design of Experiments, NY: Momentum Press, 2012
11. Nedyalkov I., Stefanov A., Georgiev G.: Modelling and studying of cloud infrastructures, Proceedings of International Conference on High Technology for Sustainable Development, HiTech,Sofia, Bulgaria, 2018, Article number 8566664, pp. 1-4, DOI: 10.1109/HiTech.2018.8566664
12. Amudjev I., Krumov K., Kuzmanov V.: Modelling of the micro hardness obtained in the burnishing process by means of adding rotations around crossing axes, Journal Mechanical Engineering and Machine Science 13(1), 2011, pp. 64-68
13. Quezada-García S., Espinosa-Paredes G., Polo-Labarrios M.A., Espinosa-Martínez E.G, Escobedo-Izquierdo M.A.: Green roof heat and mass transfer mathematical models: A review, Building and Environment 170, 2020, Article 106634, https://doi.org/10.1016/j.buildenv.2019.106634
14. Dimitrienko Yu.I., Dimitrienko I.D.: Modeling and simulation of textile composite plates under a punching load, Applied Mathematics and Computation 3641, 2020, Article 124660, https://doi.org/10.1016/j.amc.2019.124660
15. Sapundzhi F., Popstoilov M.: Optimization algorithms for finding the shortest paths, Bulgarian Chemical Communications 50, Special Issue-B, 2018, pp. 115-120, http://www.bcc.bas.bg/
16. Rahnev I.: Mechanics of the textile threads, International Journal of Clothing Science and Technology 17(6), 2005, pp. 39-40
17. Manusov V.Z, Matrenin P.V., Khasanzoda N.: Swarm algorithms in dynamic optimization problem of reactive power compensation units control, Interantional Journal of Electrical and Computer Engineering (IJECE) 9(5), 2019, pp. 3967-3974, http://doi.org/10.11591/ijece.v9i5.pp3967-3974
18. Amudjev I.: Applying of the morphological method for analysis and synthesis of methods for finishing of external cylindrical surfaces by means of surface plastic deformation, Journal of Technical University – Gabrovo 34, 2007, pp. 19-25
19. Andonova S.: The influence of details' mass of textile materials on the duration of ironing, Tekstil i Obleklo 12, 2006, pp. 17-20, ISSN 1310-912X
20. Trifonov K., Andonova S., Gebov V.: Computer-integrated system for measuring the temperature during pressing, Textile and Clothing 11, 2005, pp. 18-21
21. Andonova S., Stefanov A., Amudzhev I.: An investigation of the thermo-mechanical fusing process of innovative textile material, Industria Textila Journal*,* in press

DESIGN OF A CONTEMPORARY MEASURING SYSTEM FOR READING THE TREAD'S TENSION IN A NEEDLE

Snezhina Angelova Andonova, Vladimir Krumov Gebov and Ivan Marinov Amudzhev

Faculty of Engineering, South-West University "Neofit Rilski", 66 Ivan Mihailov Str., 2700 Blagoevgrad, Bulgaria
andonova_sn@swu.bg

Abstract: *In the sewing industry, one of the main quality criteria is the quality of the seam. The criterion for qualitative stitching is the interweaving of the threads (top and bottom) to take place in the middle of the materials being processed. One of the main factors that determines the way in which threads are intertwined is the tension of the upper thread. In modern sewing companies, the maximum tensile strength of the upper thread is manually adjusted by a disc brake. The adjustment is based on the experience and flair of the machine operator or technologist. This creates conditions for the influence of the subjective factor on the quality and productivity of sewing. Therefore, the purpose of the present work is to create a computer-integrated measuring system for determining the thread's tension in a needle which meets contemporary requirements for speed, ability to process information flows, communication and mobile applicability. In addition, it is proposed to use a specialized servomotor to run the machine. This creates conditions to study and analyze the relationships between speed, acceleration, torque of the machine mechanism and the thread's tension in a needle.*

Keywords: *the tread's tension in a needle, contemporary measuring system*

1 INTRODUCTION

Quality assurance and quality control is a complex area of the apparel industry. Quality assurance is not quality control, but quality control is an aspect of quality assurance. Quality assurance builds quality into each step of the manufacturing process [1]. Therefore, it is especially important to study the influence of the quality of stitching on the quality of the sewing product [2]. From the literature review it can be concluded that this issue has not been sufficiently investigated. One of the main factors influencing the quality of the stitching is the tread's tension in a needle.

In modern sewing companies, the maximum tensile strength of the upper thread is manually adjusted by a disc brake. The adjustment is based on the experience and flair of the machine operator or technologist. This creates conditions for influence on the quality and productivity of sewing by the subjective factor. Therefore, it is necessary to carry out many preliminary studies to define the nature and magnitude of the tensile strength [3] of the upper thread at specific technological parameters (composition and structure of the textile material, number of treated layers, type of stitch formation, etc.). In this regard, studies have been conducted on monitoring and control of industrial sewing machines research on thread tension behavior in lockstitch machines [4]. Research has also been done on the determination of the sewing thread friction coefficient [5].

The power tension of the upper thread is calculated by complex physical laws, as the sum of:

- the tensile forces of the thread to the disc brake;
- the tension of the thread from the disc brake;
- stretching the thread from the brake to the material.

In the light of the foregoing, it is necessary to investigate this tension with specialized equipment which takes into account the total tensile strength of the upper thread. This in turn necessitates the creation of a modern, fast-acting computer-integrated measuring system for measuring the total tensile force of the upper thread of a sewing machine.

The literature overview reveals that attempts to create systems for automatic process control have been made [6]. The automatic process control ensures that a certain degree of tension (preset) of the upper thread is maintained continuously. This makes it possible to avoid the influence of the subjective factor during the stitch formation process. The problem originates from the fact that the intensive development of electronics and information technology has outpaced the development of technologies in the sewing industry. That is, systems for automatic maintaining the tensile strength of the needle thread have been created [6], but they work with preset required values for that force. The optimal levels of these values need to be established beforehand so that they can be assigned to automatic control systems [7-9]. However, research in this area has not been comprehensive enough yet.

It is necessary to determine the optimum tensile strength values for different working conditions and different textile materials in advance. This is precisely the task that sewing technology professionals are facing. Therefore, it is of importance to carry out a number of investigations and analyses to determine the optimum values of the upper thread tension when sewing different textile materials (TM), different number of layers and types of seams. In this one can determine the values to be set in the automatic control of the process. In this sense, it is particularly important to look for a method for measuring the total tread's tension in a needle under different technological conditions. Globally, many elite companies have conducted research in this area, but their studies are commercial or confidential. Different types of thread voltage sensors are proposed in [10]. There is no proposal for a measuring system for determining the tread's tension in a needle. In [11], a computer-integrated measurement system has been proposed that has the following characteristics: high level of interactivity; universality and modularity; polymorphism and inheritance; communication; industrial applicability. At the time of its creation, the system proposed in [11] met the real needs of the sewing industry. The rapid development of electronic equipment and computer technology, however, determine the insufficient communication of this system [11] at the present stage. The global development of industrial technologies today defines the need for faster action, greater ability to process information flows and mobile applicability [8, 9, 12].

2 DISCUSSION AND ANALYSIS

The purpose of the present work is to create a computer-integrated measuring system for determining the thread's tension in a needle which meets the contemporary requirements for speed, ability to process information flows, communication and mobile applicability.

2.1 Conditions to execute the experiment - requirements for the measurement system

In formulating the conditions and methods for studies the thread's tension in a needle, the principles of the morphological method for the analysis and synthesis of methods are applied [13]. An analysis of the technological features of stitch formation shows that it is necessary to study and analyze the relationships between speed, acceleration, torque of the mechanism of the machine and the thread's tension in a needle. It is particularly important that the measurement is synchronized with the rotation of the main shaft. In addition, the principle of measurement with the measuring system must make it possible to carry out studies concerning all types of stitches, all types of processed textile materials and all types of thread used.

2.2 Results

In light of the above, this work proposes the use of a specialized servomotor to run the machine. The functional diagram of the servomotor is given in Figure 1. This creates conditions to study and analyze the relationships between speed, acceleration, torque of the machine mechanism and the thread's tension in a needle.

Figure 1 Functional diagram of a servomotor

The block diagram of the servo control for speed and position control is given in Figure 2. The application of the servo control allows to establish the effective operating modes (values of the thread's tension in a needle for certain speed and acceleration of the machine mechanism at a given needle number, type of thread and the processed textile materials (TM), number of layers of TM, type of the stitch line, etc.).

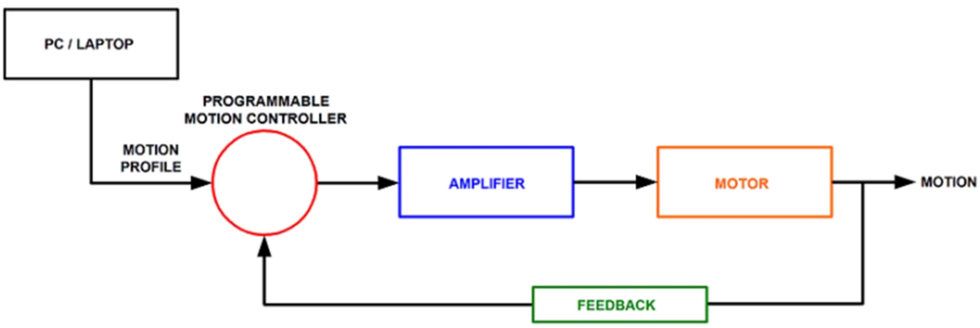


Figure 2 Structural diagram of servo control for speed and position control

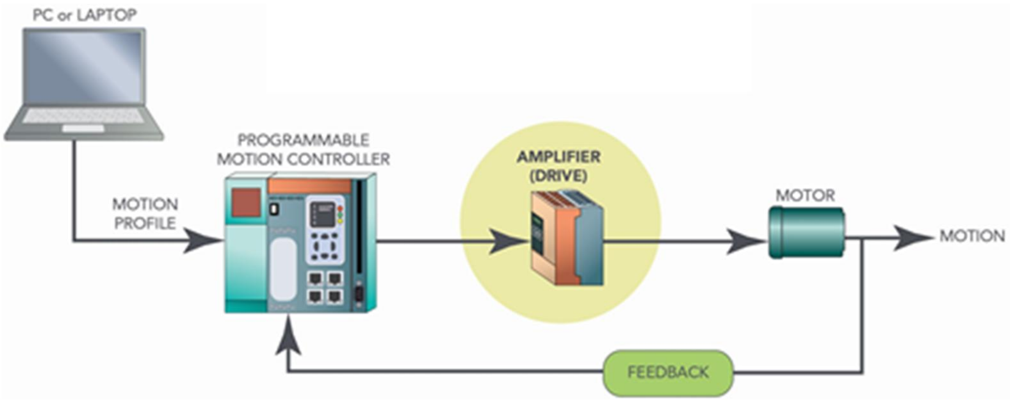


Figure 3 Functional scheme of servo control for speed and position control of mechanisms

Figure 3 shows a functional scheme of a computer-integrated information-measuring system for determining the tensile strength of a needle thread.

The system shown in Figure 3 includes the following modules: personal computer, PLC of Siemens, capacitive sensor Rothschild, module to convert the signal from the capacitive sensor Universal Transducer Interface (UTI), inductive position sensor Servo Motor Incremental Encoder, Servo Motor with Servo Control ELAS DA2.

The system configuration created has the following distinctive features:

- Modern high level of interactivity provided by industrial software TIA Portal and ET 200SP.
- TIA Portal of Siemens is a fully integrated automation portal. This is a software package that makes process automation more efficient.
  Here, many of the basic features are readily available in one software package. The TIA portal includes the following features: networks configuration, drives and I/O stations, PLC programming, programming of security applications, migration of STEP7 projects, design of HMI panels, simulations, data management and online diagnostics.
- SIMATIC ET 200SP has a compact design that saves up to 50% of the space required compared to older Siemens controllers.
- The interaction of the ET 200SP with other components allows to reduce the commissioning time by about 20%.

In general, the system is characterized by contemporary communication and industrial applicability. Communicativeness enables the inclusion of additional measuring and control modules and sensors. Profinet DP provides system development in a vertical and horizontal hierarchy. Industrial applicability is a characteristic that is necessary for the application of the research and methods obtained from the result of scientific work in engineering practice.

The elements that make up the computer-integrated system for measuring the thread's tension in a needle are given in Figure 4.

Figure 4 Method of measurement with the selected sensor

The modules of the proposed system have the following characteristics:

- Sensor (position 1) – Model 100P D72186 AMPHEHOL, produced by "Rotchild" Zurich, Switzerland [9]. The converter is a capacitive type selected with non-rotating guides.
- Converter UTI Smartec (position 2). It provides interaction for many types of sensor elements, in this case capacitors. It has a resolution and linearity of up to 14 bits and the calibration is automatic. The output signal is compatible with the inputs of the microcontrollers.
- Incremental sensor for position feedback (position 3) - RTC70S8. The maximum number of impulses generated per revolution reaches 6000 ppr. A highly reliable photoelectric device guarantees long life, high noise resistance and a wide temperature range.
- Programmable logic controller SIMATICS7 (position 4) -ET200Sp /SIEMENS/.
- PC with environment TIA - Portal installed (position 5).

The choice of the processor and the controller type is related to the tasks that are to be solved, as well as to the great number of factors involved in the research process. Optimizing the PLC selection is always associated with a priori resource reinsurance. The principle of measurement of the created measuring system provides possibilities for its universal application in measuring the thread’s tension in a needle for different types of sewing machines. The method of measurement with the selected sensor is given in Figure 4. The overall view of the measuring system is given in Figure 5.

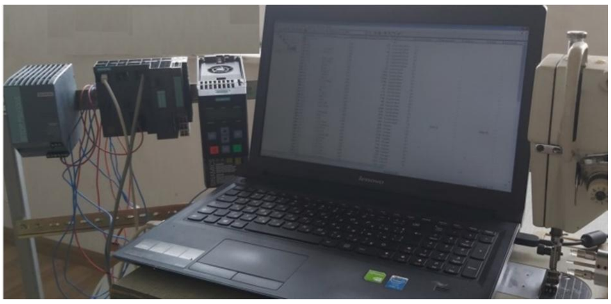


Figure 5 An overall view of the measuring system for reading the tread’s tension in a needle

A mechanical force is applied at the sensitive end of the capacitive sensor, resulting in a change in its capacity. In this case, mechanical force is created by the upper thread, which moves in the process of stitch formation. With high-speed sewing machines, the thread moves with great acceleration. It is the measurement system that helps to achieve high accuracy in measurements. The working range is from 0 to 1000 g.

The selected sensor is based on the conversion of mechanical deformations. Mechanical deformations change the dielectric constant of the sensor. Both transformations are linear. The sensor connects to the meter which is a precision measuring bridge. Changing the force in the range from 0 to 1000 g affects the measuring bridge and produces a proportional voltage from 0 to 5 V at its output, which, after conversion, is fed to the computer processing system.

Specific software has been created to perform measurements using the method shown in Figure 6.

The measurement is synchronized with the rotation of the main shaft. The tensile strength of the upper thread when rotating the main shaft from 0 to 360° is determined. The characteristics of the created measurement system allow to measure the values of the effort over a preset time interval up to milliseconds.

Through the Profinet communication interface (Figure 6), the data from the measurements and transformations of the tension of the needle thread are transferred to a database of the computer 5. This allows subsequent processing in Windows environment and Excel tools for research, analysis and mathematical modeling.

3 CONCLUSION

Measuring technological parameters is a challenge for any scientist. All researchers are faced with a difficult choice - to look for hard-to-reach and expensive equipment or to design such equipment themselves. This article offers a modern solution for measuring an important technological parameter in the sewing industry.

A contemporary computer-integrated information-measuring system for measuring the thread’s tension in a needle in sewing machines has been created.

The created configuration of the information-measuring system meets the contemporary requirements for speed, ability to process information flows, communication and mobile applicability.

The proposed system creates conditions for research and optimization of the thread’s tension in a needle at different technological parameters work and different types of TM in the sewing industry.

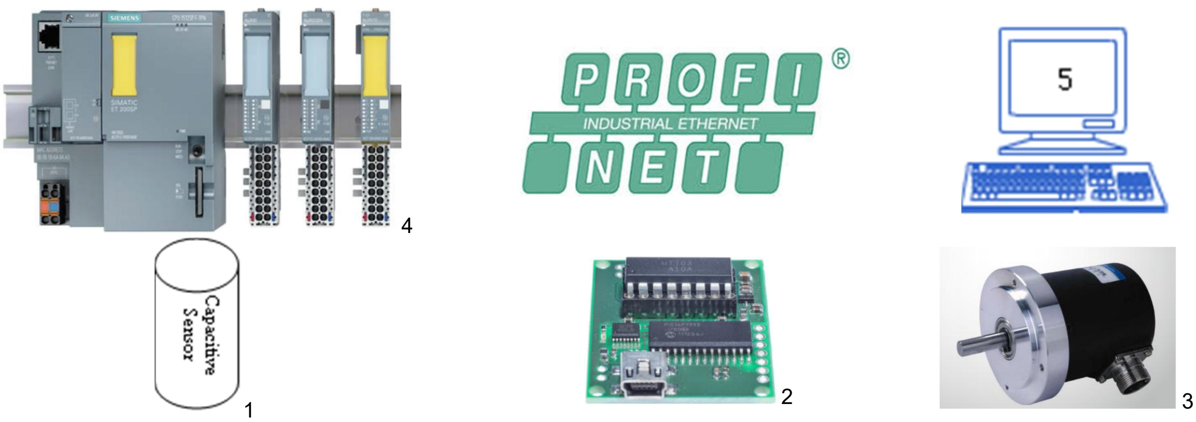


Figure 6 Elements constructing a computer-integrated system for measurement of tread’s tension in a needle

4 REFERENCES

1. Keist C.N.: 16 - Quality control and quality assurance in the apparel industry, Garment Manufacturing Technology, Woodhead Publishing Series in Textiles, 2015, pp. 405-426, https://doi.org/10.1016/B978-1-78242-232-7.00016-3
2. Gries T., Lutz V., Niebel V., Saggiomo M., Simonis K.: 14 - Automation in quality monitoring of fabrics and garment seams, Automation in Garment Manufacturing, The Textile Institute Book Series, 2018, pp. 353-376, https://doi.org/10.1016/B978-0-08-101211-6.00014-8
3. Rahnev I.: Bibliographic review of the evalnation methods of the elastic resistance of the straned textile thread, Textile and Garment Magazine 9, 2016, pp. 8-18
4. Mellero P., Biegas S., Carvalho H., Ferreira F.: Monitoring and control of industrial sewing machines research on thread tension behavior in lockstitch machines, Proceedings of International Conference on Engineering, Technology and Innovation (ICE/ITMC), Funchal, Portugal, 2017, pp. 1031-1036, DOI: 10.1109/ICE.2017.8279995
5. Žunič-Lojen D., Geršak J.: Determination of the sewing thread friction coefficient, International Journal of Clothing Science and Technology 15, 2003, pp. 241-249, https://doi.org/10.1108/09556220310478341
6. Randima L.M.L., Sandaranga D.M.B.C., Jayawardana T.S.S., Fernando E.A.S.K.: Design and fabrication of an automatic tension monitoring and regulation system for needle thread, Moratuwa Engineering Research Conference (MERCon), 3-5 July 2019, pp. 738-743, DOI: 10.1109/MERCon.2019.8818866, https://ieeexplore.ieee.org/document/8818866
7. Amudjev I., Krumov K., Kuzmanov V.: Modelling of the micro hardness obtained in the burnishing process by means of adding rotations around crossing axes, Journal of Mechanical Engineering and Machine Science 13(1), 2011, pp. 64-68
8. Nedyalkov I., Stefanov A., Georgiev G.: Modelling and studying of cloud infrastructures, Proceedings of International Conference on High Technology for Sustainable Development, HiTech, 2018, Article number 8566664, pp. 1-4, http://doi:10.1109/HiTech.2018.8566664
9. Sapundji F., Popstoilov M.: Optimization algorithms for finding the shortest paths, Bulgarian Chemical Communications 50, 2018, pp. 115-120
10. Ajzenberg L., Kipnis A., Storozhenko U.: Technological measurements and control and measuring devices in the textile and light industry, Legprombytizdat, Moscow, 1990
11. Trifonov K., Andonova S., Gebov W.: Creating information and measuring system to establish the threads tension in a needle, Textile and Garment Magazine 5, 2006, pp. 17-20
12. Atanasov N., Atanasova G., Stefanov A., Nedialkov I.: A wearable, low-profile, fractal monopole antenna integrated with a reflector for enhancing antenna performance and SAR reduction, IEEE MTT-S International Microwave Workshop Series on Advanced Materials and Processes for RF and THz Applications (IMWS-AMP), Bochum, Germany, 2019, pp. 67-69
13. Amudjev I.: Applying of the morphological method for analysis and synthesis of methods for finishing of external cylindrical surfaces by means of surface plastic deformation, Journal of Technical University of Gabrovo 34, 2007, pp. 19-25

ANALYSIS AND PRACTICAL CRITERIA FOR ASSESSING THE UNIFORMITY OF FABRIC MASS PER UNIT AREA

Snezhina Angelova Andonova[1] and Gaetano Rimini[2]

[1]*Faculty of Engineering, South-West University "Neofit Rilski", 66 Ivan Mihailov Str., 2700 Blagoevgrad, Bulgaria*
[2]*E. Miroglio EAD – Sliven, Industrial zone, 8800 Sliven, Bulgaria*
andonova_sn@swu.bg; Gaetano.Rimini@emiroglio.com

Abstract: *The fabrics' mass per unit area (FMUA) is one of the main technological parameters in their production. This is one of the main reasons in the stage of fabric quality control obligatory to be checked the correspondence between the set mass per unit area /as a technological parameter in the weaving/ and the resulting mass per unit area of the finished fabric. In manufacturing practice, there are no clear rules or methodology to be followed when carrying out this inspection. The location over the fabric surface from which the specimens have to be taken is clearly formulated. However, taking the appropriate type and number of samples depends on the experience and skill of the quality controller. This creates preconditions for occurrence of subjective influence during the quality control of the final product in the weaving mills and the incoming fabrics in the sewing enterprises. The purpose of this work is to provide, through research and analysis, a practically accessible and scientifically sound method for determining the uniformity of mass per unit area along the length and width of the fabric (along warp and weft threads).*

Keywords: *fabrics, mass per unit area, criteria for assessing, quality.*

1 INTRODUCTION

The fabrics' mass per unit area (MUA) is one of the main technological parameters in their production [1-3]. This is one of the main reasons in the stage of fabric quality control obligatory to be checked the correspondence between the set mass per unit area /as a technological parameter in the weaving/ and the resulting mass per unit area of the finished fabric. In manufacturing practice, there are no clear rules or methodology to be followed when carrying out this inspection.

The location over the fabric surface from which the specimens have to be taken is clearly formulated [4-6]. However, taking the appropriate type and number of samples depends on the experience and skill of the quality controller. This creates preconditions for occurrence of subjective influence during the quality control of the final product in the weaving mills and the incoming fabrics in the sewing enterprises. On the other hand, the mass per unit area of fabrics is one of the main input factors influencing the quality criteria in the sewing industry. The uniformity of the mass per unit area in length and width of the fabric is of particular importance for the qualitative realization of a number of technological processes in the apparel industry. When the mass per unit area in the different fabric areas is not constant, it becomes possible the various details of the same sewing article to have different characteristics (determined by the unevenness of the mass per unit area).

From conducted scientific researches it is known that the mass per unit area influences the main technological parameters of the moisture-heat treatment of the textile materials in sewing production [7, 8]. The statistical significance of the influence of SM on the tensile strength of the needle thread has been demonstrated [9]. In general, however, there are no clearly established rules in the sewing companies for the procedure for controlling the uniformity of MUA of the fabrics (in their length and width) when receiving and storing them. This is a prerequisite for the majority of sewing companies not to carry out such control at all. The standards prescribe the manner of sampling and testing as a methodology [4-6]. However, they do not provide how to assess if the distribution of the MUA across the width of the fabric is uniform. There have been attempts at metrological selection of woven fabrics [3], which consider the complex evaluation of tissues and indirectly target the uniformity of MUA. In the light of the above, it is particularly important to look for a clearly formulated and relatively accessible and rapid method for determining the uniformity of MUA of fabrics in their length and width. In the world, some elite weaving and sewing companies are doing research on this issue, but they do not publish their results because of commercial or confidential reasons.

The present work describes the research and analysis conducted to solve these important technological issues with own resources. The application of statistical methods of analysis and evaluation put this research on a scientific basis.

2 THEORY APPROACH - OCCURRENCE OF NON-UNIFORMITY OF FABRICS IN WIDTH OF FABRIC

During the weaving process, the raw fabric is subjected to various types of stresses and deformations. The predominant group of loads is one-way oriented and applied throughout the width of the fabric. These are the attractive cross, brace, birch and similar static guides on the warp threads and the woven fabric. Sometimes, the broad bands (templets) adjustment is accompanied by a small and seemingly insignificant asymmetry, such as height relative to the midline of the loom or depth of selvedges. These differences in geometric conditions during fabric formation subsequently affect the density of the warp and weft threads, as well as their interaction and incorporation. The allowed asymmetry in the setting of the loom along its width leads to a difference and asymmetry in the distribution of the mass per unit area along the width of the fabric. By its origin and because of the principle of uniformity of the weaving cycles ($\cong$0.15 s), the longitudinal distribution of the mass per unit area varies small and is symmetrically arranged as a function of the distribution. Therefore, the longitudinal variation of the mass per unit area is determined by the normal distribution of single measurement values. Greater differences may occur between identical fabric pieces on different looms, which is generally due to subjective factors that occur during the equipment use and maintenance. There is a prerequisite for a natural reference to the variation in mass per unit area, i.e. a longitudinal variation to be applied to estimate the transverse distribution of the mass per unit area along the width of the fabric.

3 EXPERIMENTAL WORK

The purpose of this work is to provide, through research and analysis, a practically accessible and scientifically sound method for determining the uniformity of mass per unit area along the length and width of the fabric (along warp and weft threads). The practical conditions make it possible to examine only one end of the roll with input quality control. The usual allowable length of the cut sample is about 1.0 m. Considering the need to prepare test specimens for other tests, such as strength, shrinkage, etc. no more than 30 to 35 cm remain to determine the mass per unit area. This means that no more than two mass per unit area tests along the length of the section are possible - test specimen. The actual conditions allow only one longitudinal test, or 3 tests in the middle and at both ends of the fabric. With these tests, it is necessary to obtain a statistically reliable evaluation of the uniform distribution of the mass per unit area along the width of the fabric.

The advantageous opportunity is the ability to measure all the rolls in the lot/batch and so to determine the boundary criterion for deviation of uniformity, after which the top fabric in question is subject to quality declaring. The solution is to find that parameter /estimate/ that is universal in nature, such as the coefficient of variation, for example.

3.1 Conditions to execute the experiment

For the experiment was used Vamatex Leonardo looms with 8 shed frames.

The samples were prepared by the Fabric Sample Cutter SDL Atlas, and mass per unit area was measured by means of electronic scales Precisa XB620C.

Representative sample was derived from the total supply of woven fabric according to the methodology described in BDS EN 12751:2003 and the samples were prepared according to the methodology of BDS 229-92.

In this case, a passive experiment was performed, i.e., the parameters of the fabric produced were measured without changing the technological conditions of the weaving cycle.

3.2 Materials

The textile material studied was a woven fabric purposed to stamped summer garments, produced by "E. Miroglio SA" – Sliven, Bulgaria.

The woven fabric is produced from 100% PES (polyester) with a width of 145 cm and a nominal mass per unit area of 85 g/m^2. The characteristics of the woven fabric are: warp threads of Tt 5.60 tex/36 filaments at warp density of 1040 threads/dm and weft threads of Tt 5.60 tex/ /72 filaments at weft density of 460 threads/dm.

Table 1 gives the primary numerical data from the measurements of a representative fabric sample, where “StDev” is a standard deviation; “C Interval” is confidence interval. Of the total 547 fabric rolls in 21 lots, 42 were separated by random selection and measured. Measurements were made at the beginning of each roll by measuring the masses per unit area in the middle at both ends - left and right on the fabric. In order to imagine, the consecutive measurements of the sample show the change in surface mass along the entire aggregate of more than 80000 meters of fabric.

At the same time, the three measurements along the width of the fabric represent the transverse distribution of the surface mass.

3.3 Methods

In formulating the conditions and methods for conducting the experiment, the principles of the morphological method for analysis and synthesis of methods are applied [10].

Table 1 A data from the measurements of SM

2019	Woven fabric		82469.0 m			547 rolls			
Test №	Fabric roll		Surface mass [g/m^2]			Cross evaluation – width			
	Length [m]	Width [cm]	Left	Middle	Right	Average	StDev	C Interval	CV
1	90.00	148.0	91	90	87	89.2	2.02	5.02	2.27
2	151.00	153.0	90	88	89	**88.5**	1.00	2.48	**1.13**
3	94.00	148.0	89	89	91	**89.2**	1.15	2.87	**1.29**
4	155.00	149.0	94	92	93	**92.7**	1.26	3.13	**1.36**
5	157.70	149.0	90	90	91	**90.3**	0.58	1.43	**0.64**
6	157.00	148.0	88	87	85	**86.5**	1.50	3.73	**1.73**
7	160.50	147.0	92	91	92	**91.5**	0.87	2.15	**0.95**
8	155.20	152.5	91	88	88	**89.0**	1.73	4.30	**1.95**
9	105.70	152.0	91	90	91	**90.5**	0.50	1.24	**0.55**
10	163.00	148.0	94	92	93	**92.5**	1.00	2.48	**1.08**
11	158.20	148.0	91	90	89	**90.0**	1.00	2.48	**1.11**
12	154.80	148.5	91	88	90	**89.7**	1.53	3.79	**1.70**
13	165.10	148.0	89	88	88	**88.3**	0.58	1.43	**0.65**
14	155.40	147.5	91	89	91	**90.3**	1.15	2.87	**1.28**
15	161.20	150.0	94	91	93	**92.7**	1.53	3.79	**1.65**
16	155.00	149.0	91	88	91	**90.0**	1.73	4.30	**1.92**
17	165.00	148.0	88	88	89	**88.3**	0.58	1.43	**0.65**
18	60.00	147.5	90	89	86	88.3	2.08	5.17	2.36
19	159.80	149.0	91	90	90	**90.3**	0.58	1.43	**0.64**
20	155.90	147.5	89	89	93	90.3	2.31	5.74	2.56
21	152.80	150.0	94	93	90	**92.3**	2.08	5.17	**2.25**
22	160.00	148.0	94	93	94	**93.7**	0.58	1.43	**0.62**
23	158.40	148.0	90	89	92	**90.3**	1.53	3.79	**1.69**
24	155.90	149.0	89	89	91	**89.7**	1.15	2.87	**1.29**
25	187.90	150.0	92	93	91	**92.0**	1.00	2.48	**1.09**
26	148.80	148.0	94	94	92	**93.3**	1.15	2.87	**1.24**
27	155.10	149.0	96	92	93	**93.7**	2.08	5.17	**2.22**
28	155.10	149.0	96	92	93	**93.7**	2.08	5.17	**2.22**
29	153.70	148.5	90	90	91	**90.3**	0.58	1.43	**0.64**
30	156.10	149.5	87	90	90	**89.0**	1.73	4.30	**1.95**
31	154.50	148.0	92	93	91	**92.0**	1.00	2.48	**1.09**
32	155.60	148.5	92	94	92	**92.7**	1.15	2.87	**1.25**
33	155.30	149.0	90	89	90	**89.7**	0.58	1.43	**0.64**
34	154.00	149.0	90	91	87	89.3	2.08	5.17	2.33
35	158.50	150.0	92	92	91	**91.7**	0.58	1.43	**0.63**
36	158.40	150.0	92	92	93	**92.3**	0.58	1.43	**0.63**
37	153.10	150.0	91	92	94	**92.3**	1.53	3.79	**1.65**
38	154.30	148.0	89	90	92	**90.3**	1.53	3.79	**1.69**
39	154.40	150.0	91	90	91	**90.7**	0.58	1.43	**0.64**
40	181.00	149.0	92	93	90	**91.7**	1.53	3.79	**1.67**
41	152.50	150.0	92	94	92	**92.7**	1.15	2.87	**1.25**
42	155.80	151.0	94	90	93	**92.3**	2.08	5.17	**2.25**

However, the application of statistical methods must be based on a thorough knowledge and analysis of the physical nature of the relevant technological processes.

Samples of 1 m from the end of each sample shall be sampled when conducting tissue MUA uniformity tests. That is, one examines part of the batch, not the whole batch, so it is necessary to determine the confidence level [6, 11].

The absolute choice error is determined according to (1) [6, 11]:

$$q_{\overline{X}} = \frac{t \times \sigma}{\sqrt{n}} \quad (1)$$

where: t - Student's coefficient; σ - the standard deviation; n – number of trials.

The relative (percentage) value of the confidence level is determined according to (2) [6, 11]:

$$P_{\overline{X}} = \frac{q_{\overline{X}}}{\overline{X}}.100 \quad (2)$$

where: $\overline{X}$ - the arithmetical average of the measured MUA.

According to [11], if condition (3) is fulfilled, therefore, the accuracy of the test is sufficiently good, i.e. a sufficient number of trials are included.

$$P_{\overline{X}} \lhd 2.5\% \quad (3)$$

If condition (3) is not fulfilled, then the number of trials n must be increased so that condition (4) [11] is fulfilled.

$$n \rhd \frac{t^2 \times CV^2}{2.5^2} \quad (4)$$

where: CV - coefficient of variation (is a dimensionless measure of the variability of a parameter, defined as the ratio of the standard deviation to the mean).

In order to evaluate the quality of the product, it is necessary to compare the results of the surface test with the requirements of norms and standards [11]. For us, the norm is the set MUA, which must have the final product in the weaving or MUA laid in the passport of the fabric, which is obtained in the sewing company. Student's t - test can be used to make the comparison. To do this, the calculated Student's t - test value is determined as given in (5) and the Student's t - test tabular value (Student's distribution) as given in (6) [10, 11].

$$t_C = \frac{\left|\overline{X} - X_i\right|}{\sigma} \times \sqrt{n} \quad (5)$$

$$t_t \begin{Bmatrix} f = n-1 \\ r = 0{,}05 \end{Bmatrix} \quad (6)$$

where: f - degree of freedom, r - significance level, $i \in (1 \div n)$.

According to [11], if condition (7) is fulfilled, the difference between the required value (norm) for area mass and the measured average value for MUA is not statistically significant and the product can be considered qualitative. If condition (7) is not fulfilled [12], the difference between the required value (norm) for MUA and the measured average value for MUA is statistically significant and the product cannot be considered qualitative.

$$t_c \lhd t_t \quad (7)$$

In the case where the main task is focused on the uniform distribution of MUA across the width of the fabric, the following circumstances are determining. The representativeness of the two samples is guaranteed. The longitudinal distribution of the mass per unit area can cover the whole population (547 rolls of fabric), while the transverse distribution is based on 3 measurements: in the middle and at both ends. The sample in this example comprises 42 rolls of fabrics.

From this point of view, the variation of the large, longitudinal sample, which as a reference evaluates the variation in the transverse sample, is crucial. In other words, the mean value of the variation of the longitudinal distribution of the MUA can be taken as the limit value for the variation of the MUA in width for each top fabric:

$$meanCV = \frac{\left(CV^{left} + CV^{middle} + CV^{right}\right)}{3} \quad (8)$$

where: CV^{left} - coefficient of variation measurements (MUA) on the left of the roll of fabric; CV^{right} - CV measurements on the right side of the roll of fabric; CV^{middle} - CV measurements in the middle of the roll of fabric.

Another method to evaluate the distribution of MUA over the width of the fabric is to compare the variation of the longitudinal MUA with the transverse. The assumption that the transverse variation of the MUA is accepted shall not exceed the longitudinal variation of the area for the sample.

$$crossCV \leq meanCV \quad (9)$$

Otherwise, if the limit value is exceeded, the qualitative fabric is declassified or sent for another type of product.

4 RESULTS AND DISCUSSION

4.1 Experimental results

Table 2 presents the statistical estimates of the measured area distribution in longitudinal and transversal directions. The convergence of the longitudinal variation of the MUA can be seen, which for the three lines on the woven fabric varies within small limits:

CV^{left} = 2.30%; CV^{middle} = 2.17%; CV^{right} = 2.32%.

The average value of the longitudinal variation is *meanCV = 2.26%.*

Table 3 illustrates the results of the central moment of 3rd rank $\mu(3)$ and the central moment of 4th rank $\mu(4)$.

Table 2 Summary characteristics of the measured SM

2019	Woven fabric		82469.0 m			547 rolls			
Tests 42	**Length [m]**	**Width [cm]**	**Surface mass [g/m²]**			**Cross evaluation – width**			
General evaluation			**Left**	**Middle**	**Right**	**Average**	**StDev**	**C Interval**	**CV**
Average	151.21	149.02	91.24	90.44	90.74	90.81	1.26	3.14	**1.39**
StDev	22.67	1.33	2.10	1.97	2.10	1.75	0.56	1.38	**0.61**
C Interval	7.06	0.42	0.65	0.61	0.65	0.54	0.17	0.43	**0.19**
CV	14.99	0.90	**2.30**	**2.17**	**2.32**	1.92	44.07	44.07	44.12

Table 3 Asymmetry and excess of the SM

Surface mass W [g/m²]						
distribution	**moment of 3rd rank - μ(3)**			**moment of 4th rank - μ(4)**		
curve	**W left**	**W middle**	**W right**	**W left**	**W middle**	**W right**
statistical	-3.1171	-1.3025	7.2128	50.6904	30.0676	60.8130
evaluation	*asymmetry K=μ(3)/S³*			*excess E=μ(4)/S⁴*		
	-0.3371	-0.1712	0.7768	-0.3880	-0.9907	0.1163
	16.0450			1341.1560		
n=42	S_K			S_E		

In Table 3 "K" is the asymmetry indicator (Skewness) of the distribution curve, "E" is the Kurtosis, "S_K" is the standard deviation of the K, "S_E" is the standard deviation of the E.

4.2 Discussion of experimental results

The first check shows that the conditions for a uniform distribution of the longitudinal MUA, i.e. the asymmetry and excess of the distribution curves with respect to the statistical central moments of 3rd and 4th rank are many times smaller than the confidence intervals of the mathematical expectations in the samples. In this sense, the normal distributed longitudinal variation of the mass per unit area can serve as an estimate for the transverse variations.

After the verification, it is established that the unacceptable fabric rolls and their lots/batches are № 1, № 18, № 20 and № 34 (in Table 1 they are given in blue).

The experiments were performed with one type of material, but it is extremely uniform. However, differences were found in the mass per unit area at the exit of the weaving machine. Therefore, for other more uneven material, the conclusions drawn will be even more significant.

5 CONCLUSIONS

In the first place, the uniform distribution of the mass per unit area of the woven fabrics along the length and transversely, in the middle and at both ends, is simultaneously considered.

The proposed methodology for the practical evaluation of the uniform distribution of mass per unit area can equally be applied in the textile and apparel industries.

The proposed methodology is based on scientifically sound solutions to applied statistics and established practices in the approved international standards for quality management of the textile and apparel industry.

6 REFERENCES

1. Damyanov G.: Fabric Texture and Design of its Parameters, Coxmoor Publishing Company, Oxford, UK, 2009, 224 p., ISBN: 9781901892321
2. Shinohara T., Takayama J., Ohyama S., Kobayashi A.: Analysis of textile fabric structure with CT images, SICE 2003 Annual Conference (IEEE Cat. No.03TH8734), Fukui, Japan, 2003
3. Rahnev I.: Work cloth weave metrological selection, Textil i obleklo 1, 2006, pp. 21-27, ISSN 1310-912X
4. BDS 229-92:1994. Standard, Textile materials. Woven fabrics. Determination of the mass on a unity of length and the mass on an unity of surface, M09, Sofia
5. BDS EN 12751:2003. Textile. Samples getting to test fibres, yarns and fabrics, 044-0006018-1-0, Sofia
6. Germanova-Krasteva D.: Textile Testing and Analysis, TU Sofija - University Press, Sofija, 2012, pp. 321-322
7. Andonova S.: The influence of details' mass of textile materials on the duration of ironing, Tekstil i Obleklo 12, 2006, pp. 17-20, ISSN 1310-912X
8. Bassily M., Colver G.: Correlation of the area-mass transfer coefficient inside the drum of a clothes dryer, Drying Technology 21(5), 2003, pp. 919-944, https://doi.org/10.1081/DRT-120021692
9. Andonova S., Rahnev I.: Study of the stretching force of the needle's thread in the work with woollen textiles, IOP Conference Series: Materials Science and Engineering 2017, Volume 254, Textile Processing, 082002, http://iopscience.iop.org/article/10.1088/1757-899X/254/8/082002
10. Amudjev I.: Applying of the morphological method for analysis and synthesis of methods for finishing of external cylindrical surfaces by means of surface plastic deformation, Journal of Technical University of Gabrovo 34, 2007, pp. 19-25
11. Damyanov G.: Mathematical methods for the planning of an experiment in the research in the textile industry, IOT: Sofia, 1977

STUDY OF EFFECTIVENESS OF UV ELECTROMAGNETIC WAVES SHIELDING BY TEXTILE MATERIALS

Sergey Bereznenko[1], Natalya Bereznenko[2], Viktoria Vasylenko[1], Nina Merezhko[3], Julia Koshevko[4], Serhiy Horiashchenko[4], Larisa Shpak[5], Olena Shkvorets[5], Oleksandr Saukh[5] and Sergii Gakhovych[3]

[1]Kyiv National University of Technologies and Design, Nemyrovycha-Danchenka Street 2, Kyiv, Ukraine
[2]State Scientific Research Institute MIA of Ukraine, Y. Gutsalo Lane 4a, Kyiv, Ukraine
[3]Kyiv National University of Trade and Economics, Kyoto Street 19, Kyiv, Ukraine
[4]Khmelnytskyi National University, Instytutska Street 11, Khmelnytskyi, Ukraine
[5]Kherson State University, University Street 27, Kherson, Ukraine
s_bereznenko@i.ua

Abstract: *The article is devoted to a study of effectiveness of ultraviolet (UV) electromagnetic radiation shielding by textile materials. Degree of protection from UV radiation and their ability to be used as a protective material was determined. Polyethylene terephthalate (PET) fabric having a high degree of absorption was investigated. Its modification by Cu increased protective properties and degree of absorption from UV radiation. Positive effect of Cu on the bleached calico was determined and indicated that it energy illumination significantly decreases. New kind of "sandwich" material, which consists of different materials: 2 layers of PET fabric, 2 layers "Sharnet" and 3.0% silicon dioxide, was developed. Developed material was characterized by high level of protection from electromagnetic radiation.*

Keywords: *textile materials, electromagnetic radiation, textile composite materials, electromagnetic field, shielding.*

1 INTRODUCTION

Today, a large number of textile materials is used in everyday people life. The clothing that was made from textile materials provide various functions. A protective function is most important. The clinical, physiological and epidemiological studies have shown that UV electromagnetic radiation (UVEMR) has a negative influence on the human body. Genetic changes, lower immunity and a fatigue are very dangerous for human [1].

The problem of protecting a human body from UVEMR has become a very important through an extremely high level of development of electronic equipment (computers, mobile phones, home appliances, health diagnostics and physiotherapy, etc.). That is why development of a modern effective methods and means of individual protection of the human body from artificial UVEMR is one of the most urgent tasks for scientists [2]. Protective textile materials and their products must play a special role in this task. A long-term durable and stable fabric for all-weather outdoor application was conducted in the study [3]. In this work, a facile dip coating design has been adopted to fabricate PEG/PEDOT: PSS treated fabric. The enhancement in electrical conductivity was found. The exclusive "void-filler" inclusion in the whole fabric has been evaluated in order to correlate their microstructure (both 2D and 3D) along with the desirable conducting features. But, this work is limited by X-band electromagnetic spectrum.

Conductive filler loading in the polymer matrix is a common practice to transform insulative polymers to conducting composites [4]. In case of the textiles, a highly promising approach has been coined by virtue of fabricating with conductive adhesive homogeneous coating. Fabrication approach has been developed by two-stage of wet mixing technique including synthesis of silver nanoparticles, decorated by graphene sheets (rGO/Ag). In this work the novelty lies in the choice of conductive material and coating to make lightweight and flexible smart electronic fabric. However, the electromagnetic interference (EMI) shielding effectiveness of the prepared coated textile measured only in the long range X-band (8.2-12.4 GHz). The verification of conducted research, in terms of the reliability and effectiveness of textile materials, is necessary.

A high mechanical strength of a cotton fabric with EMI shielding properties has been developed [5]. The coated fabric was tested under rigorous environmental and practical factors, which provide information regarding the sustainability of the fabric for outdoor applications. For extensive functionality an EMI shielding of the coated fabric was experimented under some simulated practical forces. But, there is no application technology of silver nanoparticles deposition in the fabric surface.

In the work [6], conductive natural high-performance fabric was prepared by plasma assisted coating of cotton fabrics with different conductive polymers in presence or absence of silver nanoparticles. By changing the type of conductive polymer and the incorporation of silver nanoparticles, high-performance fabrics with altered or improved multifunctional properties were obtained. Such materials receive antibacterial, electrical conductivity, thermochromism, acid sensitivity and responsiveness to metal ions for a variety of potential purposes, such as biomedical, geo-textile and antistatic applications. However, the conducted studies do not cover a protective property from UVEMR. An intelligent cotton fabric was fabricated [7] using a non-ionic surfactant based on the macro structured carbonaceous coating through the 'knife-over-roll' technique. Developed fabric shows an outstanding EMI shielding efficiency over the X-band frequency range (8.2-12.4 GHz). But, proposed technology doesn't use lover frequency which can lead to a decrease of all the proposed characteristics.

There is a need to create a new concept of textile composite materials (TCM) that screen EMR across a wide range of electromagnetic waves lengths [8-10]. Development of the textile "sandwich" structures, which are obtained by stratification of two or more layers of textile fabrics of a certain raw material composition, is actual task. The maximum number of layers is determined by several factors, main of them – required degree of protection and thickness of the textile composite.

It is possible to modify each of the surfaces of textile layers and an interlayer space (nano- and polydispersed fillers, nano-layers of metal or pigments). Thus, layered textile structures can be extremely effective in absorbing electromagnetic field (EMF), especially for electronic shielding of means [11]. EMR in all wavelengths affects on the human health and has long-lasting effects, according to ecologist's and doctors-hygienists [12]. Electric fields of industrial frequency are surrounding a man every day through radiation from wiring, lighting, household appliances, power lines, etc. It is proved, that effect of these EMFs on humans is more dangerous than radiation [13].

Statistics showed: increasing magnetic field from 0.1 to 4 μT increases in several times the risk of developing leukemia in children. In general, oncological diseases occur in a twice where the magnetic field value is 0.3 μT or higher. The Swedes introduced a hygienic standard of a low-frequency magnetic field of 0.2 μT value basis of these data. Similar results were obtained in the USA, Canada, France, Denmark and Finland, but today in many countries of the world it is considered safe level of a low-frequency magnetic field 0.2 μT [14].

Ukraine has developed standards and norms that are toughest in the world [15]. The standards (health standards) determine the values of EMF parameters, which don't cause disease or abnormal health in population (Table 1).

Table 1 Exceeding limits of EMR standards

EMR source	Radiation indicators [μT]	Excess [times]
Wire from the lamp	0.7	3.5
Refrigerator	1	5
Coffee maker	10	50
Electric shaver and hair dryer	15-17	75-85
Mobile phone	40	200
Computer	1-100	5-500
Microwave oven	8-100	40-500
Tram, trolley bus	150	750
Metro	300	1500

Electromagnetic pollution has become so serious that the World Health Organization has considered this problem as one of the most relevant for humanity. Experts consider EMR one of the most powerful factors with is a possible catastrophic effect on the human gene pool. Nowadays it is necessary to have fundamentally new methods of diagnostics and an appropriate metrological base in comparison with the existing.

The mechanism of EMF effect on human body has not been thoroughly studied. The threshold intensity of thermal action of electromagnetic waves is normalized depending on frequency range, in particular on electrical and magnetic component of EMF [16-18].

The analysis of scientific, technical and patent literature shows that a specially designed multi-layered textile structures as protection means from UV electromagnetic waves have not been sufficiently investigated. That is why this study is an actual.

The motivation of this study is to protect a human from UV electromagnetic waves. The main goals are: study of effectiveness of UV electromagnetic waves shielding by textile materials; developed a special textile sandwich material for protect peoples from UV electromagnetic waves.

2 EXPERIMENTAL

The different tools and measures are applied to protect a person from the action of EMF: distance, shielding radiation sources, reduction of radiation directly at the source of radiation, establishment of sanitary boundaries around the EMF source, screening of workplaces, allocation of radiation zones, remote control in a screened room, medical examination, shortening of a working days, using personal protective equipment and other.

Comparative studies with conductive filaments (carbon or steel) were conducted first of all.

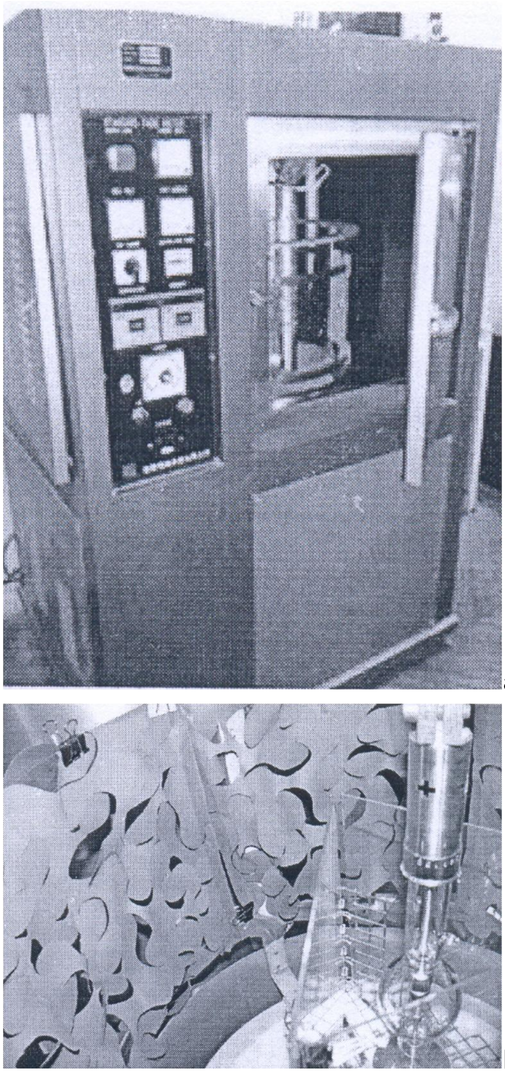
The layered textile composite materials (TCM), which screen UVEMR over a wide range of electromagnetic wavelengths, were investigated.

Each textile layer in "sandwich" structure can be further modified by metal nanoparticles.

The interlayer space in the TCM can also be modified by the selected fillers. Such structure of TCM will provide additional multiple reflection, dispersion, refraction and partial absorption of UVEMR. The maximum number of layers is determined by several factors, main of them – required degree of protection and thickness of textile composite.

2.1 Equipment

When using the mixture of highly dispersed fillers, which have different dispersion and chemical nature (metal, organic, ceramic, carbon, etc.), their particles will be "selectively" absorbed, reflect, disperse and refract the UVEMR with different wavelengths. Polydispersity of fillers of different chemical nature and possible additional modification of surface of mineral fillers metal nanolayer will increase the level of reflection. As a result is reducing the permeability of UVEMR through textile composite material as a whole.



a)

b)

Figure 1 Experimental equipment, Fadometer LE-1 model KT7035: a) external view; b) internal view

The relative absorption of UVR in the studies of degree of UVEMR screening was conducted. The basis of this method is the measurement of energy illumination (*E*) in front and behind of the sample under the action of UVR. The samples were irradiated on Fadometer LE-1 model KT7035 (Figure 1).

The UVR source is xenon arc lamp with air-cooled thermal and light filters of Osram Xenon Short Arc Display/optic lamp, XBO^{R} Xtreme Lite with a wavelength range of 200-400 nm.

The irradiation intensity and the irradiation dose were measured on a Tensor-71 UV radiometer. The scheme of Fadometer is given in Figure 2.

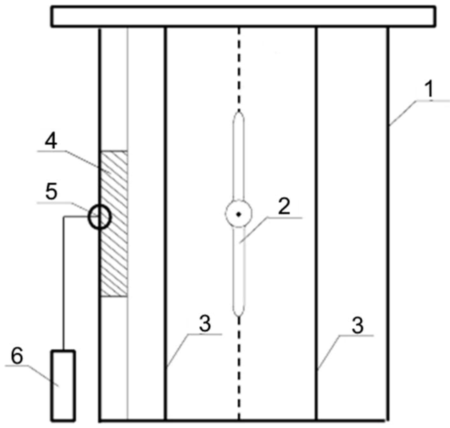


Figure 2 Scheme of Fadometer: 1) frame for placement of textile samples; 2) xenon lamp of arc type; 3) triangular prism filter; 4) textile material sample; 5) UV radiometer Tenzor-71; 6) electronic unit with UV radiometer screen

There is an opportunity to determine a degree of protection from UVR and ability for use as a protective material for different textile materials, using Fadometer LE-1.

2.2 Materials

Textile materials used in the experimental studies were polyethylene terephthalate (PET) fabric, bleached calico and developed "sandwich" material. New kind of "sandwich" material that characterized of a high degree of protection was proposed. Its characteristics are described below.

PET fabric - art. AS 703 with conductive thread (99% PET and 1% carbon thread); fabric structure - simple weave; thickness 1 mm; surface density 114 g/m^2;

Bleached calico - 100% cotton; fabric structure - simple weave; thickness 1 mm; surface density 140 g/m^2;

Adhesive material – "Sharnet" 3116 is fusible polymer mesh (copolymer of ethylene and vinyl acetate) with melting point of the material 90°C; thickness 1 mm and surface density complex.

"Sandwich" material - two-layers textile composite (2 layers of PET fabric, 2 layers "Sharnet" 3116, 3.0% silicon dioxide).

Samples of multi-layered textile materials with 1 mm thickness where obtained by the adhesive bonding method. Special press EB-K2 was used for this purpose and for a textile materials duplication. The press is equipped with means for regulating of the pressing force with a heating temperature of pillows up to 200°C.

3 RESULTS AND DISCUSSION

Experimental study, that was conducted, allowed to explore different textile materials, determined their degree of protection from UVR and their ability to be used as a protective material. The degree of absorption of UVR by textile material is calculated as differences ratio between radiation intensity of xenon lamp and energy illumination by sample when dividing by radiation intensity of xenon lamp.

The research allowed to determine a nature of protection of different fabrics from UVR. Investigated, that PET fabric artic AS 703 have a high degree of absorption in the range A and in the range B. Modification of such material by Cu greatly increases its protective properties from 4.2 W/m^2 to 0.2 W/m^2 after sample.

The energy illumination decreases significantly for range A (on 4 W/m^2) and for range B not significantly 0.2 W/m^2. Also increases degree of absorption from UVR: range A on 7.8% and range B on 2.3%. In general, it has a positive effect on overall level of human protection from electromagnetic radiation and shielding effectiveness.

The positive effect of Cu on bleached cotton fabric was determined. Energy illumination significantly decreases for range A (on 4.1 W/m^2) and for range B 4.4 W/m^2. Defined increasing degree of absorption from UVR: range A on 8% and range B on 49.4%. For bleached cotton fabric in comparison with PET fabric artic AS 703 observed a significant improvement of characteristics. General level of increasing is in average of 28.7%. It has a positive effect on overall level of man protection from electromagnetic radiation and shielding effectiveness.

Such positive effect is produced by Cu, which penetrates into the fibers of fabric, providing guaranteed saturation and protection from action of ionizing radiation. Also, saturation of fabric fibers with particles of Cu has an antibacterial effect.

“Sandwich” material has a high degree of protection in the range A (98.6%) and average degree of protection in the range B (72%). A special structure of material improves characteristics and performs a multifunctional value. That indicates increasing protective properties of PET fabric and will help to protect peoples from a harmful effect.

During the proposed "sandwich" method, the thickness of the textile material was controlled by special equipment. The movement of EM waves can be detected through the two layer "sandwich" model.

A wave that reached to the first layer passes through it on a certain principle. It is partially reflected, absorbed by the textile layer, passes into an interlayer space and “meets” with the second textile layer. These processes are repeated on a second layer, especially if the textile composite is multi-layered.

A wave that meets with another textile layer is behaves similarly. But, the degree of its passing is a greatly reduced. This principle of passing through different layers is typical for fabrics. Thus, their ability to reflect UV electromagnetic waves will depend on the number of layers of materials and their characteristics.

The numbers of absorption were measured by according to experimental purposes and mathematical methods of statistics. The mean values and 95% confidence intervals of means where used in a researches. The statistical error of the studies did not exceed 5%, which is in the acceptable limits. The minimum number of experiments was determined by the methods of mathematical statistics. It was 32 experiments in our investigations. Average values of the characteristics were calculated after the experiments. The results are presented on Figures 3-5.

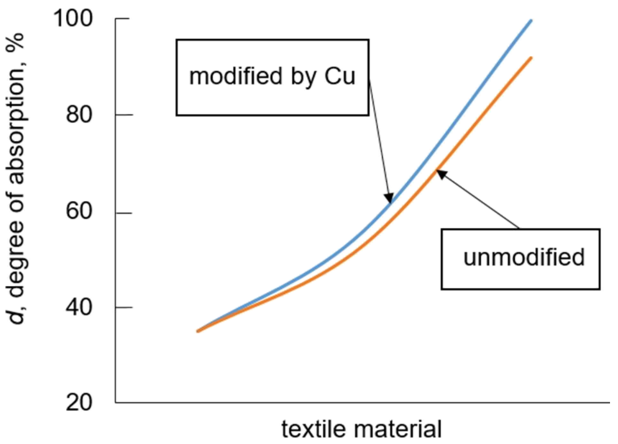


Figure 3 Graphical dependence of the change of absorption degree *d* for PET fabric art. AS 703

PET fabric art. AS 703 after modifying by Cu is characterized by growing of a degree of absorption (Figure 3). Modification of such material by Cu increases its protective properties from 4.2 W/m^2 to 0.2 W/m^2. An energy illumination decreases for range A (on 4 W/m^2) and not significantly for range B 0.2 W/m^2. A degree of absorption from UV radiation it is also increases for range A on 7.8% and for range B on 2.3%.

After modifying by Cu a bleached calico increases on 8% in comparison with unmodified sample (Figure 4). There is a positive effect of Cu on a bleached calico. Energy illumination decreases significantly for range A on 4.1 W/m^2 and for range B on 4.4 W/m^2. Defined degree of absorption from UVR range A is 8%

and for range B 49.4%. It has a positive effect on overall level of man protection from electromagnetic radiation and shielding effectiveness.

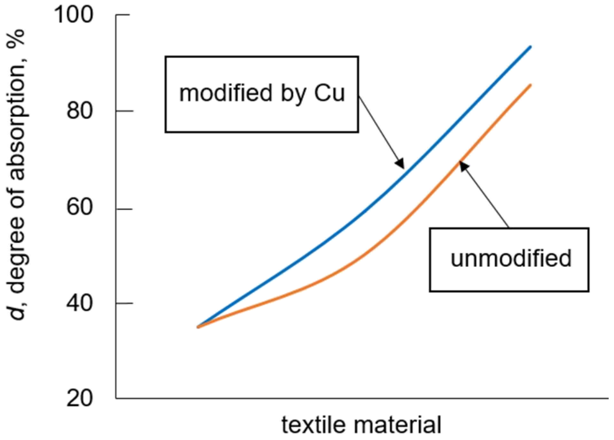


Figure 4 Graphical dependence of the change of absorption degree *d* for bleached calico

Developed "sandwich" material is characterized by a high degree of protection from UV radiation (Figure 5) in range A 98.6% and in range B 72%. Developed material is characterized by improved protection from electromagnetic radiation.

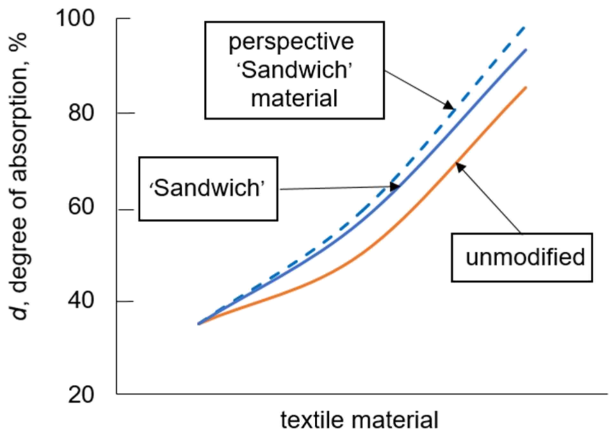


Figure 5 Graphical dependence of the change of absorption degree *d* for developed "sandwich" material

Therefore, a new method for modifying metal nanoparticles has been proposed and investigated. It is based on the method of impregnation in a solution of salt followed by the recovery of metal ions, in the structure and on the surface of textile material (for example, copper sulphate solution). This technique can be used to obtain metal nanoparticles from soluble metal salts of the first group; some salts of the second group of metals (chlorides, bromides, iodides, nitrates) and some others. The proposed method is simple, available and effective (cheap and available reagents, treatment is possible on the painting equipment); can be used for porous substrates of any chemical nature.

There are some drawbacks of research. A much larger number of different materials should be tested to increase variability and quality of experiments. Proposed two-layer textile composite "sandwich" material in range B has insufficient characteristics for quality human protection (Table 2). The series of experimental studies should be carried out in order to improve this parameter. It will provide the opportunity to eliminate the disadvantages and enhancing the characteristics of the proposed material. These disadvantages do not impair conducted researches, but indicate a prospective ways of further research.

4 CONCLUSIONS

The studies of effectiveness of electromagnetic radiation shielding by a textile materials were conducted and explored different textile materials. The experimental results of this work can be summarized as follows:

- The degree of protection from UV radiation for different materials and their ability to be used as a protective material was determined;
- A nature of protection of different fabrics from UVR was determined;
- PET fabric art. AS 703 have a high degree of absorption. Its modification by Cu increases a protective properties and degree of absorption from UV radiation. Energy illumination decreases for range A on 4 W/m^2 and for range B on 0.2 W/m^2. A degree of absorption from UV radiation it is also increases, for range A on 7.8% and for range B on 2.3%.

Table 2 Research results of determining UV absorption efficiency of radiation by textile materials

№	Sample characteristics	Energy illumination [W/m^2] (range A*) in front of the sample	Energy illumination [W/m^2] (range A*) behind of the sample	Degree of absorption in range A d_A [%]	Energy illumination [W/m^2] (range B**) in front of the sample	Energy illumination [W/m^2] (range B**) behind of the sample	Degree of absorption in range B d_B [%]
PET fabric, art. AS 703							
1	unmodified	51.1	4.2	91.8	8.9	0.5	94.4
2	modified by Cu		0.2	99.6		0.3	96.7
Cotton fabric							
1	unmodified	51.1	7.5	85.3	8.9	5.1	42.7
2	modified by Cu		3.4	93.3		0.7	92.1
'Sandwich' material, two layer textile composite (2 layers of PET fabric art. AS 703, 2 layers "Shamet" 3116, 3.0% silicon dioxide)							
1	1AS+2Sh+SiO_2+1AS	48.2	0.7	98.6	9.6	2.7	72

Note: *range A – 315-400 nm; ** range B – 315-280 nm

- There is a positive effect of Cu on a bleached calico. Energy illumination decreases for range A on 4.1 W/m^2 and for range B on 4.4 W/m^2. There was defined an increasing degree of absorption from UVR, for range A 8% and for range B 49.4%. It has a positive effect on overall level of man protection from electromagnetic radiation and shielding effectiveness.
- A new kind of “sandwich” material was developed (2 layers of PET fabric art. AS 703, 2 layers “Sharnet”, 3.0% silicon dioxide). It is characterized by a high degree of protection from UV radiation (range A 98.6%; range B 72%). Developed material is characterized by a high level of protection from electromagnetic radiation.

5 REFERENCES

1. Diachok T., Bereznenko S., Yakymchuk D., Aleksandrov M., Bakal V., Budzynskyi M.: Development of equipment for complex man protection from artificial non-ionizing EMR, Vlakna a Textil (Fibres and Textiles) 26(2), 2019, pp. 9-13
2. Rivero P.J., Urrutia A., Goicoechea J., Arregui F.J.: Nanomaterials for functional textiles and fibers, Nanoscale Research Letters 10(1), 2015, pp. 1-22, https://doi.org/10.1186/s11671-015-1195-6
3. Ghosh S., Ganguly S., Remanan S., Das, N.C.: Fabrication and investigation of 3D tuned PEG/PEDOT: PSS treated conductive and durable cotton fabric for superior electrical conductivity and flexible electromagnetic interference shielding, Composites Science and Technology 181, 2019, 107682, https://doi.org/10.1016/j.compscitech.2019.107682
4. Ghosh S., Ganguly S., Das P., Das T.K., Bose M., Singha N.K., Das A.K., Das N.C.: Fabrication of reduced graphene oxide/silver nanoparticles decorated conductive cotton fabric for high performing electromagnetic interference shielding and antibacterial application, Fibers and Polymers 20(6), 2019, pp. 1161-1171, https://doi.org/10.1007/s12221-019-1001-7
5. Ghosh S., Remanan S., Mondal S., Ganguly S., Das P., Singha N.K., Das N.C.: An approach to prepare mechanically robust full IPN strengthened conductive cotton fabric for high strain tolerant electromagnetic interference shielding, Chemical Engineering Journal 344, 2018, pp. 138-154, https://doi.org/10.1016/j.cej.2018.03.039
6. Ahmed H., Khattab T.A., Mashaly H.M., El-Halwagy A.A., Rehan M.: Plasma activation toward multi-stimuli responsive cotton fabric via in situ development of polyaniline derivatives and silver nanoparticles, Cellulose 27, 2020, pp. 2913-2926, https://doi.org/10.1007/s10570-020-02980-7
7. Ghosh S., Mondal S., Ganguly S., Remanan S., Singha N.K., Das N.C.: Carbon nanostructures based mechanically robust conducting cotton fabric for improved electromagnetic interference shielding, Fibers and Polymers 19(5), 2018, pp. 1064-1073, https://doi.org/10.1007/s12221-018-7995-4
8. Ibanescu M., Musat V., Textor T., Badilita V., Mahltig B.: Photocatalytic and antimicrobial Ag/ZnO nanocomposites for functionalization of textile fabrics, Journal of Alloys and Compounds 610, 2014, pp. 244-249, https://doi.org/10.1016/j.jallcom.2014.04.138
9. Ilic V, Šaponjic Z, Vodnik V, Molina R, Dimitrijevic S, Jovancic P, Nedeljkovic J, Radetic M.: Antifungal efficiency of corona pretreated polyester and polyamide fabrics loaded with Ag nanoparticles, Journal of Materials Science 44, 2019, pp. 3983-3990, https://doi.org/10.1007/s10853-009-3547-z
10. Textor T., Fouda M., Mahltig B.: Deposition of durable thin silver layers onto polyamides employing a heterogeneous Tollens’ reaction, Applied Surface Science 256(8), 2010, pp. 2337-2342, https://doi.org/10.1016/j.apsusc.2009.10.063
11. Babaahmadi V., Montazer M.: A new route to synthesis silver nanoparticles on polyamide fabric using stannous chloride, The Journal of the Textile Institute 106(9), 2015, pp. 970-977, https://doi.org/10.1080/00405000.2014.957468
12. Montazer M., Seifollahzadeh S.: Enhanced self-cleaning, antibacterial and UV protection properties of nano TiO_2 treated textile through enzymatic pretreatment, Photochemistry and Photobiology 87(4), 2011, pp. 877-883, https://doi.org/10.1111/j.1751-1097.2011.00917.x
13. El-Gabry L.K., Allam O.G., Hakeim O.A.: Surface functionalization of viscose and polyester fabrics toward antibacterial and coloration properties, Carbohydrate Polymers 92(1), 2013, pp. 353-359, https://doi.org/10.1016/j.carbpol.2012.08.108
14. Radic N., Obradovic B.M., Kostic M., Dojcinovic B., Hudcova M., Kuraica M.M., Cernak M.: Deposition of gold nanoparticles on polypropylene nonwoven pretreated by dielectric barrier discharge and diffuse coplanar surface barrier discharge, Plasma Chemistry and Plasma Processing 33, 2013, pp. 201-218, https://doi.org/10.1007/s11090-012-9414-8
15. Mihailovic D., Saponjic Z., Vodnik V., Potkonjak B., Jovancic P., Nedeljkovic J., Radetic M.: Multifunctional PES fabrics modified with colloidal Ag and TiO_2 nanoparticles, Polymers for Advanced Technologies 22(12), 2011, pp. 2244-2249, https://doi.org/10.1002/pat.1752
16. Ibanescu M., Musat V., Textor T., Badilita V., Mahltig B.: Photocatalytic and antimicrobial Ag/ZnO nanocomposites for functionalization of textile fabrics, Journal of Alloys and Compounds 610, 2014, pp. 244-249, https://doi.org/10.1016/j.jallcom.2014.04.138
17. Mihailovic D., Saponjic Z., Molina R., Puac N., Jovancic P., Nedeljkovic J., Radetic M.: Improved properties of oxygen and argon RF plasma-activated polyester fabrics loaded with TiO_2 nanoparticles, ACS Applied Materials & Interfaces 2(6), 2010, pp. 1700-1706, doi: 10.1021/am100209n
18. Mihailovic D., Saponjic Z., Molina R., Radoicic M., Esquena J., Jovancic P., Nedeljkovic J., Radetic M.: Multifunctional properties of polyester fabrics modified by corona discharge/air RF plasma and colloidal TiO_2 nanoparticles, Polymer Composites 32(3), 2011, pp. 390-397, https://doi.org/10.1002/pc.21053

FORMATION OF HYDROPHOBIZED LEATHER OF SPECIAL PURPOSE

Anatolii Danylkovych and Oksana Romaniuk

Kyiv National University of Technologies and Design, Nemirovich-Danchenko Street 2, Kyiv, Ukraine
knutdromanuk@gmail.com

Abstract: *The influence of the chemical composition of the alkene-maleic composition on the water resistance, hygienic and physico-mechanical properties of the hydrophobized chrome tanned leather obtained from the leather of open cow is studied. It is established that hydrophobization of the leather semi-finished product with an alkene-maleic composition significantly increases the water resistance of the obtained leathers compared to unmodified ones, which results in an increase in the water-bathing time in dynamic conditions 35-47 times depending on the thickness and stability of the elastic-plastic properties of the leather during cyclic watering-drying. It is shown that with an increase in the thickness of hydrophobized leather from 1.8 to 2.4 mm, the water vapor permeability and air permeability decrease, respectively, by 1.2-1.6 and 1.5-1.7 times, at the same time, their hygroscopy increases by 10%. The complex physico-mechanical and hygienic properties of the leather, formed by the developed technology of hydrophobization of the chrome semi-finished product using alkene-maleic composition, meet the requirements of DSTU 2726-94 Leather for shoes and DSTU 3115-95 Leather for garments. As a result of the research, a technology for hydrophobization of semi-finished chrome tanned leather can be implemented in industrial production for the manufacture of water-repellent leather for special purposes.*

Keywords: *hydrophobization technology, semi-finished chrome tanning, alkene-maleic composition, special-purpose elastic leather, hygienic and elastic-plastic properties.*

1 INTRODUCTION

Natural leather, in comparison with synthetic materials, has a number of valuable advantages. This applies primarily hygienic properties. Such properties are due to the peculiarities of the porous structure of natural leather, the pore volume of which reaches 60%. At the same time, an important role belongs to such properties as pore size, their shape and size distribution. It should be noted that 45% of the pore volume can be considered macropores with sizes of 20-40 µm and 10% of micropores with sizes of 0.06-0.12 µm [1]. The nature of the porous structure of the leather and its chemical composition substantially depend on the effectiveness of the colloid-chemical processes of the technological cycle of processing raw leather.

For comfortable use of products made of natural leather in extreme conditions, it is necessary that the shoe upper material provides good vapor permeability, but is resistant to moisture in both static and dynamic conditions. Therefore, in after tanning processes, the chemical structure of natural leather is modified using different methods and compositions of different chemical composition.

During the formation of the leather of high water resistance, two types of composite materials are mainly used [1], taking into account the method of their use. At the same time, fatty and hydroxycarboxylic acid esters and their derivatives, oxyethylated fatty acids, nitrogen-containing compounds, etc., are used for volumetric hydrophobization of the leather structure and others. It is known the use of polyorganosiloxanes with polyacrylates or fatty acid amides in the hydrophobization of a semi-finished product of chromium-free tanning [2]. The use of fluorine-containing silanes and polymers based on fluorocarboxylic acids [3] makes it possible to improve the performance properties of shoes made of leather split. Fluorosilane and fluoro siloxane have a persistent hydrophobic effect of leather tissue [4] with an increase in its strength. At the same time, wetting and moisture holding capacity are reduced by three times, its watering increases from 5 to 170 minutes and the elasticity of the hair without reducing hygienic properties.

The use of the maleic acid ester copolymer and α-hydroxypropyldimethylsiloxane at a ratio of 2:1, acrylic acid and 1-octadecane by the authors of works [5, 6] made it possible to significantly increase the resistance of leather and elasticity of the leather. When used to hydrophobize a semi-finished product of polyethylhydroxyloxane acrylate polymers [7], tanning and film-forming effects are observed. In work [8], the authors used to hydrophobize compositions based on polyvinyl ethylene dihydroxychlorosilane, which was applied by spraying. Hydrophobic leather surface with a wetting angle of 110° is achieved in this case. This effect is reduced to 94° after 300 cycles of erasure on the device "ACL-1". When using the composition of organosilicon compounds modified with fluorotoluene, a significant reduction in water wetting and water penetration of the leather in dynamic conditions is achieved [9]. This increases the heat-shielding properties of the material. An increase in the hygienic properties of hydrophobized leathers has been established [10] due to the use of a composition that includes the reaction products of an amino alcohol with fatty acids of vegetable oils of the C_{12-22} fraction and boric acid at their molar ratio of 2:1:1 in mineral oil.

To determine the effect of retanning agents of synthetic polymers and plant extracts in the hydrophobization of white leather, fluoride-woven compound was used [11]. At the same time, the hydrophobic effect is more reduced due to the use of acrylic polymer and Inditan RS dispersing agent in addition. The effect of fat emulsions based on rapeseed oil and fish oil triglycerides on the sorption-desorption process and the mechanism of water diffusion into the structure of the processed semi-finished product was investigated by the authors of [12]. The dependence of the diffusion of water into the semi-finished product on the humidity of the medium is established. The use of non-equilibrium low-temperature plasma can be attributed to innovative methods of hydrophobization of semi-finished leather-fur [13, 14]. When using an argon/propane-butane gas mixture in the 70/30 ratio, as a result of the decomposition of hydrocarbons, carbon is formed, which is adsorbed on the surface of leather elements and ensures its long-lasting hydrophobization.

For improve the water resistance of the leather in dynamic conditions, Lubritan XS product of Lanxess (Leverkusen) and Rohm and Haas (Philadelphia), a special silicone polymer can be used by [15]. These two products can be used to obtain waterproof leather with individual properties of the desired quality of [15], however, the publication does not indicate the duration of the hydrophobic effect. Thus, despite the wide range of water-repellent compositions and various ways of using them, the results of determining the effect of waterproofing under dynamic conditions are practically absent. In this regard, it is difficult to objectively evaluate how the water-repellent action of the corresponding composition and methods of its use for the production technologies of elastic hydrophobic leathers.

The aim of research is studying the influence of the conditions of hydrophobization-retanning of a leather semi-finished chrome tanning using alkene-maleic compositions on the complex of structural-mechanical and operational properties of the leather. The following tasks were solved:

- determination of the effect of the composition of alkene-maleic-containing composition on the physico-chemical properties of the leather;
- study the effect of the thickness of the semi-finished product on the sorption-diffusion properties of the resulting leather;
- studies of the restorability of the porous structure of the hydrophobized leather and the physico-mechanical properties of the material obtained by the developed technology, while modeling the mode of its operation;
- establishment of hydrophobization parameters of leather semi-finished chrome tanning of various thickness.

2 MATERIALS AND METHODS

Samples of semi-finished chrome tanning products from cattle raw materials - medium open cow, manufactured according to the technology of Chinbar PJSC (Ukraine, Kyiv) and plane for 1.2-2.4 mm thickness were subject to research. Samples with a size of 180x300 mm were cut out from the area of a plane semi-finished blanked by the method of symmetrical strips. Prototypes after washing and neutralizing the subunit with the use of 7% vegetable extract of quebracho based on the weight of the semi-finished product. For the control samples, a mixture of acrylic polymer Relanal RCN-40 from the company Cromogenia-Units, S.A. (Spain), synthetic tanning material Relugan D from BASF (Germany) and Quebracho extract (China), wt.% respectively 3, 5 and 6. The hydrophobization of the chrome semi-finished product was carried out in a laboratory drum with a volume of 10 dm^3 while rotating at a speed of 12-14 min^{-1}. Prefabricated prototypes with thicknesses of 1.2; 1.8 and 2.4 mm (respectively, D-1.2, D-1.8, D-2.4) were treated with an alkene-maleic composition (AMC) containing an alkene maleate polymer (AMP) [16], oleic acid (OA) and cod liver oil (CLO) followed by fixing the ingredients of the composition of potassium alum (Table 1).

Control semi-finished unmodified samples (CU-1.8) after neutralization were treated with fish oil composition/sulfite fish oil composition/synthetic fat at a ratio of 1/4/5, and modified (CM-1.8) – only AMP. The resulting samples of the leather semi-finished product, after aging for 48 hours, were pressed, dried, moistened, kneaded, dried, stretched and conditioned for 24 hours.

The study of the chemical composition and physico-mechanical properties of the leather samples was carried out according to the methods of [17]. Moisture content in the leather was determined by gravimetric method at 100-105°C. The total ash was determined thermogravimetrically after oxidizing the sample (7.5 g) in porcelain crucibles at 600°C.

Table 1 Hydrophobization parameters of chrome tanned semi-finished product

Process	Reagent	Yield [%]	Duration [min]	Temperature [°C]
Washing	Water	200	10-15	32-36
Drain				
Neutralization	Water Sodium formate Sodium bicarbonate	120 1 1	60	32-36
Washing	Water	200	10-15	40-42
Drain				
Retanning-filling	Water Queberacho natural extract (solution) Sodium sulfite	70-80 6-7 0.6-0.7	60-80	40-42
Hydrophobization-fatting	Water Alkene-maleic polymer Oleic acid Cod liver oil	100 4.0-4.5 1.2-1.3 6.0-7.0	40-60	55-60
Fixation	Aluminum potassium sulfate Sodium formate	0.4-0.5 0.3-0.4	20-30	55-60
Washing	Water	200	10-15	22-25
Drain				

Note: The process duration, depending on the thickness of the planed semi-finished product

The content of substances extracted with organic solvents (unbound fat) was determined using a Zaichenko extraction apparatus. A crushed sample (5 g) within a paper shell was put into the extractor and solvent extraction with tetrachloromethane was carried out for 1.5 h. After solvent evaporation under vacuum, the fatty substances were dried in an oven at 128-130°C for 1 h. After cooling the flask in the desiccator, the flask with unbound fat was weighed and the mass fraction of unbound fat was calculated.

Bound fatty substances were determined after removal from a sample of UFS (unbound fatty substances) by their hydrolytic destruction with an alcoholic solution of sodium hydroxide, followed by extraction of fatty acids with diethyl ether. The protein content was estimated based on nitrogen content determined by the Kjeldahl method. Chromium content was determined by iodometric titration and expressed as the mass fraction of chromium (III) oxide.

Porosity of leather was determined by the ratio of pore volume to the sample apparent volume [%]. Volumetric yield was determined by the ratio of the volume of an air-dry leather sample to the volume calculated as a product of the sample mass and sample apparent density.

Vapor permeability was determined by desiccator method using sulfuric acid. The air permeability of the leather was determined by the volume of air that penetrated in 1 h through 1 cm^2 of the leather sample at a pressure difference on both sides of the sample of 1 kPa.

Hygroscopicity was determined by the increase in the mass of leather samples kept in a desiccator over water for 16 h. The mass of the air-dried samples were used for comparison. Moisture release was determined by the amount of moisture lost by the leather sample (hygroscopically moistened) during air drying for 8 h under normal conditions.

In determining the water wetting of leather in dynamic conditions (WDC), minutes, the used equipment "DWD-2" (RF) and "IG/IUP 10" by Giuliani (Italy) at a deformation rate of 24, 70, 120 and 52 min^{-1}, respectively. The properties of leathers with spherical deformation were evaluated on a DOTL device (Ukraine) using a punch with a hemisphere radius of 5 mm. The physico-mechanical properties of the output leathers, after contacting them with water at a temperature of 20-22°C for 24 hours, their drying in a free state and conditioning of the same duration were evaluated on a PT-250M (RF) machine at a deformation rate of 90 mm/min. At the same time, the following are determined: tensile strength [MPa]; elongation under load 9.81 MPa $L_{9.8}$ [%], and other indicators. Determination of stiffness [cN], and elasticity [%], indicators (respectively, S and E) was carried out on a DSE-12M device (RF) with cyclic drenching-drying of samples of hides of size 20-160 mm. The relative error in determining the sorption-diffusion parameters was 3-4%, the physico-mechanical characteristics were 5-7%.

3 RESULTS AND DISCUSSION

In this paper, a complex of studies of the physico-chemical properties of leather obtained using the results of a study of the effect of AMC composition on the physico-chemical properties of leather 1.8 mm thick are given in Table 2.

The data show that with an increase in the AMP content in the composition in the presence of oleic acid, the duration of watering under dynamic conditions at a deformation rate of 24 min^{-1} reaches an extreme value. The value of this indicator is stabilized for the composition of option 2 and compared with the control option is more than 32%.

Table 2 Physical and chemical properties of the leather, modified by alkene-maleic composition

Composition content	Ingredients [%]*			Indicators			
	AMP	OA	CLO	WDC-24	σ	$L_{9,8}$	S
1	3.75	0.90	5.50	187	22.0	29.0	26.0
2	4.25	1.20	4.50	317	23.5	30.0	25.8
3	4.75	1.40	3.50	290	22.8	25.0	29.5
CM-1.8	4.50	–	–	240	20.5	26.0	35.0

*Note: *semi-finished product mass*

In a similar way, as well as the water treatment of the leather, with changing composition of the composition, its physical and mechanical properties change. At the same time, the elasticity of the samples reaches a maximum value, and the minimum hardness for leathers obtained by modifying a semi-finished product with compositions of the same variants. Introduction to the modifying composition of oleic acid makes it necessary to increase the degree of CLO dispersion.

So, when modifying a chrome semi-finished product with an alkene-maleic mixture, the adequacy of the ingredients is, wt.%: AMP:OA:CLO as 4.25:1.2:4.5 achieved the hydrophobic effect of maximum magnitude. It is possible to obtain elastic leather with minimum stiffness and maximum elongation under a load of 9.81 MPa.

During the operation of leather products, especially hydrophobized, its thickness and layer-by-layer structure are essential, from which the effectiveness of the process of hydrophobization and, accordingly, operational properties of such products. The response of the structure of the modified leather, to a large extent, depends on the conditions of its deformation, the effectiveness of the hydrophobization, the interaction with the fibrillar structure of the leather semi-finished product of the modifier ingredients and their distribution in its volume.

According to the obtained data (Table 3), an increase in leather thickness is accompanied by an increase in the duration of its watering.

Table 3 Water wetting of leather with a modified alkene-maleic-content composition under dynamic conditions

Leather	Water wetting [min] at speed of specimen deformation [min^{-1}]			
	24	*52*	*70*	*120*
D-1.8	315	276	243	190
D-2.4	337	298	265	207
CM-1.8	240	226	200	158
CU-1.8	9	7	5.5	4

At the same time, the duration of water treatment of modified leather is significantly longer compared to control-modified and unmodified leather, especially compared to unchanged, respectively, by 1.2-1.3 and 35-47 times, depending on the rate of deformation of the samples.

That is, the effectiveness of the hydrophobization of the leather structure is manifested in the degree of reduction of watering with an increase in the rate of deformation of its samples. At the same time, the increase in the deformation rate is five times, which is accompanied by a decrease in the length of the water wetting by 1.6-1.7 times.

Additional information on the interaction of hydrophobized leather with water can be obtained by examining wetting in static conditions. The kinetics of wetting of the modified leather of prototypes D-1.8 (Figure 1) indicates a significant increase in mass only after five hours of contact with water, and after 24 hours their mass increases to 38%. Non-hydrophobized samples after 1 h increase the mass to 75%, reaching 160% in a day. Compared to the control-modified samples, the prototype has a lower degree of wetting at 5 and 24 hours by 33 and 17%.

Thus, the use of an alkene maleate composition in the presence of oleic acid makes it possible to significantly reduce the hydrophilicity of the leather structure, especially when compared with the unmodified version. The research results of the effect of the thickness of the hydrophobized leather on the complex of its sorption-diffusion characteristics are given in Table 4.

Table 4 Sorption-diffusion properties of the developed leather

Indicator		Leather		
		D-1.8	*D-2.4*	*CU-1.8*
Porosity [%]		55.0	57.0	51.0
Volume yield [%]		243.0	256.0	217.0
Vapor permeability [$mg/cm^2 \cdot h$] from the side	- flesh - facial	11.2 2.3	7.1 1.9	14.0 3.9
Air permeability [$cm^3/cm^2 \cdot h$] from the side	- flesh - facial	790.0 630.0	540.0 370.0	370.0 290.0
Hygroscopy [%]		12.1	13.3	11.7
Water-yielding capacity [%]		5.7	5.1	2.6

The increase in the porosity of the hydrophobized leather in comparison with the control samples may indicate the formation of a more developed fibrillar structure. This leads to an increase in the volume output of the leather by 12-18% and the preservation of its finely dispersed fibrous structure after carrying out drying and moisturizing processes and operations.

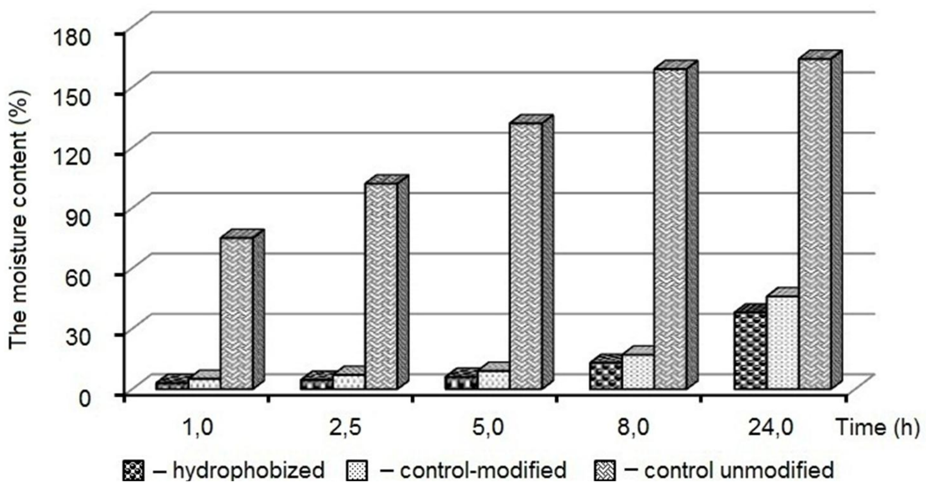


Figure 1 Wetting kinetics of leather

A significant increase in air permeability of the research leather D-1.8 and D-2.4 compared to unchanged by 2.1-2.2 and 1.3-1.5 times, respectively, may indicate the presence of a significant number of through pores. The higher relative air permeability of the leathers from the flesh side compared with the control sample indicates an increased porosity of the flesh layer of hydrophobized leather.

The effect of vapor permeability of hydrophobized leather compared to unchanged may be due to the complex transport mechanism of water vapor based on sequential processes of their sorption and desorption. This may indicate the presence of a significant number of pores of smaller sizes in the leather D-1.8, which facilitate the process of condensation of water vapor, on the one hand, and complicate their transportation through the thickness of the leather. Features of the porous structure of experimental samples explain the nature of the change in hygroscopy and moisture return of hydrophobized leather, which depend on the thickness and composition of hydrophobic-fat composition. Thus, the moisture return of the leather, the fattened, and the alkene-maleic composition with the addition of oleic acid is 2.0-2.2 times higher than that of the non-hydrophobized leather.

So, the conducted studies indicate a significant influence of the hydrophobization process both on the nature of the porous structure of the leather – the ratio of micro- and macropores, and hydrophilicity, due to the interaction of the ingredients of alkene - maleic - content compositions with the surface of the fibrillar collagen structure of the chrome semi-finished product. The inadequacy of changes in the indicators of hydrophobized leather compared with only their collagen structure, which in terms of air permeability, moisture return and volume output significantly exceeds the non-hydrophobized, is established.

Analyzing the effect of leather thickness on its chemical composition (Table 5), it can be noted that modified leather is characterized by a high content of bound fatty substances. It should be noted that the amount of chemically related fatty substances in the leather structure is greater in the case of a smaller thickness.

Table 5 The chemical composition of hydrophobized leather

Mass content [%]	Leather		
	D-1.8	***D-2.4***	***CU-1.8***
moisture	11.26	11.98	12.32
chromium oxide	4.38	4.32	4.43
ash	6.53	6.36	6.18
substances extracted with organic solvents (SEOS)	9.12	8.27	8.34
bound fatty substances	4.18	3.98	1.32
crural substance	61.57	62.69	65.38

Note: Mass content of leather ingredients are given in terms of absolutely dry substance

Due to the layer-by-layer study of the hydrophobized leather D-2.4 (Figure 2), it is established that the content of both bound and unbound fatty substances in large quantities is contained in the facial layer.

This distribution of fatty substances is due to the structural features of the facial layer after hair removal and destruction of hair follicles located in the papillary layer. The content of bound fatty substances in the papillary and flesh layers is 2.2 times and 1.6 times higher than the middle layer. The obtained result may be due to the effective interaction of the ingredients of the developed composition with the structure of the leather semi-finished product. At the same time, a decrease in the chromium (III) oxide content in the middle layer of the leather is observed as compared with the outer layers by 30-40%.

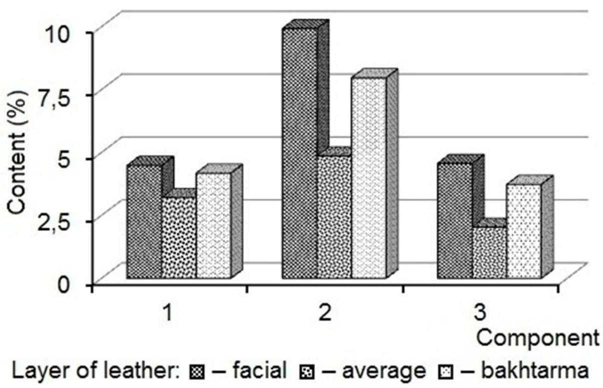


Figure 2 Layered content in leather material [wt.%]: 1 - chromium oxide, 2 - SEOS, 3 - bound fatty substances

So, the most uniform layer-by-layer distribution in hydrophobized leather is observed for chromium (III) oxide, and the distribution of bound fatty substances is the least uniform, with the highest content in the facial layer. At the same time, the absolute values of the amount of bound fatty substances in hydrophobized leather are three times more than non-hydrophobized.

The complex of physico-chemical characteristics of leather, mainly determines their operational properties. The results of the study of physico-mechanical parameters of hydrophobized leather of various thicknesses before and after their contact with water are given in Table 6.

From the obtained data it is clear that the samples of hydrophobized leather after contact with water show a slight decrease in strength with almost the same values of indicators of the appearance of cracks of the face layer compared with the values of the initial samples. At the same time, the elastic deformation of the hydrophobized specimens D-1.8 and D-2.4 grows over the output, respectively, by 15 and 18% with an increase in the residual elongation by 39 and 30%. It should be noted that samples of non-hydrophobic leather are characterized by a decrease in strength by 13%, an increase in deformation indicators by 17-21% and an elastic elongation only by 7.0% with a significant increase (81%) of the residual elongation.

So, leather hydrophobized by AMC in the wet state have increased elastic-plastic properties compared to unmodified leathers.

During cyclical watering-drying, the strength characteristics of both hydrophobized and unmodified leathers change in a similar way during spherical deformation after their contact with water (Table 7).

With complex deformation of hydrophobized specimens in the wet state, the strength values of the leather, the face layer and elongation change in the same way. At the same time, the meridional elongation increases by 13-15%, and after drying, both their strength and elongation practically correspond to the values of the physico-mechanical parameters for the output leathers. The strength of samples of unmodified leather increases slightly with decreasing meridional elongation.

Table 6 Physico-mechanical properties of the leather during uniaxial deformation

Indicator		Leather		
		D-1.8	*D-2.4*	*CU-1.8*
Ultimate tensile strength [MPa]		22.0/21.3	25.0/24.0	23.2/ 20.5
The appearance of cracks of the facial layer [MPa]		22.0/21.3	25.0/24.0	21.0/20.5
Elongation [%]	under load 9.81 MPa	36.0/39.0	34.0/37.8	37.0/42.0
	rupture	46.0/54.0	43.0/52.0	53.0/63.0
	residual	8.7/12.1	9.9/12.9	9.2/22.1
	elastic	37.3/42.9	33.1/39.1	42.8/40.9

Note: Numerator and denominator correspond to dry and wet leather

Table 7 Physico-mechanical properties of the leather during spherical deformation

Indicator		Leather					
		initial[1]			*after drying*		
		D-1.8	D-2.4	CU-1.8	D-1.8	D-2.4	CU-1.8
Strength of leather [N]		580/565	730/705	540/475	575	710	570
Strength of the facial layer of leather [N]		580/565	720/705	430/380	575	710	420
Elongation [%] with	appearance of cracked facial layer	59.0/67.0	52.0/60.0	32.0/35.0	60.0	53.0	30.0
	leather breakthrough	59.0/67.0	52.0/60.0	43.0/49.0	60.0	53.0	41.0

Note: [1]Numerator and denominator correspond to dry and wet leather

Table 8 The stiffness and elasticity of the leather after cyclic watering-drying

Leather	*initial*[1]		*after drying*	
	S [cN]	E [%]	S [cN]	E [%]
D-2.4	36/24	56/31	38	59
D-1.8	27/21	53/29	29	57
D-1.2	21/16	51/26	20	55
CU-1.8	29/15	58/20	36	64

Note: [1]Numerator and denominator correspond to dry and wet leather

Accordingly, after contact with water, the indicators of stiffness and elasticity of the samples change with their large absolute values in the second case (Table 8).

During the restoration of the moisture content in the leather during drying, the rigidity and elasticity of the hydrophobized specimens remain almost unchanged, and the unmodified specimens show an increase in rigidity and elasticity, respectively, by 24 and 10%. It should be noted that with an increase in the thickness of hydrophobic leather twice the stiffness index increases 1.7 times.

Thus, according to the changes in the elastic-plastic properties in the process of cyclic watering-drying of hydrophobized leathers, their structure is effectively restored.

Based on the carried out complex of sorption-diffusion and physicochemical studies of the properties of hydrophobized leather using AMC of different chemical composition, a technology has been developed for the formation of the hydrophobic properties of elastic leather of special purpose (Table 1).

According to the developed technology, the chrome semi-finished product obtained by Chinbar PJSC technology after pressing and planing to the required thickness was to be neutralized to a pH of the spent solution of 5.8-6.0. The following retanning-filling is performed using plant extract, in particular quebracho, when adjusting its solution with sodium sulphite to an initial pH of 5.8-6.0. Hydrophobization-fatting semi-finished product is carried out on the spent solution after raising its temperature to the required by adding the appropriate volume of water with a temperature of 80-85°C. Then the calculated amount of required materials is added to the drum. At the end of the process, the pH of the working solution is reduced to 4.0-4.2 aluminum potassium sulfate for fixing the reagents in the semi-finished product. In this case, oleic acid aluminate is formed, which enhances the effect of hydrophobization of the structure of the semi-finished product. The following drying and moisturizing processes and operations, namely: extracting, dilution, drying, moisturizing, stretching, pressing the obtained leathers are performed according to the technology of Chinbar PJSC.

Consequently, taking into account the results of the study of the properties of the obtained leather semi-finished product at the retanning-hydrophobization stage, a technology for the formation of hydrophobic leathers has been developed, which can be recommended for introduction into the technological cycle of industrial production of elastic leather for special purposes.

4 CONCLUSIONS

The hydrophobization process of semi-finished chrome tanned leather of various thicknesses using alkene-maleic composition for the manufacture of elastic leather for special purposes was studied.

It is established that the hydrophobization of the leather semi-finished product with the alkene-maleic composition significantly increases the water resistance of the obtained leathers compared to unmodified ones, which is reflected in an increase in the water-watering time in dynamic conditions 35-47 times depending on the thickness and stability of the elastic-plastic properties of the leather during cyclic watering-drying.

It is shown that with an increase in the thickness of hydrophobized leather from 1.8 to 2.4 mm, vapor and air permeability decreases by 1.2-1.6 and 1.5-1.7 times, respectively, while their hygroscopy increases by 10%.

The nature of the changes in the physico-mechanical properties during watering-drying of the leather semi-finished product indicates the plasticization effect of water on the collagen structure of the chromium semi-finished product, which causes the formation of additional inter-fibrillar bonds.

According to the complex of physico-mechanical and hygienic properties of the leather, formed according to the developed technology of hydrophobization of the chrome semi-finished product using alkene-maleic compositions, they meet the requirements of DSTU 2726-94 Leather for Upper Shoes and DSTU 3115-95 Leather for garments.

As a result of the research, a technology for hydrophobization of semi-finished chrome tanned leather can be implemented in industrial production for the manufacture of hydrophobized leather for special purposes.

5 REFERENCES

1. Nikolayenko G.R.: Modern methods of hydrophobization of natural materials, Bulletin of Kazan Technological University 8, 2014, pp. 79-83, https://cyberleninka.ru/article/n/sovremennye-metody-gidrofobizatsii-naturalnyh-materialov-legkoy-promyshlennosti/viewer
2. Meyndt R., Germann H.P.: The hydrophobing of chrome-free leather, World Leather 8(49-50), 2007, pp. 52-54
3. Nizamova Z.K., Kalinin M.V., Evsyukova N.V., et al.: Evaluation of the effectiveness of drugs for surface hydrophobization split, Leather and Footwear Industry 2, 2012, pp. 18-19
4. Evsyukova N.V., Vorobyova I.V., Polukhina L.M., et al.: Hydrophobization of leather-fursemi-finished product with fluorine-containing functional silanes and siloxanes, Design and Technology 11, 2009, pp. 68-72
5. Dahmen K., Mertens R.: Use of siloxane copolymers for treating leather and pelts, Leather Sci. Abstr. 1, 1995, pp. 9-10
6. Kovacevic V., Babic R.: Achieving resistance to water for special purpose leather, Koza i obuca (Leather and Shoes) 42(11-12), 1993, pp. 127-128
7. Dzhurav A.M., Kadirov T.Z., Toshev A. Yu.: The effect of hydrophobization on the performance properties of leather for upper shoes, Leather and Fur in the 21st Century: Technology, Quality, Ecology, Education 2015, pp. 48-54,

   https://esstu.ru/library/free/Konf/Kozha_2015/7_%D0%94%D0%B6%D1%83%D1%80%D0%B0%D0%B5%D0%B2_%D0%9A%D0%B0%D0%B4%D0%B8%D1%80%D0%BE%D0%B2_%D0%A2%D0%BE%D1%88%D0%B5%D0%B2.pdf
8. Akhmedov V.N., Dzhuraev A.M., Toshev A.Yu., et al.: Polyethylhydroxyloxane acrylate polymers to enhance the hydrophobization effect, Chemical Technology 5, 2007, pp. 145-146
9. Ermolenko N.V., Guryanova T.I., Platonov V.Ye., Puchkina G.A., et al.: On the effect of a fluorine-containing compound on the hydrophobic properties of the leather, Leather and Footwear Industry 3, 2003, pp. 30-31
10. Pat. 2404260 Russia, IPC C14C 13/00, C14C9/00, C14C9/02, C14C3/14, C14C3/28. Method for the production of hydrophobic leathers, Studenikin S.I., Yakovlev K.P., Bogomolov V.G., et al.; Applicant and patent holder Ministry of industry and trade of the Russian Federation; stated. November 6, 2009; published 11/20/2010, http://www.freepatent.ru/patents/2404260
11. Silva V.F.M., Moncada M., Crispim A., Cruz T., CrispimF.: Studies on waterproofing wet-white leather, Leather and Footwear Journal 18(2), 2018, pp.149-152, https://doi.org/10.24264/lfj.18.2.10
12. Manich A.M., Barenys J., Martínez L., Martí M., Carilla J., Marsal A.: Effect of fatliquoring and finishing on moisture absorption-desorption of leather, Vlakna a textil (Fibres and Textiles) 23(3), 2016, pp. 117-125
13. Nikolayenko G.R., Shestov A.V., Kulentsov G.N.: Hydrophobization of special-purpose leathers by treatment with non-equilibriumlow-temperature plasma, Technologies and Design 3(8), 2013, pp.1-8, (Electronic resource), http://nbuv.gov.ua/UJRN/td_2013_3_11
14. Kulentsov G.N., Stepin S.N., Nikolaenko G.R., Semenova E.N., Shestov A.V., Mingaliev R.R.: “Cold plasma” and nanomaterials as a promising method for improving the hygienic properties of special-purpose leathers for oil and gas workers, Bulletin of Kazan Technological University 5, 2013, pp. 59-62,

    https://cyberleninka.ru/article/n/holodnaya-plazma-i-nanomaterialy-kak-perspektivnyy-metod-povysheniya-gigienicheskih-svoystv-kozh-spetsialnogo-naznacheniya-dlya/viewer
15. An innovative solution for waterproofing, Leather international, 12 April, 2007, (Electronic resource), http://www.leathermag.com/features/featurean-innovative-solution-for-waterproofing-leather/
16. Pat. (Utility model patent) 38472 Ukraine, IPC C14C 9/00. Composition for hydrophobization of pile leather, fur velor, fur sheepskin and articles thereof, Danilkovich A.G., Khlebnikova N.B., Mokrousova O.R., Petko K.I.; Applicant and patent holder Kyiv National University of Technologies and Design, № u200810214; stated. August 08, 2008; published 01/12/2009; bullet №1, http://uapatents.com/3-38472-kompoziciya-dlya-gidrofobizaci-vorsovo-shkiri-khutrovogo-velyuru-shubno-ovchini-i-virobiv-z-nikh.html
17. Danilkovich A.G., Chursin V.I.: Analytical control in the production of leather and fur: A laboratory workshop: Textbook, Allowance, Moscow: INFRA-M, 2016, 176 p., https://doi.org/10.12737/17702

READY-MADE GARMENTS SECTOR IN SAUDI ARABIA IN LIGHT OF VISION 2030

Rania Moustafa Kamel Abdulaal Debes

Faculty of Human Sciences and Design, King Abdulaziz University, Jeddah, Saudi Arabia
rdebes@kau.edu.sa

Abstract: *Industry represents the utmost importance in building the economic and political power of nations and is evidence of progress or delay in the community Therefore, their development requires the formulation of plans, programs and industrial strategies with the interrelationships and coordination with other economic sectors. The garment sector considers one of the important sectors to the growth of many developing countries. This industrial sector contributes significantly to the total added value and employment, importance of the industry is evident the fact that it has an effective and direct impact on the national economy of any country, it is raising the standard of living, and has an important means of employing manpower. Garment industry in Saudi Arabia faces a major challenge as the Kingdom seeks to employ Saudi manpower and to settle the industrial sector in the presence of many obstacles, The Kingdom has great attention to the industrial sector through the vision of the Kingdom of 2030 (a prosperous economy and its active investment). So the researcher studied the problems and obstacles facing the garment industry in the Kingdom in the region (Eastern - Western - Central), in addition to study the needs and requirements of the industry.*

Key words: *Ready-made garments - Vision 2030*

1 INTRODUCTION

Economic development and growth is one of the phenomenal of the progress of countries by establishing many industries in various fields and taking advantage of the available wealth's, directing education towards attention to technical and professional specializations in order to support industries. Multiple industries have appeared, since the beginning of the twentieth century, including ready-made garment industry. The most developing countries have started in the first steps of their industrial projects towards producing ready-made garment.

Bheda [1] states that the industrial sector is considered one of the most important productive sectors in any country of the world and plays a major role with the rest of the production sectors in increasing the local production and the national product, through the contribution of this sector in increasing the volume of exports and also following the replacement policy. For the local products that are imported, the industrial sector is considered the main element in the success of the sustainable economic development process, because the sector depends on the human factor.

Industry represents the utmost importance in building the economic and political power of nations and is evidence of progress or delay in the community. Therefore, their development requires the formulation of plans, programs and industrial strategies with the interrelationships and coordination with other economic sectors. The industrial sector is considered one of the most important economic sectors, as it is considered the first reliable sector for the creation of economic development, by encouraging local industries of different types and in order to work to reduce the volume of imported goods [2].

The industrial sector is of great importance to achieve sustainable development and diversify the sources of income for the economy, especially since the human element in the Kingdom is dominated by the men category that represents more than 70% of the population, and individuals at the age of twenty-five and less reach 50% and this segment can be employed to achieve economic development through the industrial sector, which represents one of the most important options in exploiting the energies of men in the Kingdom, especially as it is expected that a huge number of this segment will enter the work sector [3].

The ready-made garment industry is one of the productive industries that require continuous development in all its stages in order to be able to withstand and competition. Therefore, the ready-made garments factories make huge efforts in planning and coordinating their production lines in order to achieve the highest productivity in the least possible time and at the lowest possible cost with an emphasis on quality component.

The increasing of productivity means increasing the volume and amount of production in relation to the unit of work time and the minimum costs possible, through the optimal utilization of available resources and obtaining maximum returns. Textile and garment industry is considered one of the most important branches in the industrial sector, and it still has a vital role in employing a significant number of manpower, as it contributes to providing some of the local needs of textiles and garment, and still faces many challenges in this sector [2].

Ready-made garment industry is one of the branches of the industrial sector in the Kingdom of Saudi Arabia, as the garment factories in the statistics of the first quarter of 2016 for the Kingdom of Saudi Arabia amounted to 101 factories and their total financing amounted to 11671.6 million riyals and the number of employment in them reached 14297 [4].

Garment sector is important to growth for many developing countries. This industrial sector contributes significantly to the total value added and employment. The ready-made garment industry faces a major challenge in the advancement and upgrading of the quality of this industry so that it can compete not only in the local markets but also in the field of exports that the state's economic and political actors advocate [5].

Jance [6] mentions that the importance of the industry is evident the fact that it has an effective and direct impact on the national economy of any country; it is raising the standard of living, and has an important means of employing manpower.

The garment industry is one of the industries that are still taking its first steps in the Kingdom of Saudi Arabia and is considered one of the necessary and required products in increasing quantities from different sectors and local production is not sufficient to meet the market need of them. This industry is considered one of the important industries at the level of the national economy where it narrowing the gap between locally produced and imported quantities [7].

Al-Ghamri [8] showed that the textile and garment industry in the Kingdom of Saudi Arabia includes carpets, tents, gowns, blankets and towels. The leather industry includes the leather products' manufacture and shoe factories. According to Saudi industrial statistics this industry falls within the transformative industries. In addition, it is considered one of the consumer industries and it is industry that has been established to meet the requirements of the local market and the excess consumption of products.

Kingdom of Saudi Arabia is passing through an important stage of its economic development today, where all the various national efforts are solidified to achieve development goals and catch up with progress, increase the diversification of the source of national income, and reduce dependence on oil as a main source of income. The Kingdom of Saudi Arabia is witnessing a wide renaissance in the various fields of economic and social life that began to follow the method of planning for economic and social development with the beginning of the year 1390 AD.

Industry is an essential and sustainable source of national income, with the idea of settling factories in industrial cities that serve as an integrated industrial clusters in which all elements of the industry are available, including basic services and equipment that take into account environmental conditions and safety requirements, and create job opportunities for citizens, and to distribute development in a balanced way to the Kingdom regions in order to limit immigration to the main regions [9].

Garment industry in Saudi Arabia faces a major challenge as the Kingdom seeks to employ Saudi manpower and to settle the industrial sector in the presence of many obstacles. Kingdom has great attention to the industrial sector through the vision of the Kingdom of 2030 (prosperous economy and its active investment).

So, researchers studied the problems and obstacles facing garment industry in Kingdom in the region (Eastern - Western - Central), in addition to studied the needs and requirements of the industry, in an effort to achieve the side of the vision of the Kingdom, which seeks to (support promising sectors and seek to make it work to be a new pillar of the economy of the Kingdom, as well as encouraging the private sector and open the doors of investment, and localization of industries)

Research aims

- Determine the problems of the garment sector in the Kingdom of Saudi Arabia.
- Determining the obstacles to the industrial growth of ready-made garment in the Kingdom of Saudi Arabia.
- Determining the requirements of the garment industry in the Kingdom of Saudi Arabia.
- To develop proposed solutions for the advancement of the garment sector.

Research importance in response to the Kingdom's 2030 vision (a thriving economy - an efficient investment):

- Connecting university scientific research with the needs and requirements of society.
- Contributing to the development and settlement of the garment sector in the Kingdom.

Research methodology

The research follows the descriptive approach in order to answer the research questions.

Research tools:
- field visits
- questionnaire
- personal interview

2 RESEARCH RESULTS

2.1 The problems and obstacles facing the garment sector in the Kingdom

Through exploratory field visits and connecting they to theoretical studies and the application of research tools, problems and obstacles were identified, divided into several axes as follows:

<u>*Financial problems*</u>

The research sample indicated that there is a real problem in each of the following:

- lack of clarity funding sources,
- low funding ratio compared to the costs of establishing and renewing factories,
- the high cost of purchasing raw materials, machinery and equipment,
- high value of salaries and wages,
- the cost of maintenance procedures,
- the cost of transporting products,
- high prices for some cost components,
- excess of primary elements or products.

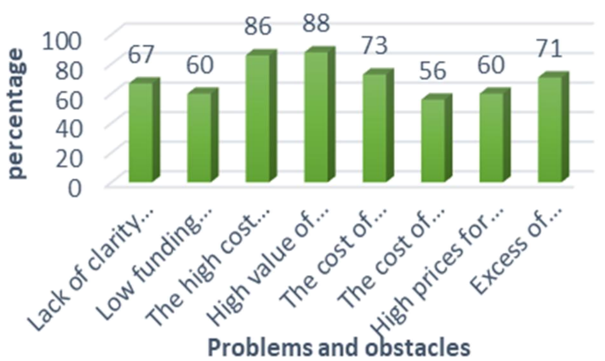


Figure 1 Financial problems

<u>*Problems related to production*</u>

The research sample stated that there are a number of problems associated with the production process that is determined in:

- providing raw materials at the required time,
- providing modern and specialized equipment and machinery,
- completion of periodic maintenance procedures on time,
- sudden breakdowns of machines and equipment,
- sudden absence of workers,
- lack of a culture of training before operation, which affects the quality of the product,
- low quality products,
- lack of clear production plans,
- the presence of idle energies, both in the (labor force - equipment and machinery).

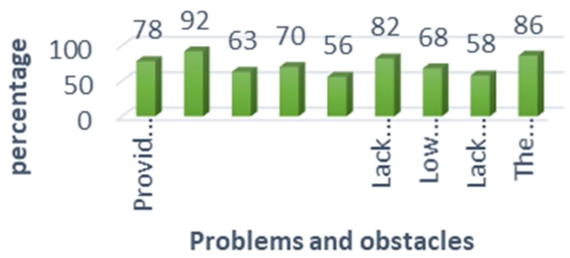


Figure 2 Problems related to production

<u>*Marketing-related problems*</u>

The research sample indicated that there are problems related to marketing which are determined in each of the following:

- the domination of imported products on the local market with low prices,
- failure to follow the theory of supply and demand, so that the supply is proportional to the demand for the product,
- changing the desires of consumers,
- conduct market research periodically when moving from one season to another,
- the high prices of the local product due to the high prices of importing raw materials,
- markets far from factories,
- insufficient publicity and advertising sufficient attention.

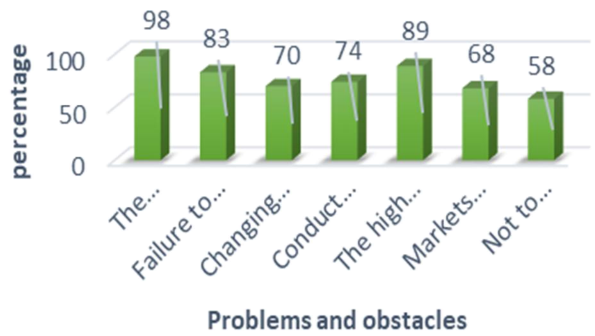


Figure 3 Marketing-related problems

<u>*Export-related problem*</u>

The research sample indicated that there are a number of export problems refer to:

- high price of domestic product in foreign markets,
- absence of local complementary industries,
- competition of foreign products in foreign markets,
- low quality of the domestic product compared to products in foreign markets,
- high export costs,
- the difference in the shipping time of orders due to the late arrival of imported raw materials.

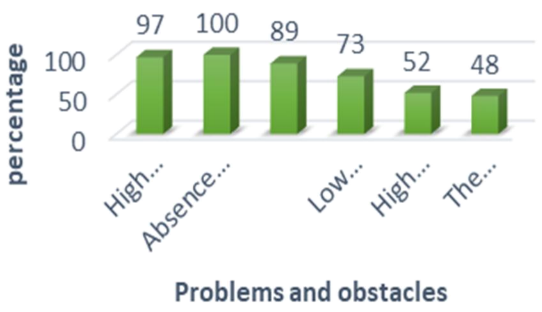


Figure 4 Export-related problems

2.2 *The requirements of the garment industry in the Kingdom of Saudi Arabia*

Through the interview, the research sample answered the requirements of the apparel industry as follows:

- provide sufficient space commensurate with the size of the project,
- factories should be close to the target market,
- preparing a financial, technical and marketing feasibility study,
- existence of an organizational structure for the industrial establishment, clarifying the job description for each individual,
- having a determined funding sources while facilitating the procedures,
- depending on raw materials locally available,
- focusing on continuous training of manpower,
- employing the right worker in the right place,
- training the worker to make several production processes,
- providing specialized, modern equipment and machines with its maintenance,
- the presence of a clear and effective maintenance plan,
- clarity of the production plan with flexibility of implementation and the existence of the alternative plan,
- attention to control production quality,
- interest in studying supply and demand.

2.3 *Suggested solutions to advance the garment industry in the Kingdom of Saudi Arabia*

Through the results of the study, some points were identified as proposed solutions for the advancement of the garment industry in the Kingdom of Saudi Arabia to contribute to the advancement of society (a thriving economy):

- Supporting and setting up factories linked to the feeder industries for the garment industry (textile factories, production requirements factories) and facilitating their procedures and licenses, which works to advance the industry and improve the economy by reducing the cost of the final product and its competition in local and global markets as it works to employ manpower and reduce unemployment in society.
- Financial support to the industrial sector by providing modern and specialized equipment and machines to raise the quality of the clothing product and make it able to withstand and compete in the internal and external market.
- Imposing conditions on the imported products offered in the local market to limit these products and providing the opportunity for local clothes to compete.
- Providing spaces suitable for setting up ready-made garment factories so that they are close to the places of the markets and close to the ports in the case of importing raw materials in order to reduce the costs and time of transportation.
- Spreading the culture of manual work among Saudi men and women and training them on the requirements of this industry, which helps to reduce unemployment and increase the income of the Saudi family.
- Attention to the establishment of small and medium-sized factories as well as large-sized factories to meet the needs of different groups

3 RECOMMENDATIONS

1) Interest in explaining the long-term strategic plans that are concerned with developing the apparel and complementary industries in the Kingdom.
2) Attention to conducting research that supports the garment industry in the Kingdom.
3) Establishing events that bring together investors inside and outside the Kingdom, determining their requirements and reaching cooperation agreements with the industry sector.
4) Holding exhibitions that include local apparel products and working to market them inside and outside the Kingdom.

Acknowledgement: *This project was funded by the Deanship of Scientific Research (DSR) at King Abdulaziz University, Jeddah, under grant no. G-1516-253-1440. The author, therefore, thanks DSR for technical and financial support.*

4 REFERENCES

1. Bheda R., Narag A.S., Singla M.L.: Apparel manufacturing: a strategy for productivity improvement, Journal of Fashion Marketing and Management 7(1), 2003, pp. 12-22, https://doi.org/10.1108/13612020310464331
2. Al-Subiani N.: Factors affecting production in the ready-made garment industry in Jeddah, Journal of Specific Education Research, 2011, Mansoura University, Egypt
3. Al-Shalhoub S.B.F.: Attention to the industrial sector within the framework of the Kingdom's Vision 2030, Industrial Cooperation Journal No. 116, 2016, Qatar
4. Website of the Ministry of Trade and Investment, http://mci.gov.sa/MediaCenter/Reports/Statistics/Pages/stat-075.aspx

5. Al-Baili R.A., Idris H.M.F.: Analysis of export barriers to the manufacture of ready-made clothes in Egypt, Journal of Science and Art, Studies and Research 15(2), 2003, Egypt
6. Bubonia J.E.: Apparel Production Terms and Processes, Fairchild Books, New York, USA, 2012, 456 p., ISBN: 978-1501315572
7. Al-Saqqaf L.: Obstacles to the development of the garment industry, an analytical study of the city of Jeddah, Master thesis, College of Home Economics, King Abdul-Aziz University, Jeddah, 2014
8. Al-Ghamri S.S.A.: The Importance of Saudi Manufacturing Industries: An Geographical Analytical Study, Journal of King Abdul-Aziz University 20(1), 2012, College of Arts and Humanities, Saudi Arabia
9. https://www.argaam.com/ar/article/articledetail/id/673562

CHALLENGES IN PRESERVING BATIK AS INDONESIA'S CULTURAL IDENTITY FACING GLOBAL DEMAND OF SUSTAINABLE ECO-FRIENDLY FABRIC

Jean Jacques Fanina[1] and Falih Suaedi[2]

[1]Sociology Department, Faculty of Social and Political Science, Airlangga University,
Jl. Airlangga No. 4-6, Airlangga, Kec. Gubeng, Kota SBY, Jawa Timur 60115, INDONESIA
[2]Public Policy Department, Faculty of Social and Political Science, Airlangga University,
Jl. Airlangga No. 4-6, Airlangga, Kec. Gubeng, Kota SBY, Jawa Timur 60115, INDONESIA
jean.jacques.fanina-2018@fisip.unair.ac.id, falih.suaedi@fisip.unair.ac.id

Abstract: *Globalization is nothing but worldwide interactions and exchanges, whether through technology, politics, culture or trade. With regard to trade itself, batik represents an important export unique to Indonesia, bearing a national pride but which is feared to have impacted by globalization as well as issues related to its quality as eco-friendly products. This paper has threefold purposes including the batik environmental quality and sustainability, examining the local community capacity and willingness to purchase batik products. The present research used primary data combined with secondary ones taken from interviews and questionnaires using purposive sampling with 125 respondents including batik owners in Solo, Central Java. The data were analyzed using Smart PLS Software 3.2.7 and SPSS 23 to test the reliability and validity. The results indicate that 65% of batik products are tested to have a significant correlation between consumers' willingness and batik environmental and sustainability aspects, with a value of 0.49 which is less than $p < 0.05$. This research though has some limitations since only few variables were considered related to the environmental aspects. Future research is then suggested to expand further details on enlarging the data scope in other regions. This paper has a social implication as it builds a social information sharing meant to boost batik business. The concept used in this research model is new having its own originality value as it examines the batik environmental quality and sustainability.*

Keywords: *Preserving, batik, cultural identity, environmental quality, sustainability.*

1 INTRODUCTION

Among the local products in textile industry known to Indonesia is batik. It is very important, seen as an economically successful industry, represented as national pride [1] and unique on its own as national identity [2]. When reminiscing back on October 2, 2009, UNESCO designated as National Batik Day [3] officially declared as national heritage for it meets the criteria it possesses like symbols, motives, with philosophical meanings of Indonesian people. Also, batik serves as cultural identity of Indonesians, with various patterns, colors and creations that symbolize the creativity and spirituality of the Indonesian people. Moreover, the batik textile industries provide numerous assets and advantages for local communities [4]. Such great positive benefits would be thriving in terms of export-import of goods and services, boosting foreign exchange through tourism sector, generating international business opportunities, hastening the emergence of modern shopping centers and creating more new jobs with a net economic profits evaluated at US $29.3 million, only in Central Java in 2007 [5].

However, in the batik industry, the production process is the main source of waste generation, among others, in the coloring, dyeing, washing and packaging processes. Authors in [6, 7] stated that the characteristics of batik industry waste are almost similar to the characteristics of waste originating from the textile and laundry industry, including alkaline waste, colored, Biological Oxygen Demand (BOD), temperature wastewater and suspended solid. On the other hand though, globalization has brought about tremendous amount of negative impacts on batik industries such as the emergence of obstacles and challenges in the development of the domestic industrial sector as most people would prefer imported products over local ones. According to [8], there were many illegal imports occurred during the past decade from China amounting Rp 290 billions of illegal imports value. Besides, the presence of information technology hastens globalization process creating diverse threats that must be solved in favor of local communities. As a result, the love for local products dwindles and the consumers' capacity to choose and their loyalty to stick on buying local products decreases. Globalization in fact has brought cultural nuances and values that affect people's tastes and lifestyles. Through media, there are incessant receptions of information and western news which encourage, introduce new civilizations coming from all corners of the world. The world is always changing and globalization is a connected world as if there is no limit [9, 10]. As a matter of fact, it is undeniably true that globalization has now become a word that has been widely heard throughout the world since the beginning of the 21^{st} century. It is hoped to bring up the whole communities together where changes would be felt collectively and affect many people across regions, countries, hitting hard the textile industries and swiping away local cultures, impacting our lifestyle and environment. Barker [11] asserted that globalization is a universal, political, cultural, social, economic connection that leads into various paths throughout the globe entering into our conscious. There have been many efforts and measures been undertaken by both local and central government in hope to tackle such issue [12]. Besides, many researchers [4, 5, 13] have conducted considerable amount of studies aimed at finding out the problems while expecting to introduce solution on how to maintain culture in the face of globalization. It seems like those measures remain on textbook only but do not have tangible or concrete answers amidst the war on globalization threats toward local cultural values, especially when it comes to trades like imports-exports problems. Both the local and central government should work hand in hand in order to have a new thriving technology along with better cultural philosophical value in hope to enhance batik quality [5].

2 PREVIOUS STUDIES

Pollution and impact on the environment [14] are found in all stages of the batik production process which includes preparation, sticking of wax, coloring, lighting and washing. Liquid waste from the batik making process comes from fabric processing, dyeing and illumination activities [14]. In the fabric processing and coloring process, the wastewater produced contains chemicals which can contribute to the increase in COD and color of wastewater. While in the highlighting activities, the resulting liquid waste contributes to the increase in BOD_5 of wastewater [14].

Disposing colored wastewater like the batik industry is not only damaging the aesthetics of waste water recipient bodies. Colored waste can poison aquatic biota in these waters [6]. In addition, concentrated colors will prevent sunlight penetration in water bodies, thus affecting the process of photosynthesis in water [6]. As a result, oxygen produced in the photosynthesis process is small and has an impact on the disruption of aquatic biota life [6]. Also, toxic heavy metal compounds found in the printed batik industrial waste, allegedly chrome (Cr), lead (Pb), nickel (Ni), copper (Cu), and manganese (Mn). Toxic effect that appears on the tissues and organs of the body is due to the interaction of heavy metals with important molecules of cells that damage the structure and function of cells in target organ [15]. Based on the Governor Regulation of Yogyakarta Special Region Number 7 (2010), the quality standard of liquid waste for batik industry activities has 8 parameters that must be met before being discharged into the environment. Test should be carried out and check the quality of solid waste originating from sediments resulting from the coagulation process of liquid waste remazol and indogosol dyes using alum. Surahman [16] in his paper, using qualitative descriptive analysis, asserts the impact of the development of technology and media which influence the cultural arts and behavior of the Indonesian people. Also, in his book entitled ‘Communication Technology Determinism and Media Globalization of Indonesian Art and Culture’, he claimed that globalization has brought up tremendous changes in people view asserting that culture shape individuals behavior.

In addition, according to the research undertaken by Roland [17], he reported that globalization is seen as a serious threat to the existence of local culture and cannot be avoided. He reiterated that people must prepare themselves to accept the real impact of globalization in their lives. His view seems to address two facets of globalization. On one hand, globalization does not always erase local identity but it could also bring a positive impact to seed and multiply the strength of local identities that have been marginalized. Leichenko and O’Brien [18] said that mass media can influence the thinking and people's behavior for better or worse. Globalization will not develop rapidly without the role of mass media. He agrees on maintaining social and cultural aspects as a national identity by filtering foreign cultures coming into Indonesia in order to preserve the nation's cultures. Scholte [19] said that communication process and international transportation has cleared away cultural boundaries among countries where globalization plays an important role in human activities. Through interactions, he continued that local communities in Indonesia have experienced a process of being influenced by foreign cultures. Mubah [20] admitted that the hegemony of foreign cultural is an inevitable condition that must be addressed. The flow of foreign cultures penetrating the nation's territorial boundaries encourages local cultural traffic which then metamorphoses into a culture adhered to by global society. He found out that local culture faces a serious threat from foreign cultures while disturbing people's lives through communication and information media. Also, he asserted that Indonesia cannot withstand against the penetration of foreign cultures due to its inability in terms of poor communication and information technology resulting into the fading of cultural heritage. In addition, Swasono [21] demonstrated the necessary strategy needed to maintain local identity eroded by foreign cultures to be gradually able to have the potential to thwart them. Such strategies can be implemented by building identity of the nation and strengthen the national identity, understanding and spreading its own cultural philosophy to all people while issuing regional regulations that protect local culture, and utilizing information technology to introduce local culture to the world community.

3 METHODS

Both primary and secondary data were used in this research basically collected through interviews and questionnaires. There were 125 respondents who met our criteria including batik owners settled in Solo, Central Java. The choice of the research area was thoughtfully considered since Solo is among the 14 districts/cities having creative economic potential according to data obtained from the Central Statistics Agency of Central Java Province.

This article uses a quantitative method. It shall shed light on a simple analysis of data obtained from batik industries in Solo, Central Java during the period April - July 2016. The data were analyzed using Smart PLS Software 3.2.7.

4 RESULTS AND DISCUSSION

Our first result demonstrates the characteristics of respondents as indicated in the Table 1.

As shown in the Table 1, the total amount of respondents are 125 including owner-managers of batik. There are 52 male respondents (41.6%) and 73 female respondents (58.4%), which unveils that there are more female respondents than male ones. In terms of age, there are more females younger than males below 35 years old. In meantime, males seem to have obtained more education reaching Master degree than females who only obtained Bachelor degree, totalling 2 respondents (1.6%). It is evident based in the Table 1 that the vast majority of respondents finish high school studies where males are 32 (25.6%) against females 25 (20%).

Besides, with regard to occupational experience, males seem to dominate with 21 respondents (16.8%) having 1-5 years of experience versus females with 15 of them (12%) whereas work experience between 5 to 10 years, males are still dominant with 38 (30.4%) of respondents against females 32 (25.6%) and finally above 10 years of experience, there are 11 males (8.8%) and 8 females representing 6.4%.

Table 2 Consumers' capacity and willingness to pay batik products (source: primary data)

Price [currency in Rupiah]	Number	Percentage [%]
> 500 000	3	2.4
< 250 000	5	4.0
< 125 000	24	19.2
< 75 000	38	30.4
< 50 000	55	44.0
Total	*125*	*100*

Based on Table 2, it appears that the surveyed respondents demonstrate their capacity and willingness to purchase batik products. It is shown that 55 (44%) of them were willing and able to purchase batik products that cost less than Rp. 50 000 while there were only 3 people represented as 2.4% had the ability to purchase batik products costing more than Rp. 500 000. Such issue was due to the price instead of quality since foreign clothing cost less in some way.

Table 1 Number of respondents' source: primary data

No.	Demographic characteristics	Category	Male	Female	Total	Percentage [%]
1.	Gender		52	73	125	100
2.	Age	< 20	3	5	8	6.4
		21-35	25	37	62	49.6
		35-50	17	22	39	31.2
		> 50	7	9	16	12.8
Total			*52*	*73*	*125*	*100*
3.	Education	Uneducated	4	6	10	8.0
		Primary	6	11	17	13.6
		Junior High	19	15	34	27.2
		High School	32	25	57	45.6
		Bachelor	4	2	6	4.8
		Master	1	0	1	0.8
		PhD	0	0	0	0
Total			*66*	*59*	*125*	*100*
4.	Work duration	1-5 years	21	15	36	28.8
		5-10 years	38	32	70	56.0
		> 10 years	11	8	19	15.2
Total			*70*	*55*	*125*	*100*

Besides, according to our objective, it has been intended to examine the impacts of batik industry in the face of global demand on eco-friendly products as shown in the Table 3.

Table 3 Environmental quality aspect of batik fabric (source: primary data)

No.	Parameters	Max content
1	Conductivity [μmhos/cm]	1.562.5
2	Temperature [°C]	15
3	BOD [mg/L]	132.56
4	COD [mg/L]	426
5	TSS [mg/L]	325
6	TDS [mg/L]	1254
7	Crude oil [mg/L]	-
8	pH	9.5

The Table 3 indicates that batik industry wastewater has the characteristics of turbid color, foaming, high pH of 9.5 and high BOD concentration of 132.56 mg/L which is still below the environmental quality standard. The sustainability indicator for this aspect of environmental quality is the reliability of technology used in reducing pollutant which is processed through the measurement of the concentration of domestic wastewater parameters

Table 3 shows the results of the average effluent wastewater quality test in certain areas in Solo, Central Java but still below the environmental quality standard.

4.1 Structural model design

The description of latent variables and their manifest variables are as follows:

1) Exogenous latent variables on environmental quality aspects represented by X1 has four indicators namely, biotic and abiotic parameters expressed by X1.1; wastes stated by X1.2; emissions stated by X1.3 and chemical products stated by X1.4.
2) Exogenous latent variables on sustainability aspects represented by X2 have four indicators namely, ecological parameters expressed by X2.1; life cycle assessment expressed by X2.2; eco-friendly products stated by X2.3 and end life phase stated by X2.4.
3) Exogenous latent variables on Individual differences (X3) has four indicators namely, information processing stated by X3.1; learning processing stated by X3.2; changes in attitudes and behaviors stated by X3.3 and motivation and involvement declared by X3.4.
4) Endogenous latent variables on consumers' capacity and willingness (Y) has four indicators namely, willingness expressed by Y1.1; capacity to choose stated by Y1.2; information on the products search stated by Y1.3 and alternative evaluation stated by Y1.4.

When evaluating the measurement model for the environmental and sustainability aspects of batik products, the indicators used were not entirely valid and reliable. The Figure 1 shows the structural model suitable for this research.

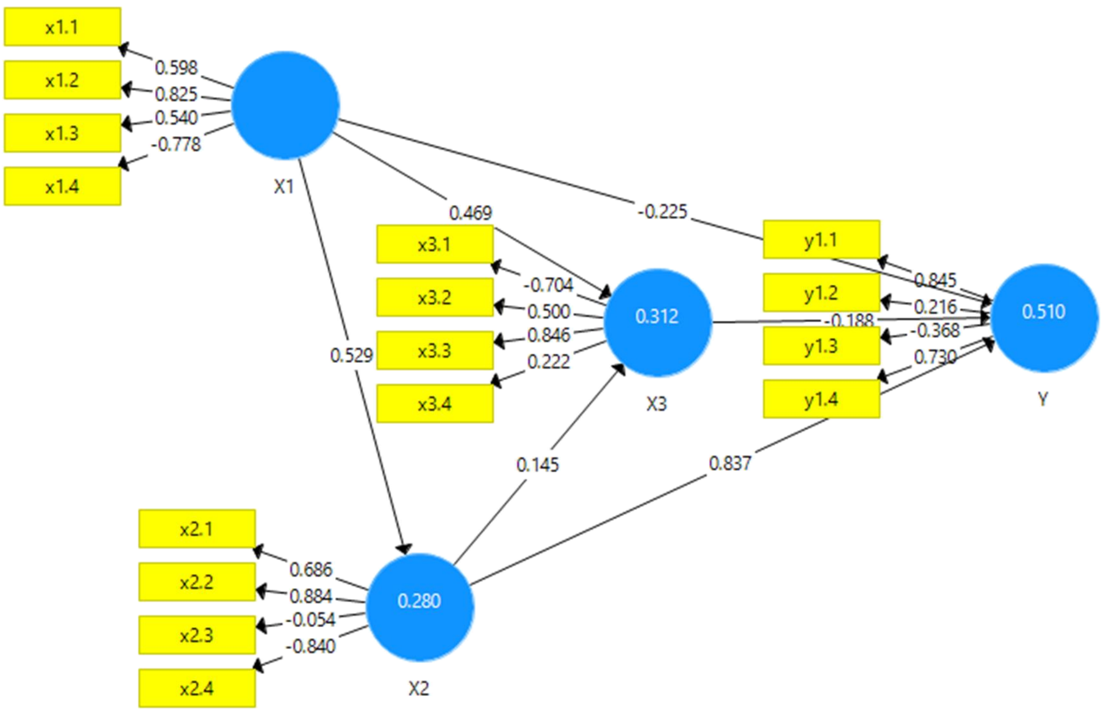


Figure 1 Structural model

4.2 *Data processing using smart PLS 3.2.7 (source: primary data)*

The evaluation of the structural model (inner model) on SEM using Smart PLS is carried out by examining the R Square (R^2) test and the significance test through the estimation of the path coefficient. The testing of R^2 (R Square) output for the R^2 value using the smart PLS 3.2.7 software program as obtained in Table 4 and Figure 2.

Table 4 Output calculation of R-Square (R^2) (source: primary data)

	R Square	R Square Adjust...
X2	0.280	0.228
X3	0.312	0.206
Y	0.510	0.387

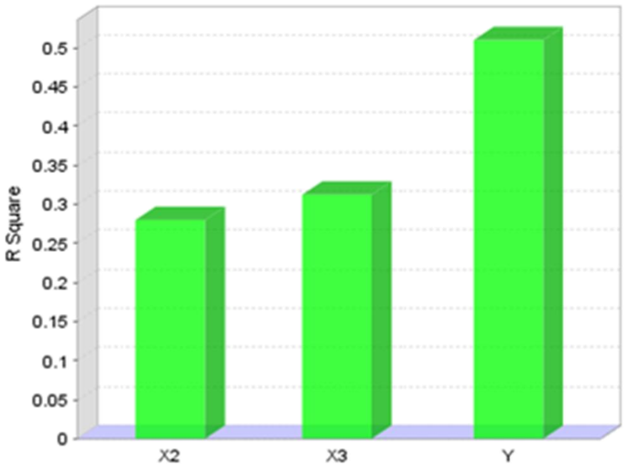


Figure 2 Output calculation of R-Square R^2 (source: primary data)

The R-squared (R^2) value was used to measure how much influence certain independent latent variables have on the dependent latent variable. According to [22], the R^2 result of 0.67 indicates that the model is categorized as good.

Table 4 shows that the R^2 value of this research is 0.510 which means it has a value a bit less than 0.67. So, it can be said that the model is categorized as a fairly good. Besides, SPSS 23 was evidently necessary in hope to measure and test the correlation between variables as demonstrated in Table 5.

Pearson's correlation coefficient was used in hope to measure and test the correlation coefficients between both independent and dependent variables meant to analyze the environmental quality aspects relationship with the consumers' willingness in Solo, Central Java.

It is indicated that not the entire variables used were correlated but some had a positive relationship with the dependent variable at the 0.01 level (2-tailed, 0.478 – 0.494). Thus, there is a significant correlation between the consumers' willingness and batik environmental quality and sustainability aspects, with a value of 0.49 which is less than p-value < 0.05.

Table 5 Correlation analysis (source: primary data)

Correlations					
		x1	x2	x3	Y
x1	Pearson Correlation	1			
	Sig. (2-tailed)				
	N	18			
x2	Pearson Correlation	0.478*	1		
	Sig. (2-tailed)	0.045			
	N	18	18		
x3	Pearson Correlation	-0.002	0.114	1	
	Sig. (2-tailed)	0.994	0.651		
	N	18	18	18	
Y	Pearson Correlation	-0.271	-0.464	0.494*	1
	Sig. (2-tailed)	0.277	0.052	0.037	
	N	18	18	18	18

*Correlation is significant at the 0.05 level (2-tailed).

5 CONCLUSION

Batik textile industries provide numerous assets and advantages for local communities. Tremendous positive benefits boost export-import of batik products enhancing foreign exchange. However, myriads of challenges emerge due to globalization which has brought about tremendous amount of negative impacts on batik industries such as the emergence of obstacles and challenges in the development of the domestic industrial sector as most people would prefer imported products over local ones. Besides, batik products seem to be eco-friendly despite certain products were tested less environmentally friendly and sustainable due to excess use of chemicals. Consequently, it was perceived that the consumers' willingness to purchase batik products has been hampered by such issue as proven by the correlation coefficient during our analysis where p-value was less than 0.05. Thus, efforts must be made in tackling these problems so that Indonesian culture would prevail. Various ways can be carried out in preserving culture, but the most important thing is that awareness should be fostered and a sense of belonging and loving of local culture should be seen in every aspect of each Indonesian person.

6 REFERENCES

1. Haryanto J.O., Priyanto S.H.: Recent future research in consumer behavior: A better understanding of batik as Indonesian heritage, Researchers World 4(4), 2013, 32 p.
2. Vanto Dimas Wahyu Meidi: Pengaruh Limbah Tambak Udang Terhadap Pertumbuhan Semai Tumbuhan Bakau Jenis Avicennia sp di Pantai Indrakilo Kabupaten Pacitan Sebagai Sumber Belajar Biologi, 2016, PhD Thesis, University of Muhammadiyah Malang. (Effect of shrimp pond waste on mangrove growth of Avicennia sp species on the Indrakilo beach in Pacitan Regency as a source of biology learning)
3. Yudhoyono A.B.: My Batik Story - a silent labor of love, Pangest M., Ekayanti Y., Sudarman D (Eds.), PT Gramedia Pustaka Utama, Jakarta, 2010, 252 p., ISBN 9789792263039
4. Paramita B.. Batik Industry is one of Pekalongan Infrastructure Asset toward Creative City, In: Working Conference Paper, Jakarta, 2010
5. Budiono G., Aryanto V.: Batik Industry of Indonesia: The Rise, Fall and Prospects, Studies in Business and Economics, Lucian Blaga University of Sibiu, Faculty of Economic Sciences 5(3), 2010, pp. 156-170
6. Setyaningsih Viji: Manajemen Pengendalian Kualitas Produk Batik Perspektif Ekonomi Islam Pada Home Indurstry Zahra Batik Kebumen), 2015, PhD Thesis, IAIN Purwokerto, (Management of quality control of batik products in Islamic economy perspective at Zahra batik home industry)
7. Adham M., Kurniawan A.N., Muhtadi A.I., Roezin A., Hermani B., Gondhowiardjo S., Tan I.B., Middeldorp J.M.: Nasopharyngeal carcinoma in Indonesia: epidemiology, incidence, signs, and symptoms at presentation, Chinese Journal of Cancer 31(4), 2012, pp. 185-196, doi: 10.5732/cjc.011.10328
8. Gatut B., Aryanto V.: Batik Industry of Indonesia: The Rise, Fall and Prospects, Studies in Business & Economics 5(3), 2010, pp. 156-170
9. Fakih, Mansor. The collapses of the Development Theory and Globalization, Jakarta: LP3ES, 2003
10. McLuhan M.: Understanding Media: The Extension of Man. London: The MIT Press, 1994, 389 p., ISBN: 978-0262631594.
11. Barker Ch.: In the Shadow of Cultural Imperialism: Television and National Identities in the Era of Globalization, The Blackwell Companion to Social Inequalities, 2005, pp. 502-522, https://doi.org/10.1002/9780470996973.ch22
12. Steelyana E.: Batik, A Beautiful cultural heritage that preserves culture and support economic development in Indonesia, Binus Business Review 3(1), 2012, 15 p., https://doi.org/10.21512/bbr.v3i1.1288
13. Dora P.E., Poetiray M.S.: The role of basic design course in the introduction and development of local culture values, Jurnal Pendidikan Karakter no. 1, 2012, pp. 23-32, doi:10.21831/jpk.v0i1.1309
14. Sembiring H.: Penurunan kadar COD (Chemical Oxygen Demand) dan konsentrasi warna limbah cair proses pewarnaan pada industri batik dengan metode proses oksidasi lanjut), 2008, PhD Thesis, Universitas Gadjah Mada. (Decrease in COD (Chemical Oxygen Demand) Level and Color Concentration of Wastewater Staining Process in the Batik Industry - Advanced Oxidation Processes)
15. Muttaqin M.H., Diansyah G., Lubis A.A.: Geokronologi Logam Berat Timbal (Pb) dan Cadmium (Cd) Pada Sedimen di Muara Sungai Way Belau Provinsi Lampung, 2018, PhD Thesis, Sriwijaya University. (Geochronology of Lead (Pb) and Cadmium (Cd) Heavy Metals in Sediments at Muara Way Belau River, Lampung Province)
16. Surahman S.: Determinisme Teknologi Komunikasi dan Globalisasi Media Terhadap Seni Budaya Indonesia), REKAM: Jurnal Fotografi, Televisi, dan Animasi 12(1), 2016, pp. 31-42, (The Impact of Communication Technology and Media Globalization on Indonesian Cultural Arts)
17. Hsu R. (Ed.): Ethnic Europe: Mobility, Identity, and Conflict in a Globalized World, Stanford University Press, 2010, 272 p., ISBN: 9780804769464
18. Leichenko R.M., O'Brien K.: Environmental Change and Globalization: Double Exposures, Oxford University Press, New York (2008), 192 p., ISBN: 978-0-19-517732-9
19. Scholte J.A.: Globalization: A critical introduction. Macmillan International Higher Education, 2005, ISBN: 978-0333977026
20. Mubah A.S.: Strategy to improve the resilience of local cultures in the face of globalization (Strategi meningkatkan daya tahan budaya lokal dalam menghadapi arus globalisasi), Jurnal Unair 24(4), 2011, pp. 302-308
21. Swasono S.E.: Arief S.: Economic Exposure: Being aware of globalization and the free market *(Ekspose ekonomika: mewaspadai globalisasi dan pasar-bebas*), Pusat Studi Ekonomi Pancasila-UGM, 2010
22. Ghozali I.: Structural Equation Modeling; Theory concepts and applications with amos program 21, Semarang Agency, 2013

MEASURING MOVEMENT EASE FOR CLOTHING PATTERN BY MEANS OF SPECIAL MADE SHIRT

Frederick Fung[1], Fatma Kalaoglu[2], Pelin Altay[2], Lubos Hes[1] and Vladimir Bajzik[1]

[1]Department of Evaluation, Faculty of Textile Engineering, Technical University of Liberec, Liberec, Czech Republic
[2]Textile Engineering Depart., Faculty of Textile Technologies and Design, Istanbul Technical University, Istanbul, Turkey
tassfashion@gmail.com; kalaoglu@itu.edu.tr; pelinaltay@itu.edu.tr; lubos.hes@gmail.com; vladimir.bajzik@tul.cz

Abstract: *Direct approach, interaction with volunteers and a specially made shirt to study the influence of races, height, weight and age to the wearing ease of clothing pattern, were used in this work. Two groups of volunteers have participated in the process of the research: group 1) 43 Chinese volunteers from the Zhejiang Fashion Institute of Technology (ZFIT) and group 2) 25 Turkish volunteers from Istanbul Technical University (ITU). Both groups went through the same procedures which were: step 1) taking upper body measurements; step 2) choosing the majority group of volunteers by the mean value of the age, weight and height and step 3) trial wearing and questionnaire. Trial shirts in the research were made of 100% plain weave cotton of 139 g/m^2, thickness 0.43 mm, warp 26/cm, weft 24/cm. Results were compared and discussed.*

Keywords: *clothing pattern; woven shirt; body movement; wearing ease; allowance.*

1 INTRODUCTION

The clothing pattern is one of the important tools in the garment industry [1]. A good fit for clothing patterns not only can be graded into different sizes [2] and it will also give consumers wearing comfort and increases sales. Especially in online shopping businesses, the well-fitted garment will decrease returning purchases [3]. Well fitted clothing pattern allows the consumer to move freely without restriction [4] but yet not too loose or too bulky in style to satisfice consumer physical and psychological need. Hence, wearing ease or allowances are needed to build in the clothing [5]. It is essential because when there is no wearing ease, there is a very less air gap between skin and layers of clothing; then the movement will be restricted [6]. However, there is no standard or guideline to show that how much wearing ease should have for any kind of clothing pattern [7]. Expert pattern makers mostly use their experience to estimate wearing ease [8-9]. A lot of researchers have experimented in different methods to find out the perfect fitted pattern: Chan et al [10-11] compared four different clothing patterns from experienced pattern makers statistically and then predicted clothing sizes by linear regression. Fang, et al [12-13] and Sungmin [14] used mesh and geometric modeling to turn 3D patterns to 2D patterns. Wang, et al [15] created a pattern by analyzing between the static state and the dynamic postures. However no wearing trial or questionnaire concerning wearer's real comfort or sensual feeling in their research was done.

In this paper, the goal of the experiment is to find out the relationship between body movement and wearing comfort, then to estimate the suitable amount of wearing ease. The approach is direct interaction with volunteers in the wearing trial. The shirts' samples were pre-estimated with wearing ease and a few cording channels were installed with loose / tight knots on several major moving parts of the upper body. Using communication and adjusting the loose / tight knots on the shirt worn by the subject to find out the balance between movement ease and wearing ease. This work is part of a series of research works that focuses on how different parameters relate to men's shirt patterns; hence to understand more about the shapes of the pattern or even to develop a better and more efficient pattern shapes for men's shirt to improve wearing comfort. Parameters included were: thermal insulation, water vapor permeability, movement comfort and breathability of clothing. Results were collected from different parameters and followed by analysis. Finally, experimenting with pattern drafting should create the ideal clothing pattern for a particular size of a men's shirt in woven fabric.

2 EXPERIMENTAL PART

2.1 Materials

Four shirts were prepared by using the total mean values of measurements from 17 Chinese and 22 Turkish volunteers (Table 1). Two of these shirts were added in 3 cm estimated wearing ease and the other two were added in 7 cm. Shirts were made with 100% cotton of 140 g/m^2 in plain weave for each group. All materials were washed and the fabric was flat-dried to eliminate shrinkage before samples were made. Samples included two long sleeves, left sleeve with cording channels (2 cm wide) on armhole, biceps, elbow and wrist area; the bodice had a round neckline and cording channels were on the back/shoulder blades, around the chest, around the waist and hips (Figures1a and 1b). Sleeve and bodice both have 1 cm seam allowance around. Nylon cording was inserted inside each channel and secured by a plastic loose/tight knot at the end for quick release or tighten wearing ease during the trial.

Table 1 The mean measurements of 17 Chinese and 22 Turkish volunteers and their combined means for pattern drafting

Body measurements [cm]	17 Chinese measurements		22 Turkish measurements		Total mean values of 17 Chinese and 22 Turkish
	Mean	SD	Mean	SD	
Neck	37.4	1.62	39.2	2.1	38.3
Shoulder	14.4	0.62	14.6	1.0	14.5
Shoulder to elbow	32.4	1.32	35.4	1.8	33.9
Shoulder to elbow to wrist	58.7	2.34	62.3	3.3	60.5
Wrist	16.3	0.92	16.7	0.8	16.5
Armhole	44.2	2.98	46.8	3.8	45.5
Biceps	27.5	2.15	29.1	2.3	28.3
Flexed biceps	30.2	2.58	32.0	2.6	31.1
Elbow	25.5	1.01	26.3	1.2	25.9
Front chest	37.0	1.56	40.0	2.0	38.5
Back chest	37.0	2.27	41.0	2.3	39.0
Full chest	86.0	3.61	98.1	5.7	92.05
Deep breath	89.0	3.55	101.0	5.7	94.8
Waist	73.8	4.63	78.9	9.6	76.35
Hips	93.3	3.95	102.4	6.3	97.85

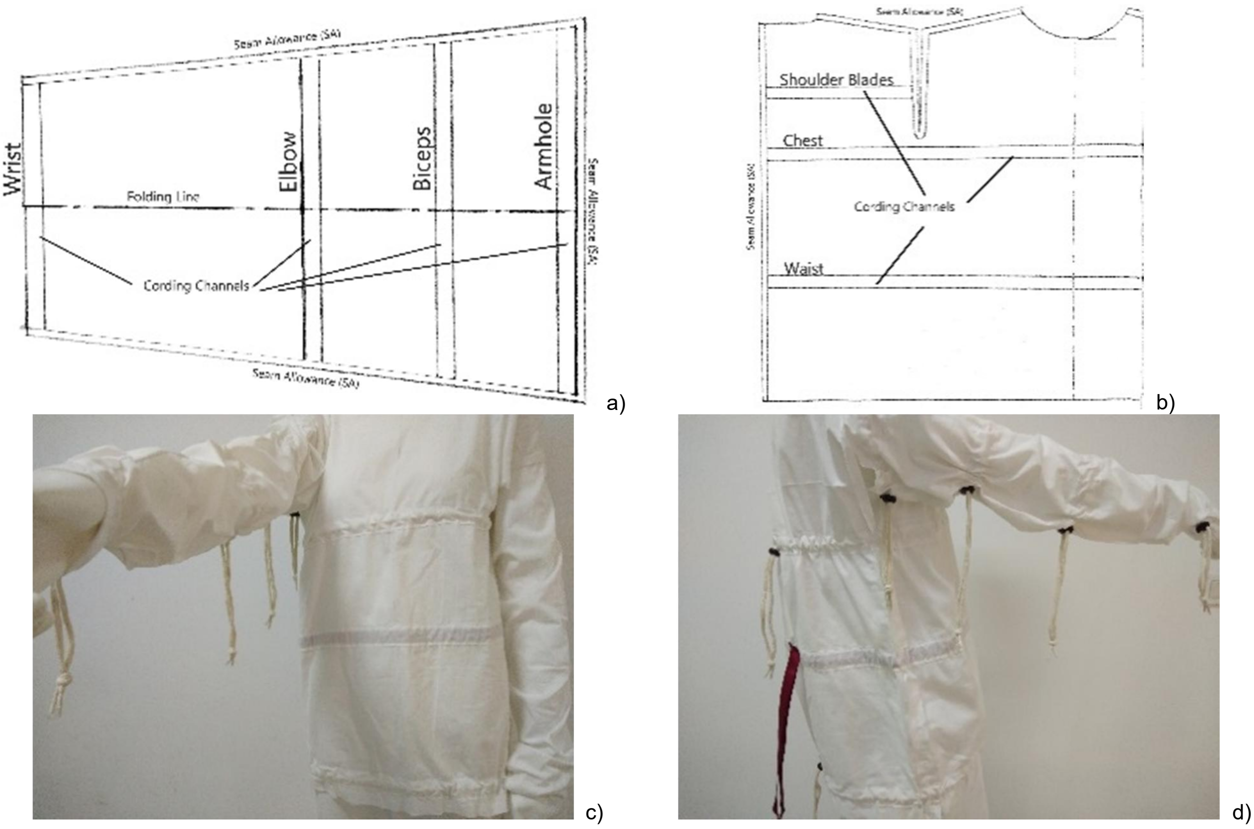


Figure 1 Trial shirt
a) Pattern of sleeve with 1 cm seam allowance and 2.5 cm wide cording channels on moving/expanding parts of the arm
b) Pattern of bodice with 1 cm seam allowance and 2.5 cm wide cording channels on moving/expanding parts of the torso
c) Front view of a sample shirt with cording channels for loose/tight knots on sleeve and bodice
d) Back and side view of a sample shirt with cording channels for loose/tight knots on sleeve and bodice

2.2 Procedures

Step 1 Volunteers were recruited to sign up for the research. Group 1) 43 Chinese volunteers from Zhejiang Fashion Institute and Technology (ZFIT) and group 2) 28 Turkish volunteers from Istanbul Technical University (ITU).

Step 2 Upper body measurements were taken from volunteers. Then according to their mean values of age, weight, and height to choose volunteer for wearing trial. Group 1) 17 volunteers were chosen, group 2) 22 volunteers were chosen (Figure 2).

Also, in Table 2 can be seen the comparison of the mean values of body measurements between group 1 and group 2. Body measurements were including: neck circumference, shoulder width - from neck to shoulder bone (acromion), shoulder to elbow - from the acromion to elbow, shoulder to elbow to wrist - whole arm, wrist circumference, armhole circumference, biceps circumference and after flexed circumference, elbow circumference, front chest - from the left under armpit across the chest to right under armpit, back chest - from the left under armpit across the shoulder blades to right under armpit, full chest - circumference around the fullest chest and the shoulder blades, deep breath - full chest and breath in, natural waist - the circumference around the waist where you bend, hips - circumference around the gluteus maximus to the pelvis to lower stomach, front length - from manubrium of sternum down to the level of hips, back length - from the C7 vertebra of the back neck down to the level of hips.

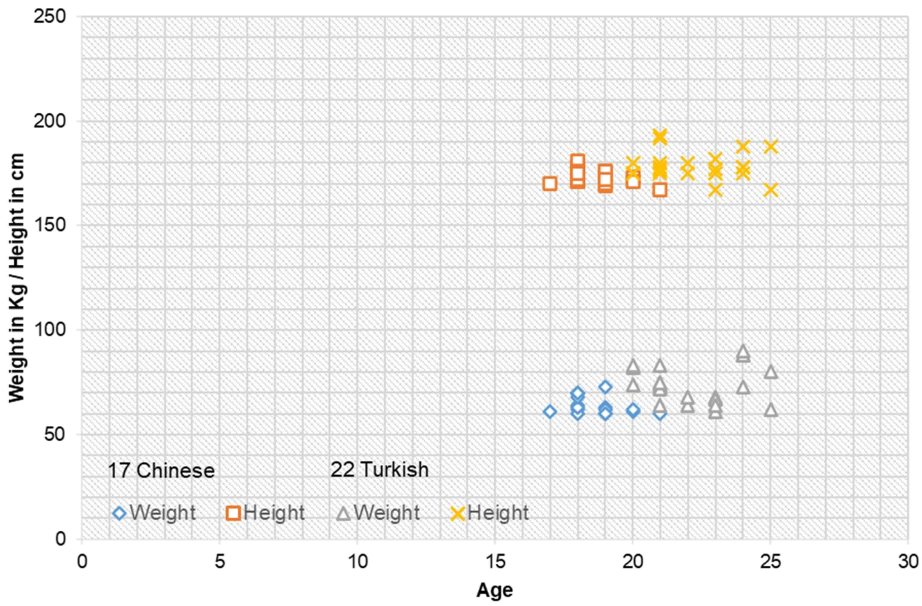


Figure 2 Comparison chart of 17 Chinese and 22 Turkish volunteers' age, height and weight distribution

Table 2 The comparison table of the mean values of body measurements between 17 Chinese and 22 Turkish

Body measurements	17 Chinese	22 Turkish	Different
Age [year]	18.7	22.2	3.6
Weight [kg]	64.0	74.0	9.9
Height [cm]	173.2	178.7	5.5
Neck [cm]	37.4	39.2	1.8
Shoulder width [cm]	14.4	14.6	0.2
Shoulder to elbow [cm]	32.4	35.4	3.1
Shoulder to elbow to wrist [cm]	58.7	62.3	3.6
Wrist [cm]	16.3	16.7	0.4
Armhole [cm]	44.2	46.8	2.6
Biceps [cm]	27.5	29.0	1.7
Flexed biceps [cm]	30.2	32.0	1.8
Elbow [cm]	25.5	26.3	0.7
Front chest [cm]	36.9	40.0	3.0
Back chest [cm]	36.8	41.0	4.2
Full chest [cm]	86.2	98.1	11.9
Deep breath [cm]	88.9	100.5	11.7
Natural waist [cm]	73.8	78.9	5.1
Hips [cm]	93.3	102.4	9.1
Front length [cm]	62.7	59.9	2.9
Back length [cm]	66.0	65.5	0.5

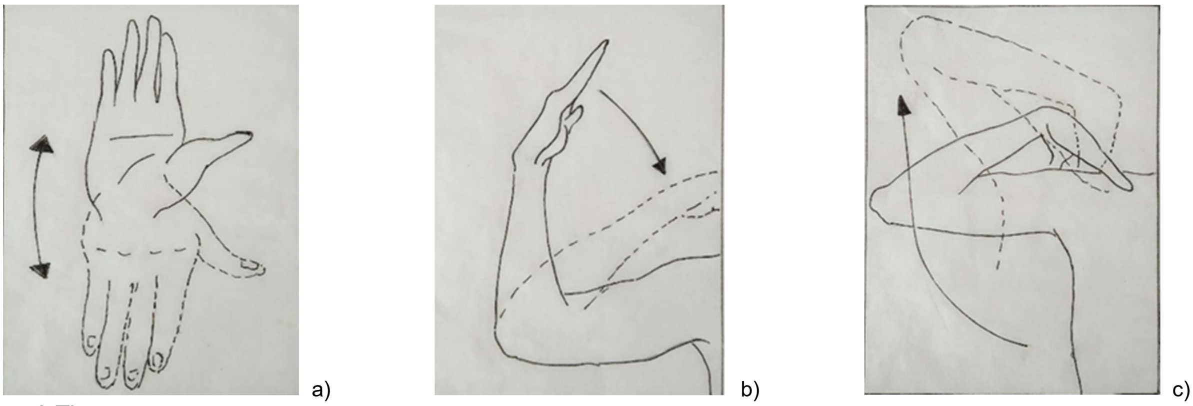


Figure 3 The arm movement
a) Wrist movement- up, down, left, right and rotate
b) Biceps and elbow movement- flexing biceps and bending an elbow
c) Shoulder joint/armhole movement- the whole arm is moving upward, downward, forward, backward and rotate

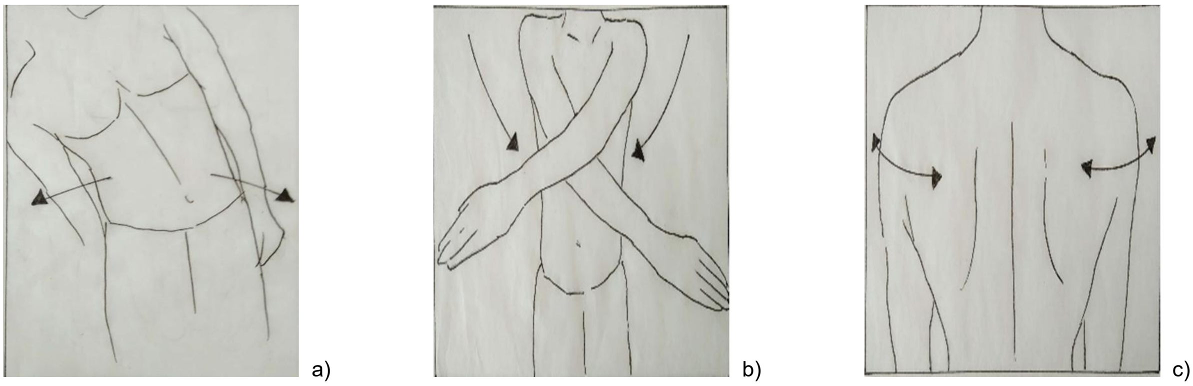


Figure 4 The upper body movement
a) Waist movement- moving waist sideways left and right, bending forward and backward
b) Chest movement- stretching both arms inward, outward and deep breath
c) Back/shoulder blades movement- shrugging shoulders upward, downward, forward and backward

Step 3 Wearing Trial. Each volunteer only wore a light undershirt or bared before he put on the sample shirt. Then he would follow the protocol of movement as the following steps:

The arm movement

(1) Volunteers would be told the goal of the trial was to find out how much of wearing ease would give him comfortable movement for a fitted shirt. This helped volunteer to understand the purpose of the test.
(2) All loose/tight knots were tightened on the arm then the cording would be marked with a water-soluble pen.
(3) Volunteers would follow instructions to move his wrist, elbow, biceps and the whole arm accordingly (Figures 3a-3c).
(4) For each movement, the loose/tight knot would be loosened a bit until the volunteer feels satisfied and comfortable. Then the second mark was drawn on the cording.
(5) The distance between the first and second mark would be the wearing ease of movement which is satisfying the comfort as well as the mobility of the shirt for the wearer.

The upper body movement

The same procedures were applied on the back/shoulder blades, chest and waist (Figures 4a-4c). The loose/tight knot on the hips was only to secure the shirt when the waist movement perform.

3 RESULTS AND DISCUSSION

3.1 Measurements comparison

Group 1) 43 Chinese volunteers were recruited. The mean value of their: age was 18.56 years old, weight was 59.77 kg and height was 170 cm. According to this result, 17 volunteers were chosen for the wearing trial and their mean values increased a bit: ag0e is 18.65 years old, weight is 64.06 kg and height is 173.18 cm. Results from the wearing trial show that the mean value of movement ease needed for the wrist, elbow, biceps and armhole is under 5 cm, chest and waist each needs over 5 cm and back/shoulder blades need the most movement ease which is over 10 cm (Table 3).

Table 3 The mean values and standard deviation of 17 Chinese and 22 Turkish movement ease

Body measurements [cm]	17 Chinese measurements		22 Turkish measurements		Difference
	Mean	SD	Mean	SD	
Wrist	2.2	1.0	1.6	1.2	0.6
Elbow	4.1	1.2	2.8	1.5	1.3
Biceps	3.6	1.2	3.0	1.9	0.6
Armhole	2.6	2.7	1.5	1.9	1.1
Chest	6.3	2.1	5.0	2.5	1.3
Waist	5.6	1.8	4.5	3.0	1.1
Shoulder blades	10.4	3.4	9.0	3.0	1.4

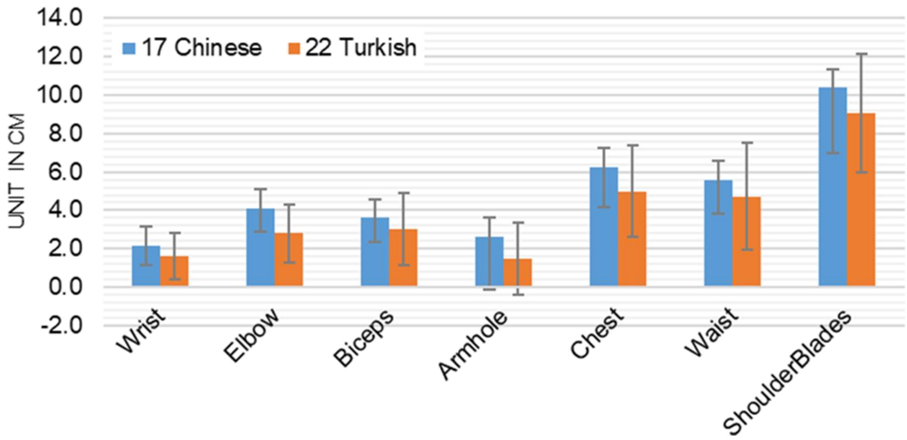


Figure 5 The mean values of difference of movement ease between 17 Chinese and 22 Turkish

Group 2) 25 Turkish volunteers were recruited. The mean value of their: age was 23.76 years old, weight was 75.12 kg and height was 178.24 cm. According to this result, 22 volunteers were chosen for the wearing trial and their mean value of age was 22.23 years old, weight was 74 kg and height was 178.68 cm. Overall the decrease is insignificant. Results from the wearing trial show that the mean value of movement ease needed for the wrist, elbow, biceps and armhole is under 3 cm, chest and waist each needs about 5 cm and back/shoulder blades need the most movement ease which is 9 cm (Table 3). In Figure 5 is shown the comparison of the mean values of movement ease between 17 Chinese and 22 Turkish.

3.2 *T-test*

To find out the significant difference of movement ease between the Chinese and the Turkish group, 17 out of 22 Turkish volunteers were randomly chosen to match up with 17 Chinese volunteers for the T-test; and the test was done three times. The T-test formula is shown below:

$$t = \bar{x}_1 - \bar{x}_i / \sqrt{S_1^2/n_1 + S_i^2/n_i} \quad (1)$$

where: $\bar{x}_1$ is the mean value of movement ease of each body part from the Chinese group and $\bar{x}_i$ is the mean value of movement ease of body part from one out of three Turkish groups; S_1^2 is the variance of each body part from the Chinese group and S_i^2 is the variance of each body part from one out of three Turkish groups; n_1 and n_i both have 17 volunteers for the T-tests.

The results are in Table 4. The critical *t* value at 0.05 is 1.75, only the elbow movement ease shows the significant difference through all three T-tests (grey areas).

Table 4 The results of T-test

Body measurements [cm]	t 0.05	Test 1	Test 2	Test 3
Wrist	1.75	1.24	2.13	1.64
Elbow	1.75	2.08	2.54	2.29
Biceps	1.75	0.19	0.39	0.95
Armhole	1.75	1.12	1.21	2
Chest	1.75	1.4	1.73	2.76
Waist	1.75	1.27	1.55	1.73
Shoulder blades	1.75	0.29	0.8	1.23

4 CONCLUSIONS

The specially made shirt services two purposes: 1) knowing the actual comfortable point of the wearer, 2) knowing the movement ease that the wearer needs. Cut and sew process is simple but it may take some time to finish. However; the finished shirt can be reuse for a long time and can be transferred to another institute for research purposes. Besides, when comparing the results from group 1 (17 Chinese) and group 2 (22 Turkish), group 2 is 3.67 years older, 9.94 kg heavier and 5.5 cm taller than group 1. However, group 1 has a bigger movement range than group 2 (Table 3) so that a bigger ease allowance is needed for each body part for group 1.

Also, the biggest difference between group 1 and group 2 is around 1.35 cm on the shoulder blades and the smallest differences are on the wrist and the biceps which are 0.58 cm and 0.6 cm respectively. Other body movements' differences are under 1.35 cm. With this result, it shows that race, age, weight and height do not influence the movement ease proportionally. Taller and heavier race does not automatically need a bigger movement range (Figure 5). Overall, from the biggest difference 1.35 cm to the smallest difference 0.58/0.6 cm is not a big amount of differences in clothing pattern drafting. Also, from the T-test; only the elbow movement ease shows the significant difference among three testes. Furthermore, the height and weight of the younger generation of different races are increasing [16] and the differences between the individual races are getting less and less [17]. This is due to different factors as food, work type and climate as well as other factors as income, education and health [18]. This phenomenon is especially clear in modern big cities because of a similar lifestyle. If this trend will continue, it will be possible to develop a new set of men's shirt pattern that can fit a large population of men globally and may even set the new pattern standard for the future generations to come. Fitting a large amount of the population globally is still a major issue to be solved [19]. More works needed to be done.

ACKNOWLEDGEMENTS: *Thank you Zhejiang Fashion Institute of Technology (ZFIT) and Istanbul Technical University (ITU) for participating and support for the research.*

5 REFERENCES

1. Ross R.: Clothing: A global history, Polity, 2008, 232 p., ISBN: 978-0745631875
2. Ashdown S. (Ed.): Sizing in clothing, Woodhead Publishing, 2007, 408 p., ISBN: 9781845692582
3. Jang S.: A study on sizing system and preferable ease in a men`s dress shirt for virtual mass customization system, Journal of the Korean Society of Clothing and Textiles 32(1), 2008, pp. 99-109, https://doi.org/10.5850/JKSCT.2008.32.1.099
4. Salvendy G.: Handbook of Human Factors and Ergonomics, John Wiley & Sons, Inc., 2012, 1760 p., DOI:10.1002/9781118131350
5. Ward J., Shoben M.: Pattern Cutting and Making Up: The Professional Approach. Routledge, 1987, 224 p., ISBN: 978-0750603645
6. Xu J., Zhang W., Xiao P.: A study on impact factors of the distance eases between body and garment, In 9th International Conference on Computer-Aided Industrial Design and Conceptual Design, 2008, pp. 201-205, DOI:10.1109/CAIDCD.2008.4730551
7. Gill S., Chadwick N.: Determination of ease allowances included in pattern construction methods. International Journal of Fashion Design, Technology and Education 2(1), 2009, pp. 23-31, https://doi.org/10.1080/17543260903018990
8. Aldrich W.: Metric Pattern Cutting for Menswear, John Wiley & Sons, 2011, 200 p., ISBN: 978-1405182935
9. MacDonald N.M.: Principles of Flat Pattern Design, 4th Ed., Fairchild Books, 2009, 416 p., ISBN: 978-1563678516
10. Chan A., Fan J., Yu W.: Men's shirt pattern design part I: An experimental valuation of shirt pattern drafting methods, Fiber (Sen'i Gakkaishi) 59(8): 2003, pp. 319-327, https://doi.org/10.2115/fiber.59.319
11. Chan A., Fan J., Yu W.: Men's shirt pattern design part II: Prediction of pattern parameters from 3D body measurements, Fiber (Sen'i Gakkaishi) 59(8), pp. 328-333, https://doi.org/10.2115/fiber.59.328
12. Fang J., Yu D.: Expert-based customized pattern-making automation: Part I. Basic patterns, International Journal of Clothing Science and Technology 20(1), 2008, pp. 26-40, https://doi.org/10.1108/09556220810843511
13. Fang J., Ding J., Huang S.: Expert-based customized pattern-making automation: Part II. Dart design. International Journal of Clothing Science and Technology 20(1), 2008, pp. 41-56, https://doi.org/10.1108/09556220810843520
14. Kim S., Park C.K.: Basic garment pattern generation using geometric modeling method, International Journal of Clothing Science and Technology 19(1), 2007, pp. 7-17, https://doi.org/10.1108/09556220710717017
15. Wang Y., Mok P., Li Y., Kwok Y.: Body measurements of Chinese males in dynamic postures and applications, Applied Ergonomics 42(6), 2011, pp. 900-912, https://doi.org/10.1016/j.apergo.2011.02.006
16. "Weight of the Nations", The Downey Obesity Report, Accessed: October 23, 2018, http://www.downeyobesityreport.com/2012/10/weight-of-the-nations/
17. Workman J.E.: Body measurement specifications for fit models as a factor in clothing size variation, Clothing and Textiles Research Journal 10(1), 1991, pp. 31-36, https://doi.org/10.1177/0887302X9101000105
18. Roser M., Appel C., Ritchie H.: Human Height, Our World in Data, 2013, Accessed: October 23, 2018, https://ourworldindata.org/human-height
19. Chen C.: Fit evaluation within the made-to-measure process, International Journal of Clothing Science and Technology 19(2), 2007, pp. 131-44, https://doi.org/10.1108/09556220710725720

INFLUENCE OF SUPERFICIAL MODIFICATION ON ELECTRICAL CONDUCTIVITY OF POLYACRYLONITRIL FIBER

Olga Garanina, Igor Panasyuk, Ievgeniia Romaniuk and Yana Red'ko

Kyiv National University of Technologies and Design, Nemirovich-Danchenko Street 2, Kyiv, Ukraine
helgaranina@gmail.com, evromanuk@gmail.com

Abstract: *Purpose - to determine the influence of surface functionalization on the electrical conductivity of fibrous material on the basis of polyacrylonitrile (PAN). Fibrous based materials possess a number of PAN properties, in particular, "wooly". However, the products based on copolymers of acrylonitrile have unpleasant disadvantages, among which should be a significant accumulation of electrical charge.* Radzyshevsky *reaction is effective in holding surface functionalization of PAN-based material. It decreases the electrical conductivity of fibers. Thus, during exploitation of the finished product a more intense and rapid process of draining the formed electrical charges will occur, which, in turn, minimizes the number of accumulated charges.*

Keywords: *superficial modification, electrical conductivity, polyacrylonitrile fiber.*

1 INTRODUCTION

Today, the use of synthetic fibers as a raw material predominates [1]. PAN textile materials have valuable properties, but they also have disadvantages, such as the ability to accumulate electrical charge during using. Accumulation of static charge of the fibers it hampered their processing and deteriorates hygienic properties of the products [2, 3]. The grade of the accumulation of static charge is depends on the humidity of the environment or fiber, and on the composition of the surface layers of the fiber. The value of the static charge is determined by the: presence of moisture, surface contamination, the presence of antistatic agents and the nature of the contact. Each type of fiber has a certain maximum charge, however, the rate of increase (accumulation) of the charge for different fibers varies, with other things being equal [5]. Moreover, the electrical charges can occur not only in friction, but also in tension and compression [8]. One way to reduce or remove of static charge is to treat products from synthetic fibers with antistatic agents. Antistatic agents absorb moisture or interact with it. They form a layer on the surface of the material which dissipates the charges and reduces the material's static charge [7-10]. The determining effect on the electrical properties of fibrous materials is exerted by their surface [11]. The state of the surface is associated with the maintenance of functional groups on it. Their composition is changed by adjusting their hydrophilic properties and value of the electrical conductivity of the textile material.

The aim of this work is to study the effect of the functionalization of the surface of PAN fibers using the Radzyshevsky reaction on electrical conductivity [4].

PAN-based fibrous materials have a range of valuable properties, in particular “wool-like”. However, products based on acrylonitrile copolymers are characterized by rather unpleasant disadvantages, among which a pronounced ability to accumulate an electrical charge during operation is highlighted. When electrostatic charge accumulation of the fibers, their processing is difficult and the hygienic properties of the products are deteriorating. When using such materials for the manufacture of clothing, their high static charge can influence blood pressure, increase fatigue, irritability, etc. [11]. The degree of static charge accumulation largely depends on the humidity of the environment or fiber, on the composition of the surface layers of the fiber. Polyacrylonitrile fibers absorb a small amount of moisture, so reducing the static charge of the filament is a complex and important problem to solve. In this research the Radzyshevsky reaction was used of the way to reduce of static charge of fibrous materials, on the basis of copolymers of acrylonitrile in the conditions of treatment. The effect is achieved by replacing a part of the nitrile groups on the surface of the fiber on the amide groups. Amides are obtained by partial hydrolysis of nitriles. The reaction mechanism of Radzyshevsky provides for a nucleophilic attack of the nitrile group by a hydroperoxide anion. The result is an unstable intermediate that is an oxidizing agent. Subsequently, the hydride transfer from the second water molecule to the intermediate formation of the hydroperoxide carboximide follows (Figure 1).

In an alkaline solution, hydrogen peroxide restores the intermediate to the amide with the release of oxygen.

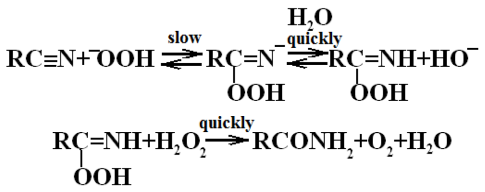


Figure 1 The hydride transfer from the second water molecule to the intermediate formation of the hydro-peroxide carboximide

In research [13] the mechanism of action of hydrogen peroxide as a nitrile activator in the medium of methyl alcohol in the presence of alkali is considered.

An interest is the analysis of the action of hydrogen peroxide in the preparation of the product with the content of amide groups. The concentration of hydrogen peroxide in the reaction of hydration depends on the structure of the output nitriles. Usually 3% of hydrogen peroxide is used. For heavy hydrating nitriles use more concentrated peroxide hydrogen (up to 30%). The concentration of sodium hydroxide varies from lowest to 50%. The reaction is conducting out when heated in an aqueous solution of ethanol or methanol.

A variation of the Radzyshevsky reaction is hydration of the nitrile group, which proceeds with the synchronous oxidation of other functional groups. In this case, the reactive groups may belong to either one or a different compound. As reagents can be used unsaturated nitriles, mixtures of nitriles with olefins and other compounds. Generally, the reaction is carried out in aqueous ethanol or methanol. Reaction temperatures are 40-70°C. As a result aromatic amides is 80-90%, aliphatic 40-60%.

However, as mentioned earlier, it was necessary to obtain an experimental confirmation of the possibility of conducting a Radzyshevsky reaction in an aqueous medium with the participation of nitrile groups of copolymer of acrylonitrile.

2 MATERIALS AND METHODS

The samples for functionalization were made on a flat knitting machine of 10th class. The yarn for samples is nitron D (factory Polimir, Republic of Belarus), with a direct linear density of 15 tex. The composition of the copolymer: acrylonitrile 91%, methyl acrylate 8%, AMPS (2-acrylamide-2 methyl-propanesulfonic acid) 1%. For processing fiber material based on PAN fibers was used a different amount of 35% hydrogen peroxide solution in the presence of ammonia (pH 10.5) and tetraborate (pH 8.0) buffer systems. To study the electrical conductivity, samples of PAN knitted fabrics were used. The studies were performed according to the standard.

Functionalization of the textile material was performed by the Radzyszewski reaction, varying the amount of hydrogen peroxide at pH 8 and pH 10.5. Functionalization of the samples was performed at a temperature of 80°C, bath modules 1:20, the amount of hydrogen peroxide (35%) varied from 50 to 100 g/l. The duration of processing was 60 minutes After functionalization, washing with water was performed until neutral.

Traditional methods of textile materials research, classical methods of textile materials technology, physical and colloid chemistry, standardized methods of textile materials science were used for the research. All methods used are defined by current international or State standards of Ukraine for the relevant textile products.

It is known that for the oxidation reaction of nitriles to amides, Radzyshevsky treated nitrides by 3% solution of H_2O_2 in KOH at pH=8.0, temperature of the process 40°C for 90 minutes.

However, the processing by 3-5% solution of hydrogen peroxide at temperatures below 80°C does not increase the ability to dye by active dyes. The reason is to get the low number of amide groups.

In addition to the main tasks (increasing hydrophilicity and reducing electrical conductivity) peroxide hydrogen is able to participate in the bleaching of PAN fibers. The bleaching is carried out at a temperature of 70°C for 90 minutes in a solution, containing 10 g/L hydrogen peroxide at pH 6.5. However, in [14] it was noted that when bleaching cotton, the active action of H_2O_2 is manifested at pH 10.5-11.0 and at temperature increase to 85-90°C.

Thus, the reactionary modification was carried out in the conditions of finishing production (the Radzyshevsky reaction in aqueous environment) using buffer solutions with pH 8.0 and pH 10.5 at temperature of 95-98°C.

3 RESULTS AND DISCUSSION

The magnitude of the emerging static charge on the surface of the fibrous material is determined by many factors: the presence of moisture, contamination of surfaces, the presence of specially applied anti-static substances, the presence of inevitable external fields, the nature of the contact and the characteristics of the measurement method [15].

A number of researches [4, 16] indicate the property of a unified theory of electrical action. It proposes to reduce the study of the mechanisms of generation and dispersion of static charge to the resistivity of textile materials. The author of the scientific paper [16] determined that for each type of fiber there is a certain maximum charge, however, the rate of growth (accumulation) of charge under other equal conditions for different fibers is different.

This is the reason for determining the ability of static charge accumulation of the fiber by its maximum charge. At the same time, other methods of measuring of static charge of the fibers and fibrous materials on their basis [16] are also available, but the results of these studies often contradict each other. Thus, the resistivity of textile fibers varies within the range of 10^6-10^{13} Ω.cm.

In our research we assume that the determining influence on the electrical properties of fibrous materials is given by their surface. In turn, the state of the surface is closely related to the content of functional groups on it. Directed change in their content can serve as an effective way of regulating, for example, hydrophilic properties, and, as a consequence, the electrical conductivity of a textile material [16-18].

The electrical conductivity is determined by the following indicators: strength of the electrical field, unit of electrical charge, surface density, electrical polarity, specific volumetric electrical resistance and specific surface resistance. In turn, if the electrical conductivity is characterized by the appearance of electrical charges on their surface when friction fibers of the finished product, then the electrical conductivity can be considered the emergence of electrical current. As electrical conductivity is the process of charge transfer, as the main conditions are: the presence in this environment of charged particles (charge carriers), a certain mobility of these carriers, which ensures their movement under the influence of electrical field forces. To evaluate the electrical conductivity of functionalized PAN-fibrous materials, we used the characteristic of the surface electrical resistivity in $\Omega.m^2$.

Important factors affecting the electrical conductivity of the material are relative humidity and the speed of motion of the contacting surfaces. If a relative humidity of 85% or more the static charge accumulation of the material process is practically not manifested, as the electrical resistance of the moistened fabric decreases. At low humidity, the electrical resistance of the fabric is high and flow of electrical charge from a static charge accumulation of clothing occurs by means of a spark discharge between fabric and metal, dielectrical parts of the equipment or the ground. Electrical spark energy may be sufficient to ignite a flammable or an explosive mixture.

In [17-19] the effect of surface modification of fibers on the capillary properties of synthetic textile materials was investigated. It is stated that the increase of hydrophilicity decreases the static charge accumulation of textile materials.

The influence of PAN functionalization on its hydrophilic properties is investigated. With increasing concentration of hydrogen peroxide, the capillarity of textile material increases.

Graphical dependences, obtained as a result of our research, (Figure 2) confirm that as a result of surface functionalization, the conductivity of the fibrous material decreases by 5 orders of magnitude (at pH 8.0) and 7 orders of magnitude (at pH 10.5).

The Radzyshevsky reaction is effective in the functionalization of the surface of the PAN and leads to a decrease of the electrical conductivity index. Thus, during the operation of the finished product will be more intensive and faster process of draining of the formed charges. This minimizes the amount of charge accumulated.

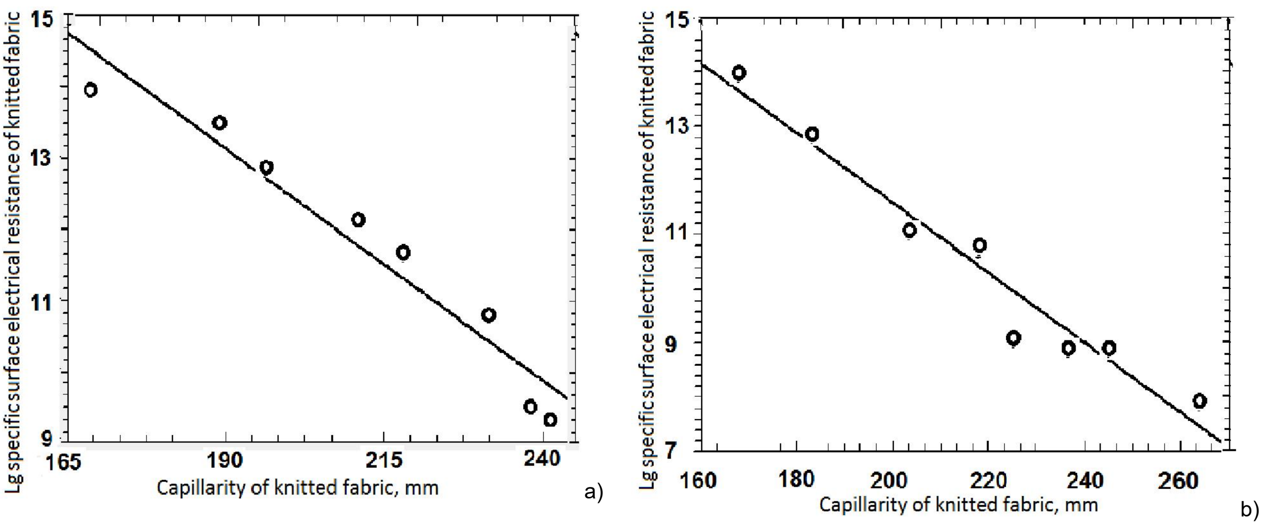


Figure 2 The dependence lg specifics surface electrical resistance on the capillarity of knitted PAN-fibrous material at: a) pH 8.0; b) pH 10.5

The presence of a clear correlation between the specific conductivity and the capillarity of the fibrous materials indicates the Radzyshevsky reaction on the fiber surface and the improvement of the hygienic properties of PAN.

Accept that the sample PAN before functionalization PAN-0, after functionalization with a concentration of hydrogen peroxide:
50 g/l at pH 8.0 - PAN-50(8),
100 g/l at pH 8.0 - PAN-100(8),
120 g/l at pH 8.0 - PAN-120(8),
140 g/l at pH 8.0 - PAN-140(8),
180 g/l at pH 8.0 - PAN-180(8),
100 g/l at pH 10.5 - PAN-100(10.5).

Figure 3 presents typical micrographs of SEM samples before functionalization PAN-0 and after functionalization with different conditions PAN-100(8) and PAN-100(10.5). It is established that as a result of functionalization changes of the surface of PAN occur (Figures 3b and 3c). It is worthy of note that after functionalization at pH 8.0 (Figure 3b) there are changes in the morphology of the fiber with the formation of longitudinal "furrows" on the surface. After functionalization at pH 10.5 (Figure 3c) the surface of fibrous materials in addition to the longitudinal has transverse "furrows", which indicates deeper transformations at pH 10.5.

The nature and size of the formed "grooves" (depressions) are shown in Figure 4. The surface of the sample PAN-0 (Figure 4a) has a relatively uniform, smooth, without visible heterogeneity microrelief. After functionalization on the surface of the samples PAN-50(8), PAN-100(8), PAN-120(8), PAN-140(8), PAN-180(8) (Figures 4b-f) the following morphological changes are observed: nanosized "caverns" and "furrows" appear.

The calculations showed that as the concentration of H_2O_2 changes, the shapes and sizes of the "caverns" very clearly change: the average numerical value of the size of the "caverns" varied from 30 to 150 nm. The formation of a similar size and shape of "caverns" in the studied samples, of course, is associated with carrying out functionalization, which changes the surface microrelief in the structure of the sample.

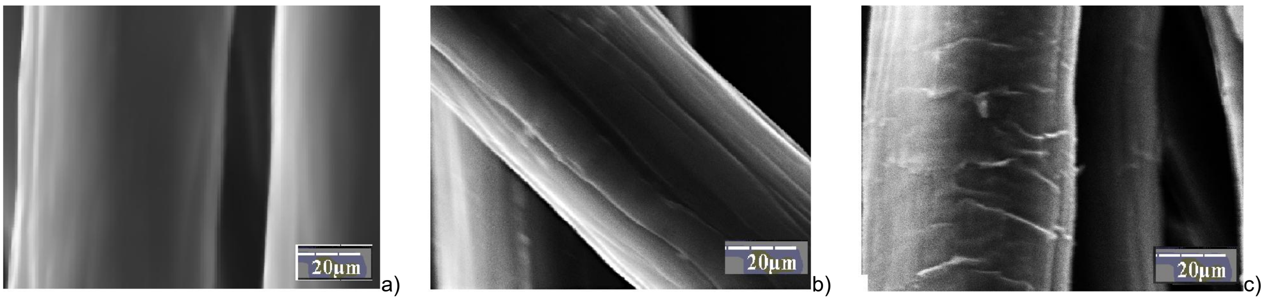


Figure 3 SEM micrographs of samples of PAN-fibrous materials: a) original sample PAN-0; b) PAN-100(8); c) PAN-100(10.5)

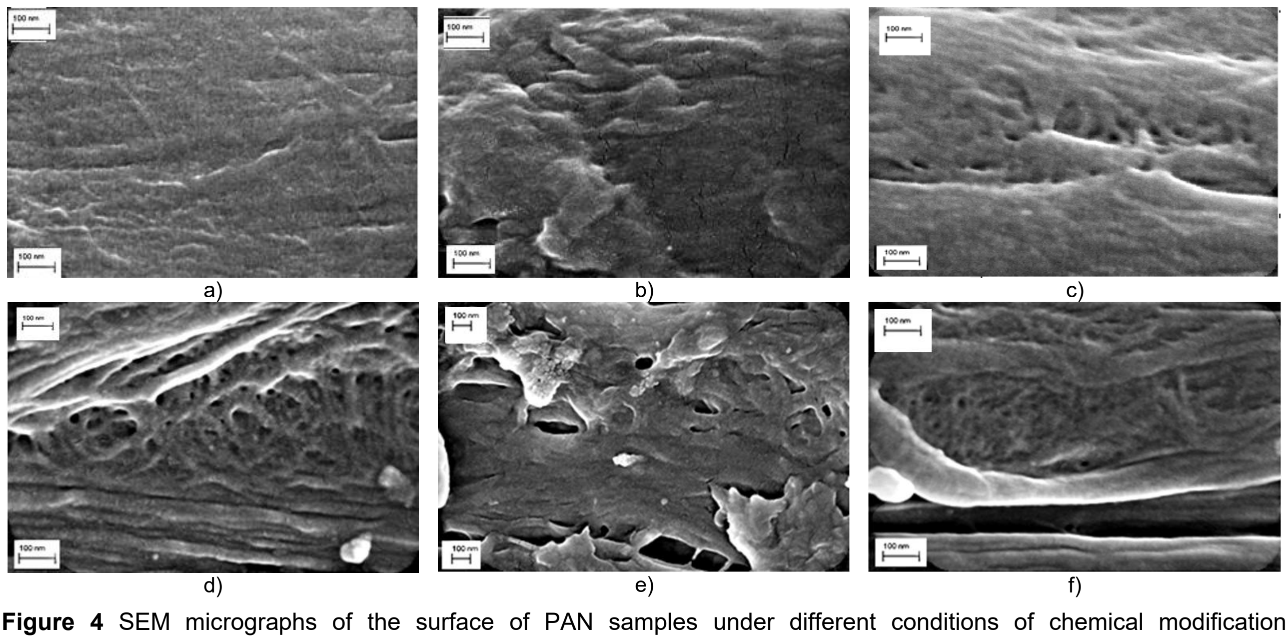


Figure 4 SEM micrographs of the surface of PAN samples under different conditions of chemical modification (concentration of hydrogen peroxide, g/l): a) PAN-0; b) PAN-50(8); c) PAN-100(8); d) PAN-120(8); e) PAN-140(8); f) PAN-180(8)

4 CONCLUSION

The Radzyshevsky reaction is effective in the functionalization of the surface of the PAN material: it leads to a decrease in the electrical conductivity of the textile material. When operating the finished product, a more intensive and faster process of draining the formed charges will occur, this, in turn, minimizes the number of accumulated charges.

The presence of a clear correlation between the specific electrical conductivity and the capillarity of fibrous materials, on the one hand, indicates the progress of the Radzyshevsky reaction on the surface of the fiber, and on the other – the improvement of the hygienic properties of fibrous materials based on PAN fibers.

5 REFERENCES

1. Heller B.E.: Status and prospects of development of production of polyacrylonitrile fibers, Chemical Fibers №3., 2002, pp. 3-10
2. Pakshver E.A.: Carbochain fibers, Chemistry, Moscow, 1973, pp.7-163
3. Morton W.E., Hearle J.W.S.: Physical Properties of Textile Fibres, Woodhead Publishing 2008, 796 p., ISBN: 978-1-84569-220-9
4. Levy J.B., Wakelin J.H., Kauzmann W.J., Dillon J.H.: Relation of charge to frictional work in the static electrification of filaments, Textile Research Journal 28(11), 1958, pp. 897-911, https://doi.org/10.1177/004051755802801101
5. Yuan X.Y., Sheng J., Shen N.X.: Surface modification of acrylonitrile copolymer membranes by grafting acrylamide III. Kinetics and reaction mechanism initiating by Fe^{2+}/H_2O_2, Journal of Applied Polymer Science 69(10), 1998, pp. 1917–1921, https://doi.org/10.1002/(sici)1097-4628(19980906)69:10<1917::aid-app4>3.0.co;2-h
6. Kurhanskyi A., Bereznenko S., Novak D., Kurganska M. Sakovets V, Bereznenko N, Haranina O.: Effects of multilayer clothing system on temperature and relative humidity of inter-layer air gap conditions in sentry cold weather clothing ensemble, Vlakna a Textil (Fibres and Textiles) 25(3), 2018, pp.43-50
7. Red'ko Y., Suprun N.: XRD and SEM analysis of iron oxide nanoparticles formation in polyamide textile material, Vlakna a Textil (Fibres and Textiles) 25(3), 2018, pp. 63-67
8. Pan W., Yang S.L., Li G., Jiang J.M.: Electrical and structural analysis of conductive polyaniline/polyacrylonitrile composites, European Polymer Journal. 41(9), 2005, pp. 2127–2133, https://doi.org/10.1016/j.eurpolymj.2005.04.003
9. Matveitsova D, Paraska O, Karvan S.: Developing compositions based on nanoparticles for final treatment of textile materials, Eastern-European Journal of Enterprise Technologies 5(10), 2016, pp. 19-25, http://dx.doi.org/10.15587/1729-4061.2016.79809
10. Van Krevelen DW, Te Nijenhuis K.: Chapter 11 - Electrical Properties, Properties of Polymers, Elsevier, Amsterdam, 2009, pp. 319-354, ISBN: 978-0-08-054819-7
11. Kukin G.N., Soloviev A.N., Koblyakov A.I.: Textile Materials Science [in Russian], 2nd ed., Vol. 2, Legprombytizdat, Moscow, 1989, pp 352
12. Romankevich O.V., Garanina O.A., Bardash N.A.: Affinity of Cationic Dyes for Polyacrylonitrile Fiber, Fibre Chemistry 46(3), 2014, pp. 161-164, http://dx.doi.org/10.1007/s10692-014-9581-x
13. von Holleben M.L.A, Livotto P.R., Schuch C.M.: Experimental and theoretical study on the reactivity of the $R\text{-}CN/H_2O_2$ system in the epoxidation of unfunctionalized olefins, Journal of the Brazilian Chemical Society12(1), 2001, pp.42-46, http://dx.doi.org/10.1590/s0103-50532001000100005
14. Rustamov M.K., Karimov M.M., Mukhamediev M.G. and etc.: Synthesis of fibrous ion-exchange materials based on polyacrylonitrile and their physicochemical properties, Mountain Spring of Uzbekistan 4(43), 2010, pp.93-96
15. Polonik P.A.: The fight against static electricity in the textile and light industries [in Russian], Light Industry, Moscow 1966, pp. 186
16. Alekseeva L.V.: Theoretical aspects of predicting the electrostatic properties of textile materials, Fibre Chemistry 39, 2007, 225–226, https://doi.org/10.1007/s10692-007-0047-2
17. Prorokova N.P.: Dissertation abstract, Directional change in the surface properties of fibrous materials in the processes of chemical-textile production, Ivanovo, 2006, pp. 34
18. Prorokova N.P., Vavilova S.U., Buznik V.M., Zavadsky A.E.: Modification of polypropylene fibrous materials with ultradispersed polytetrafluoroethylene. High molecular weight compounds [in Russian], Akademizdatcenter Nauka, 55(11), 2013, pp. 1333-1342, http://dx.doi.org/10.7868/s0507547513110044
19. Etzler F.M.: Characterization of surface free energies and surface chemistry of solids, Contact Angle, Wettability and Adhesion 3, Utrecht, The Netherlands, 2003, pp. 219-26

ANALYSIS OF ARTICLE PROPERTIES OF TEXTILES IN THE DESIGN OF INTERIORS OF PUBLIC SERVICE FACILITIES

Volodymyr Cherniavskyi[1] and Victoriia Us[2]

[1]The National Academy of Fine Arts and Architecture, Kyiv, Ukraine
[2]Interior Design Department, Kyiv National Aviation University, Kyiv, Ukraine
v.chern56@ukr.net, yc0869@gmsil.com

Abstract: *The main purpose of this study is to analyze the role of the artistic properties of textiles in shaping the interior design of public service establishments and to identify the specifics of their use. The problem of this study is the need to increase the level of aesthetic organization of the internal environment of public service institutions, the comfort of their premises. To solve the article, the problems of work of the Research Center of Monumental and Decorative Art (Kyiv) in the part of textile production for interiors of public buildings are presented. The scientific novelty of the obtained results is the scientific substantiation of theoretical provisions on the use of artistic textile in the interior design of public service establishments and the identification of the basic methods of their use. On the basis of the carried out scientific researches and performed practical works, it is established that the complex interior design of public service establishments the introduction of one of the areas of synthesis of arts, namely artistic textiles will allow: to significantly increase the level of comfort of premises; improve the aesthetic organization of the internal environment; to provide establishments with services of national color.*

Keywords: *component, formatting, style, styling.*

1 INTRODUCTION

Public service establishments include pre-school establishments and institutions, educational and health care establishments, as well as commercial and residential establishments close to residential development. The internal environment of public service facilities is created for the rational implementation of functional and technological processes. Its optimal functional and architectural and artistic organization will significantly increase the level of comfort for visitors and improve the internal aesthetic organization. Artistic textiles are an active means of decorative art in the interiors of public service establishments and occupy a significant place in the architectural and artistic formation of the interior environment of public service establishments. Decorative fabrics can act as an active artistic accent, allowing achieving an individual decision, both large halls and separate rooms [1].

In addition to the artistic and decorative qualities of great importance are the functional and technological properties of textile products, which significantly improve the comfort of the interior environment, especially rooms for children and teenagers. The high level of quality of the network of public service establishments in the social sphere, the comfort of their internal environment, to which these establishments and service enterprises belong, are an indicator of the successful development of the state. There is a considerable amount of research into the use of artistic textiles in public building interiors [2, 3]. In the XX century, Ukrainian decorative art, while keeping in touch with the traditions of folk art of the past, acquires new content, new properties and features [4, 8]. Ukrainian folk traditions are clearly reflected in the artistic works of decorative textiles [5, 6].

Analysis of modern trends in the development of applied art and textile design, taking into account history, archeology and ethnography is reflected in publications [7, 8]. The influence of textiles on the interior design of various institutions, including children, is reflected in a number of publications [9, 10].

The properties and quality of textile products play a significant role in the formation of interior design [11, 12]. The relevance of the topic of research into the possibilities of textiles in the formation of the internal environment of residential and public buildings is confirmed by the work of many young scientists [13], which are devoted to the analysis of the influence of interior items made of textile materials on the emotional and psychological state of man. Particular attention is paid to the study of psycho-design and the use of materials, color solutions, to show how one can influence the mood of the person [13].

The works of numerous authors consider different aspects of the use of textiles in the design of interiors of civil buildings and structures, but the internal environment of public service buildings has a specific specificity of their use and requires additional research.

2 MATERIALS AND METHOD

An analysis of the artistic properties of textiles, the research and numerous practical developments, which allowed to classify artistic means and identify methods of their use in the design of the interior, were done.
The methodological basis of this study is a systematic approach. In the general theoretical understanding of the problems associated with the systematic approach in art, architecture and design. The research methodology involves the collection of actual data and the systematization of field surveys, the analysis of specialized scientific materials on this problem, the design of subject filling and the role of synthesis of the arts. On the basis of the principles of the above approach, the regularities of forming the internal environment of public service establishments are revealed, the peculiarities of the use of artistic expressiveness are clarified, the classification of textile means is supplemented and developed, the possibility of improving the aesthetic qualities of the internal environment and the level of its comfort is considered. The general methodology of this study is based on the use of two levels of knowledge - theoretical and empirical and is formed on the basis of a method of complex functional and structural analysis, which includes: field surveys, historical method, statistical analysis, a method of complex study of literary and electronic sources, a comprehensive analysis of scientific research, economic analysis by the criteria of expediency of choice, compositional analysis, methods of analysis and synthesis of artistic properties of products and works of textiles.

3 RESULTS AND DISCUSSION

3.1 Classification of articles and works of artistic textiles

The classification is based on the principle of tissue delimitation on the basis of: operational (functional purpose); artistic and constructive (making ornamental or graphic decisions, plastic properties of tissues, and their relationship with the environment); technological (manufacturing method, raw materials, dyeing); qualitative (requirements for the processes of artistic design of fabrics, production and operation) [2].

The analysis of proposals for classification of artistic textiles, developed by different authors for use in public buildings in Ukraine, as well as personal experience in the design of interiors of public service establishments, allowed clarifying the classification of textiles and works for use in the interior of this group of buildings.

It is proposed to distinguish five main groups: panels made in painting technique, macramé, applique, mini tapestry; curtains for the stage; furniture; upholstery fabrics (for curtains, curtains, wall decoration); carpets and floor coverings. Each group has characteristic architectural and artistic techniques of use.

The panels are made in the technique of painting, macramé, applique and mini tapestry. Textile panels made in the technique of painting - cold or hot batik, macramé, applique and mini tapestries can be used in rooms of offices, conferences, meeting rooms and dining rooms of social enterprises. You can use decorative fabric in an indoor environment in one of two directions. The first is when decorative fabric plays a major role in the artistic image of the environment. In the second case, the decorative fabric is more neutral and only emphasizes the main artistic element - be it ceramics or painting.

Curtains for the stage. Decorative curtains of music halls of kindergartens, assembly halls of schools and hospitals can be made in the technique of cold batik or cloth stuffing on stencils.

Furniture fabrics. In different epochs, the pattern and color of furniture fabrics obeyed the general style of furniture and architecture in general, each epoch had its distinct features [3]. Decorative fabrics are assigned different roles in contemporary furniture. In some products, the fabric is increasingly associated with the design of furniture and is one with its shape. The color of furniture fabric is one of the main elements of expressiveness. The selection of fabrics in relation to the color and texture of the wood can be tonal or contrasting. The furniture industry has widely included plastic, metal, and wood, which have become painted.

Upholstery fabrics. Art history shows that upholstery fabrics have always been associated with the nature of interior decoration, that is, with a general style of architecture. Upholstery fabrics occupy a large enough volume in the decoration of dining halls, treatment rooms, games rooms and bedrooms, so their color and pattern is important in the overall interior design [14]. The curtains protect from the bright sun in the daytime, from the bright advertisement and street lighting at night. The dense fabric of the curtains significantly dampens the noise of the streets, protecting the room from the flow of cold air.

For the interior environment the following upholstery fabrics are used: smooth monochrome, structural, jacquard, printed and in the technique of hand painting. Smooth textured fabrics, whose pattern is based on the interlacing of threads, have become widespread. Such fabrics add a certain elegance and rigor of the interior, they can be applied in any premises of buildings of various purpose. In addition to the texture is the color of the fabric itself. Smooth textured fabrics are available in various colors: from white, light gold to dark green and blue. The selection of colors of upholstery fabrics in the interior environment depends primarily on the purpose of the room.

Curtains are an important background for furniture and other equipment, interior decoration. The fabric of the curtains must be in harmony with the color or wallpaper of the walls, be tonal or contrasting to them. The tone is created when the color of the fabric and the color of the wall or wallpaper are close in scale. For example, warm gamut is the color of the walls, mustard or terracotta curtains. Contrast scale - the color of the walls is white, the curtains are blue; golden walls - green or turquoise curtains.

Carpets and floor coverings. In the modern interior of playrooms of kindergartens, medical and health-improving establishments, floor carpets are used in a wide range - artificial carpets, carpets and carpets covering the entire floor plane. The use of artificial carpets is determined by the composition and manufacturing technology. When choosing carpets for the interior environment, it is very important to correctly determine the color, nature and scale of the drawing, depending on the purpose of the room and the intended composition.

Particularly important when selecting floor rugs is their color. The background color is the main color in the composition of the carpet and therefore dominant in the interior. It is very important to choose the right carpet by color, given the purpose of the room. Carpets and rugs are selected by structure depending on the degree of use.

With the development of the production of non-woven fabrics as solid floor coverings, carpet flooring may be used in some public service facilities. The variety of texture, pattern and color scheme made them a defining element in the artistic decision of the interior. The floor can be the main decorative element in the interior design; all other surfaces and furniture are solved as additional color components. Even a single-colored carpet covering the entire floor surface remains the most important component of the interior color scheme. Carpets are also used for stair marches.

3.2 Techniques for the growth of artistic textiles

Art textile works performed at the Art Textile Laboratory for Public Service Establishments allowed to determine the main architectural and artistic techniques of placement of artistic textile goods in the interior environment: monumental and decorative; easel and decorative; decorative and functional; combined.

It is revealed that nowadays high cost-effectiveness have products and works in batik technique, which uses artistic techniques of many fine arts - watercolors, graphics, stained glass [15, 16]. Nowadays, batik art is becoming more and more popular as the most distinctive product of decorative textiles that can enrich the architecture of public buildings, including public service establishments [17].

Thus, it should be noted the high efficiency of the use of artistic textiles, which have a large number of architectural and artistic methods of use in shaping the internal environment of public service institutions.

4 CONCLUSIONS

On the basis of generalization of domestic and foreign experience of theoretical and practical developments in the field of interior design of civil buildings, the use of artistic textiles as one of the directions of art synthesis for public service institutions is substantiated, which will allow: to increase the level of comfort of premises; improve the aesthetic organization of the internal environment; to provide institutions of national color service, taking into account the high level of artistic properties of textiles.

This formed a basis for solving other problems related to the use of artistic textiles in the interiors of public service establishments. Thus, one of the possible areas of research may be the issue of environmental friendliness of materials, the technology of their production, taking into account a significant part of institutions and institutions intended for children and adolescents in the system of social services for the population, or the prediction of the development of textile nanotechnologies [18, 19].

5 REFERENCES

1. Zhohol L.Y.: Fabrics in the interior, Kyiv: (Budivelnyk), 1968, 96 p.
2. Gasanova N.S.: Textiles in interior design, Kiev: (Budivelnyk), 1987, 88 p.
3. Zhogol L.Y.: Decorative art in a modern interior, Kiev: (Budivelnyk), 1986, 200 p.
4. Kara-Vasylieva T.V., Chehusova Z.A.: Decorative art of Ukraine of the twentieth century. In search of "great style": the development of decorative art, Kyiv: Lybid, 2005, 280 p.,
5. Nykorak O.: Ukrainian folk fabric of the XIX-XX centuries: typology, localization, artistic features. Part 1. Interior fabrics. (according to the materials of the western regions of Ukraine), Lviv: In-t narodoznavstva NAN Ukrainy, 2004, 584 p.
6. Chehusova Z.: Decorative art of Ukraine of the end of XX century. 200 names: album catalog, Kyiv: ZAT (Atlant YuEmSi), 2002, 511 p.
7. Isaeva T.I.: Archaic and traditional technologies in modern textile design, SPb: FGBOUVPO (SPGUTD), 2012, 117 p.

8. Draper J.: Stitch & Structure: Design and Technique in two- and three-dimensional textiles, London: Batsford, 2013, 128 p.
9. Ryzhikov V.O.: Registration of interiors and object-developing environment of educational institutions that implement the educational program of preschool education, Moskva: MGKhPA im. Stroganova, 2013, 254 p.
10. Ivanova O.V., Smirnova N.A.: Products for textile interior design: design methods taking into account technological, material science, psychological and socio-cultural factors, Kostroma: KGTU, 2016, 131 p.
11. Ostanina P.A.: The method of integrated assessment of the texture of materials as an element of product design, Candidate's thesis, SPb: FGBOU VPO (SPGUTD), 2013 (in Russian)
12. Kazakova N.A., Ivanova: Design of curtain fabrics, (дизайн портьерных тканей), Vestnik molodykh uchenykh Sankt-Peterburgskogo gosudarstvennogo universiteta tekhnologii i dizayna, 2, 2017, pp. 397-403, ISSN 2312-2048 (in Russian)
13. Alekseeva O.V., Nessirio T.B.: Textiles in the interior and their impact on the emotional state of a person. Vestnik molodykh uchenykh Sankt-Peterburgskogo gosudarstvennogo universiteta tekhnologii i dizayna, 3, 2018, pp. 274-279, ISSN 2312-2048 (in Russian)
14. Sarac T., Stepanovic J., Cirkovic N.: Analysis of a fabric drape profile, Vlakna a Textil (Fibres and Textiles) 25(1), 2018, pp. 27-34
15. Mulyanto, Prameswari N.S., Afatara N., Hartono L.: Pattern design and motif placement of batic sanggit in short-sleeve shirt style, Vlakna a Textil (Fibres and Textiles) 26(2), 2019, pp. 37-42
16. Syamwil R., Sugiarto E., Rohidi T.R., Nurrohmah S.: Weeds as a source of development idea on batik motive, Vlakna a Textil (Fibres and Textiles) 26(2), 2019, pp. 69-73
17. Melnychenko H.Yu., Cherniavskyi V.G.: Use of fabric painted batik while forming the interior design of the restaurant, (Використання тканинного розпису батику при формуванні дизайну інтер'єру ресторану), Visnyk Kharkivskoi derzhavnoi akademii dyzainu i mystetstv 7, 2009, pp. 74-79 (in Ukrainian), http://nbuv.gov.ua/UJRN/had_2009_7_13
18. Kyosev Y., Nicolau A., Schacher L., , Adolphe D., Reiners P., Heimlich F: Investigation about the influence of the yarn tension over the mechanical properties of tubular braided fabrics, Vlakna a Textil (Fibres and Textiles) 22(1), 2015, pp. 31-33
19. Yezhova O.V.: Prognosing development of textile nanotechnologies, Vlakna a Textil (Fibres and Textiles) 24(4), 2017, pp. 66-69

INVESTIGATION OF THE COLORFASTNESS PROPERTIES OF NATURAL DYES ON COTTON FABRICS

Shariful Islam[1], Shaikh Md. Mominul Alam[2] and Shilpi Akter[3]

[1]Department of Fabric Engineering, Bangladesh University of Textiles, Tegjaon, Dhaka, 1208
[2]Department of Textile Machinery Design and Maintenance, Faculty of Science and Engineering, Bangladesh University of Textiles, Tegjaon, Dhaka, 1208
[3]Department of Fabric Engineering, Faculty of Textile Engineering, Bangladesh University of Textiles, Tegjaon, Dhaka, 1208
sharifultextiles@gmail.com; head.tmdm@butex.edu.bd; shilpiakter@butex.edu.bd

Abstract: *The aim of this research was to identify the color fastness properties of the natural dyes on cotton fabrics using different types of dyes like mehedy/henna, turmeric, tea leaf and pomegranate, which were cheap, easily obtainable and ecofriendly. The findings established that, mehedy/henna dye reacted with cellulose of cotton in alkaline condition to form a permanent covalent bond between the dye and the cellulose, which would not be removed by frequent washing treatment with steaming water in neutral conditions and exposed excellent color fastness properties. Mehedy dye had a reactive group that acted as an integral part of fiber and this covalent bond was formed between the dye molecules and the terminal reactive group. With necessary treatments these dyes were collected from nature in powder form and liquefied them for dyeing on 100% cotton mercerized fabrics with necessary chemicals and auxiliaries as natural dyes had affinity towards cellulosic fibers. Continuous dyeing process was carried out with the facilities of "Pad Dye Pad Steam" machine in open width form and then steamed wash to fix the colors with natural dyestuffs. Dyeing process and color fastness tests were carried out in accordance with the test method provided by AATCC and ISO standards. Dye absorption and color strength tests were conducted with the facilities of lab spectrophotometer "Data Color Spectra Flash SF600" in agreement with Kubelka Monk equation through the spectral reflectance, absorption and scattering characteristics of the samples. "Nicolet IS 50 FTIR" instrument was applied to attain the color intensity properties through the passage of Infrared Radiation (IR) within the spectrum. This research was practice based and the findings were advantageous to the personnel involved in textile industries who were responsible for dyeing the fabrics with natural dyes and to controlling of their color fastness properties.*

Keywords: *Natural dyes; color fastness; FTIR; spectrophotometer; dye absorption; color strength; color intensity; infrared radiation.*

1 INTRODUCTION

The research under discussion was undertaken in the field of cotton fabric dyeing with natural dyes which were economical, simply accessible in nature and sustainable. There is a great importance of this research in textile and clothing engineering since the task of dyeing the cotton fabrics with natural dyes were always challenging due to the poor colorfastness properties. Dyeing processes were conducted in textile mills and they involved the application of natural dyestuffs along with necessary chemicals and auxiliaries. The research may be considered important in textile wet processing zone since the dyeing of fabric with natural dyes can reduce the impact on the environment resulting from the disposal of toxic chemicals due to the application of ecofriendly substances. Different researcher worked related to this subjected matter at different times, where literature review exposed different results. For an example, due to the variety of variable involved, if one constraint was changed during experimentation, then there was also a change in the other property of fabrics, and this investigation was carried out with some substances obtained from nature. While experimenting with the cotton fabrics, it was observed that if one condition or amount of chemical or auxiliaries was changed, then there was an unexpected change occurred in the fabric's color fastness properties or the fabric's color staining properties [1]. Ford et al [2] reported that some dyestuff like indigo or lichen showed good color fastness property during dyeing. These dyes were known as direct dyes or substantive dyes since the majority of natural dyes necessitate the application of a mordant, which was applied to "fix" the color in the textile fibers. These dyes were also called sustainable dyes. These dyes were ecofriendly and did not do any harm to the environment. Kabir et al [3] reported that by applying various mordants with dyes, dyers can obtain outstanding colors and shades. Fibers or fabrics were treated with mordants and these mordants were integrated in the same dye bath [4]. In the customary dyeing process, the conjoint mordants included substances such as vinegar, oak galls, ammonia and potassium made with wood ashes were dissolved in the dye bath [5]. Shabbir et al [6] reported that natural dyes were prepared from fruits, leaves, flowers, nuts and berries. These colors were extracted easily and were dyed on fabric quickly. Adeel et al [7] also reported that natural dyes were less bright than synthetic dyes but these natural color components were sustainable and biodegradable. Dyeing of fabric with natural dyes was cost effective. Rather et al [8] reported that most of the synthetic dyes were prepared from chemical compounds those were not always welcoming for the human. On the other hand all the natural dyes were suitable for human and these dyes did not do any harm to the skin [9]. Mir et al [10] reported that textile fibers were dyed before spinning if "heather effect" was wanted on fabrics. "Heather" is the process of dyeing the fibers before producing yarn. Yarns could be dyed before producing fabrics which was called yarn dyed fabrics. In fabric dyeing process, fabric is dyed at wet processing zone that is the most common process of dyeing [11]. Shahid et al [12] also reported that garment dyeing was costly and there remained more chances to damage the cloths. Dyeing at fabric stage can give good effect compared to garment dyeing stage. Baig et al [13] experimented that mordants were necessarily required to fix the colors on fabric and also to bind the color compounds to the textiles fibers or fabrics. Shahidul Islam et al [14] reported that synthetic dyes were prepared for commercial use and thoughts for profit. But natural dyes were not prepared for commercial use and these dyes were prepared for human welfares [15]. If these natural dyes compounds were be produced in large volume then ecological impact could be enhanced [16]. Patel et al [17] reported that synthetic dyes were produced for economical reason in huge extent. On the other hand natural dyes were prepared for dyeing cellulosic fibers without any ecological hazard. Fan et al [18] experimented that natural dyes were produced for obtaining light shades with true colors but synthetic dyes were produced for obtaining bright colors with deep shades, which were suitable for textile dyeing and printing. Tiwari et al [19] reported that the awareness should be increased to use the natural dyes in great extent. Consumers from the western countries were more conscious about the health issues. The environmental influence of synthetic dyes for engineering and manufacturing showed great demand for the products and quality requirements [20]. Western union inspired their nations to use ecological substances for dyeing with locally available natural dyes [21]. Wang et al [22] also reported that cellulose fibers need direct or substantive dyes which were generally known as vat dyes those were colorless and could be fixed suitably in the presence of light or oxygen. Protein fibers needed mordants to create bonding with the medium and the substance. Each synthetic fiber needed individual dyeing technique [23]. Likewise nylon needed acid dyes, rayon needed disperse dyes those were suitable for vat dyeing application [24]. Kumbhar et al [24] explained that the manmade chemical compounds used in textile fabrics showed hygiene problems. Natural dyes like indigo blue had a reactive group in its chemical structure [25]. During that time, it was impossible to define the functional group for indigo dyes. People used them in great extent, produced them in great extent and exported them in great extent with lower expenses [26]. The majority of the natural dyes are obtained from floras, flowers, leaves or vegetables from plant sources like roots, berries, barks, wood and other organic sources like mildews and lichens [27]. Blue, red, yellow, brown and violate dyes were obtained from natural vegetables or plant sources throughout the Indian subcontinent [28]. Su et al [29] also explained that the important procedure of dyeing needed to saturate the materials comprising with the dye particles in water, adding the substances to dye in the solution or dye bath. It should be continued with solution up to a required period till the color started to transfer from aqueous medium to the textile substances [30]. Velmurugan et al [31] also reported that reactive dyes have a chromophore group that is responsible for reacting with the substrate. These dyes have good color fastness properties due to the covalent bond that is established while dyeing. Patil et al [32] reported that salt was used while dyeing to increase the color fastness properties of the textile materials. Vinegar was beneficial to improve the shade of red and purple color. Ammonia-stale urine was useful in the fermentation of natural indigo dyes [33]. Natural alum or known as Aluminum Sulfate was the utmost popular metallic salt mordant [34]. The iron mordants aided fabric deterioration which was known as "dye rot" [35]. Benli et al [36] reported that additional compounds were used while dyeing to improve the color shades. Rehman et al [37] also reported that different natural plants like lichens, henna, alkanet and avocado pits produced red dyes. Kilinc et al [38] reported that madder was a dye that was produced commercially in the Western Union and in the Eastern Europe to dye the red coats of military person in 1869. Jafari et al [39] also informed that the madder was applied for dyeing the "hunting pinks" in Great Britain. Rehman et al [40] also reported that in the Western Europe and in the Eastern Europe the colors like purple and violet were similar colors and they were manufactured by dyeing wool with indigo. Mongkholrattanasit et al [41] experimented that madder might produce purple shade during dyeing with potash alum. Brazil wood could produce purple colors while dyeing with blue vitriol.

2 EXPERIMENTAL PART

2.1 Materials used

100% cotton plain woven fabric was used in this research. The construction of the fabric was 20×16/130×70 meant that the count of the warp yarn was 20 Ne and the count of the weft yarn was 16 Ne. Warp ends per inch (EPI) in warp way was 130 and weft picks per inch (PPI) in weft way was 70. The weight of the fabric was 280 g/m^2. The width of the fabric was 56″.

Mehedy/Henna leaf dye

Henna is known as mehedy, which is a natural dye particle, prepared from the plant leaves. Henna is most commonly used from ancient times to dye skin, hair and fingernails and also fabrics made up of cotton, silk, wool, etc.

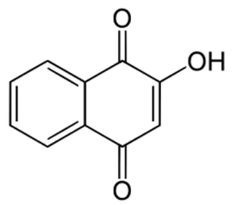


Figure 1 Molecular structure of henna leaf

Turmeric powder dye

Turmeric is a bright yellow colored natural compound that is extracted from the roots of several species of the ginger family. Turmeric powder is also used to dye the fabric and the yarns.

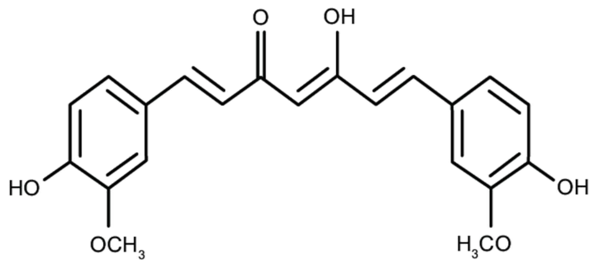


Figure 2 Molecular structure of turmeric powder

Pomegranate dye

Pomegranate is a fruit bearing shrub that is very deciduous and now it is being used to dye fabric. This is pinkish color and gives a mild light shade to the fabric and to the yarn.

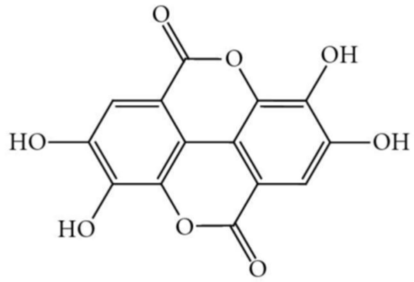


Figure 3 Molecular structure of pomegranate

Tea leaf dye

Tea is a sweet smelling liquid product that is produced by pouring boiling water in a cup. This natural color bearing compound is now used to dye fabrics, fibers and yarns.

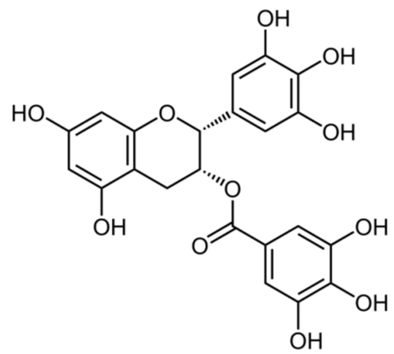


Figure 4 Molecular structure of tea leaf

Chemical and auxiliaries used

Various chemical compounds showed in Table 1 were used in this research during dyeing the specimens.

Table 1 Chemicals and auxiliaries used in this research

S.N	Trade/chemical name	Chemical formula	Medium	Function
1	Hydrogen peroxide	H_2O_2	acidic	an oxidizing agent used to produce oxygen and sodium carbonate
2	Wetting agent	$C_{20}H_{37}NaO_7S$	alkaline	reducing surface tension of water
3	Leveling agent	$C_{17}H_{25}OSO_3Na$	alkaline	to enhance the migration and leveling of dyes
4	Salt	NaCl	alkaline	to enhance dye exhaustion
5	Acetic acid	CH_3COOH	acidic	to eliminate extra dyes from fabric surface
6	Soap	$C_{18}H_{35}NaO_2$	alkaline	to wash up the fabric
7	Fixing agent	$(NH_4)_2S_2O_3$	alkaline	to fix the dye
8	Soda ash	Na_2CO_3	alkaline	to maintain the pH
9	Sequestering agent	$C_{15}H_{10}Cl_2O_3$	alkaline	to remove water hardness

2.2 Method used

Kubelka monk defines an equation (K/S) with the spectral reflectance, absorption and scattering characteristics of the sample. CIE states an equation for the total color difference ∆E* that was measured with the term ∆L*, ∆a*, ∆b*, ∆c* and ∆h* with the equations (1) and (2).

$$\Delta E * ab = [(\Delta L *)2 + (\Delta a *)2 + (\Delta b *)2]½ \quad (1)$$

$$\Delta H * ab = [(\Delta E * ab)2 - (\Delta L *)2 - (\Delta C * ab)2]½ \quad (2)$$

Light Fastness Tester TF421 was used to test the color fastness to light of the specimen. The purpose of light fastness testing was to subject the tested samples to artificial light to evaluate the influence on the material against day light while using by the end user.

Launder meter TF418 was used to test the color fastness to wash of the specimen. The property of a dyed sample, which hold its color when the dyed material were subjected to laundering or washing from being washed away was known as wash fastness.

Perspirometer TF416A of Testex was used in this research to test the color fastness to perspiration of the specimen. This instrument was used to determine the perspiration fastness of fabrics, which contains 1 stainless steel frame with 21 acrylic separator plates to hold the samples.

Color fastness to crocking was tested by crock meter TF410 to dry and wet condition of fabrics. The crock meter was modeled with an electronic counter that had a handle in its top to function smoothly. Sandpaper was set under the tested sample for the purpose of crocking the specimen.

FTIR instrument Nicolet IS 50 FTIR was used in this research to get the colorfastness properties and the color intensity properties of the natural dyed cotton fabrics through the refrection of Infrared Radiation (IR) within the sprectrum.

Data color spectra flash SF600 lab spectrophotometer was used in this research for getting the color strength and color measurement values. It had duel beam transmission system with xenon rays illumination. It can work in the spectral analyzer of dual 256 diode array with high resolution holographic grating system. It can work in the wavelength range from 360 nm to 900 nm.

Pad dye pad steam is a dyeing machine of continuous fabric dyeing, where the fabric is dyed in open width with dyestuff and is then steamed. Steaming is the process of fixing the colors with natural dyestuffs. Light, medium and heavy shades can be achieved with this dyeing machine. Steamer was used for diffusion of reactive, vat, sulphur, direct and natural dyes into cellulosic fibers in a thermosphere condition created by inundated steam vaccinated into the steamer.

Figure 5 shows the sample dyeing process with pad dye pad steam machine [42].

Figure 5 Sample dyeing process in pad dye pad steam machine

2.3 Dye extraction process

Henna dye extraction process

Henna leaves were collected from the plant. The leaves were washed away to remove dust and adhering material. The leaves were then dried in heavy sunlight. The dried leaves were then crushed into powder for dye extraction with a grinding machine. 500 gram henna powder was taken in Na_2CO_3 solution for 24 hours in room temperature with the pH level of 8-9. The henna solution was reddish orange color. The solution was saturated with Na_2CO_3 solutions till the color was detached from powder to the aqueous medium. Reddish orange color of henna was developed at the presence of alkaline solution.

Acetic acid was mixed at the alkaline reddish orange color solution of henna to make the pH neutral. As it was natural dyes compound, 5 ml of chloroform was mixed at the solution to protect it into a funnel. The solution was dried with anhydrous sodium sulfate. The solution produced orange yellow color. The solution was kept away from light till chloroform was evaporated. Then the solution was kept separately for storage.

Turmeric dye extraction process

Raw turmeric was collected from garden. Fresh turmeric were cleaned, washed off in clean water, sliced and dried in the sunlight for a week. The cleaned turmeric was dried at 40°C for 6 hours at oven. The dried turmeric was cut into small pieces and then powdered in a grinder. The powder was air dried in sunlight for 12 hours to remove moisture. 500 gram powder of turmeric was taken into a funnel and placed in a sox let apparatus. 500 ml water was added and extracted for six hours at boiling temperature. The solution was passed through a colander of 30 mesh size to get uniform liquor so that uniform dyeing was possible. As this was natural dyestuff, chloroform was sued in this solution for perseverance.

Pomegranate dye extraction process

The pomegranate fruits were collected from garden and then they were piled off from their skin. Pomegranate pills were taken out to extract the dyes. Pomegranate pills were crushed with a juicer or grinder and taken their juice was taken out of it. 500 ml juice was taken into a funnel and boiled at 100°C. The solution was passed through a colander of 30 mesh size to get uniform liquor so that uniform dyeing was possible. As that was natural organic dyestuff, some natural destructive conditions like weather, oxygen, light and all other environmental gases can fade and destroy certain colors. Therefore, natural dyestuffs should be preserved after finishing in boiling temperature. Chloroform was used in this solution for perseverance.

Tea leaf extraction process

Green tea leaf was collected from the plant. The leaves were washed away to remove dust and adhering material. The leaves were then dried in sunlight. The dried leaves were then crushed into powder for dye extraction with a grinding machine. 500 gram tea powder was taken in CH_3COOH solution for 12 hour in room temperature with the pH level of 3 to 4. The color of tea leaf was extracted in aqueous medium. Tea leaf was acidified with the pH range of 3.0 to 4.0 at aqueous solvent with boiling temperature for 7 to 8 minutes at the air pressure of 90 to 100 PSIG to provide a high temperature acid extract. The color bearing acid extract was used to dye the textile materials with necessary auxiliaries and substrate.

2.4 Dyeing process

Dyeing of cotton fabric with henna dye

Cotton fabric was cationized prior to dyeing with henna dye. 70 grams of (3-chloro-2-hydroxypropyl) trimethylammonium chloride was liquefied in 300 ml deionized water. 30 grams of sodium hydroxide was then mixed to form (2, 3-epoxypropyl) trimethylammonium chloride (EP3MAC) solution. After that the fabric was saturated with EP3MAC solution at 60°C for 18 min and then it was padded at 21 meter per minute speed with the pressure of 1 kg/cm^2. The fabric was then covered in an elastic film by 24 hours at 30°C for averting the passage of chemicals on the fabric and desertion of water. Afterward, the fabric was simply washed twice with clean water and neutralized with acetic acid solution by 5 g/l ratio. Lastly, the fabric was again washed to get a neutral pH of 6 to 7 and then it was dried and collected in a batcher. Henna dye solution was used to dye the cationized cotton fabrics without addition of salt. Cotton fabrics were submerged in a dye bath composed of henna dye solution and sodium carbonate solution of 15 g/l, using dye liquor ratio of 1:20. The process of dyeing was conducted at the temperatures of 60°C for 30 min at the pH medium of 6 to 7. After dyeing the cotton fabric washing was done at first in clean water subsequently in detergent water of 2 g/l, Na_2CO_3 10 g/l, liquor ratio 1:25 at 90°C for 8 minutes. Finally, the dyed fabrics were dried and collected safely.

Dyeing of cotton fabric with turmeric dye

At first the cotton fabric was submerged in mild detergent solution (about 15%) and kept it for 12 hours. Then the fabric was washed off with clean water with acetic acid to make the pH 7 and then dried. It was better if the fabric can be dried with sunlight. Turmaric dye was prepared by extracting turmeric powder from de-ionised water at neutral pH. The applied temperature was 95°C for 1.5 hours. Turmeric dye extract had the color of yellow. The liquor ratio of the water and turmeric extract was 15 g/l using liquor ratio of 1:20 with the temperature of 60°C for 30 minutes at the pH medium of 6 to 7. After dyeing the fabric, the sample was washed in normal clean water with the presence of acetic acid to make the pH level neutral.

Dyeing of cotton fabric with pomegranate dye

Cotton fabric samples were treated with two mordants such as ferrous sulphate and copper sulphate for 1 hour at 75°C. The technique of pre-mordanting was applied with the liquor ratio of 1:20. The samples were washed after mordanting and dried at 30°C and then used for dyeing process. Cotton fabric was dyed with pomegranate peel extracted dye solution. The dyeing process was carried out at 90°C to get better results. The cotton sample fabric was dyed for 1 hour with the liquor ration of 1:20. After dyeing, the sample was washed off with clean water at 30°C. At last the sample was dried and kept in store for testing purpose.

Dyeing of cotton fabric with tea leaf dye

Mercerized cotton fabric was used for dyeing with natural tea leaves dyestuff. The fabric was treated with 5 g/l of acetic acid in aqueous medium at 30°C to make the pH neutral. The dyeing process was conducted with 90°C in continuous dyeing machine at the speed of 40 m/min to get better results with the liquor ration of 1:20. After that, the sample was washed with detergent at 30°C to clean the unfixed dyestuff. Again, the fabric was washed with 5 g/l of acetic acid in aqueous medium at 40°C to make the pH neutral. Finally, the sample was dried and kept in store for testing purpose.

2.5 Dye absorption and color measurement test

Dye absorption and color strength of the dyed cotton fabrics were measured with the facilities of the instrument of spectrophotometer SF-600. Sample fabrics were cut in the size of 3″×2″ to place it in the instrument. For getting the spectro-photometer reading, the jack of the instrument was opened and then the sample fabrics were placed inside it. Color strength values K/S, color shade L*, a*, b*, C* and h* values were taken as shown in Table 2. Spectrophotometer used tungsten halogen lamp as the most common light source, which was comprised of tungsten filament light with a wavelength number of 330 nm to 900 nm inside the visible region.

2.6 Color fastness test

Color fastness test of the cotton fabrics were carried out in accordance with the test method provided by ISO Standard. Color fastness to light was conducted in agreement with the test method provided by ISO 105-B02 Standard. Color fastness to rubbing was conducted in agreement with the test method provided by ISO 105-X12 (dry and wet) Standard. Color fastness to washing was conducted in agreement with the test method provided by ISO 105-C01 Standard. Color fastness to perspiration was conducted in agreement with the test method provided by ISO 105-E04 Standard. Color strength and dye absorption of the dyed sample were measured by K/S value. Results were shown in the Table 3 for the 4 types of dyestuff. Commercially, the dyestuffs of the best color fastness properties were recommended due to cheap price and availability.

2.7 FTIR test

FTIR experiments were carried out on four different dyed samples of cotton fabric to take the peak of infrared radiation. The clamp of the FTIR machine was unlocked to clamp the dyed samples. Infrared radiation (IR) was secreted through the dyed samples to identify the enhanced color fastness properties. Infrared radiation could pass through the sample fabric on the basis of the intensity of the color shade. Where the color intensity was higher, IR radiation showed a higher peaks at those points and vice versa. At the higher saturated region of color, the infrared radiation established higher peak weaves.

3 RESULTS AND DISCUSSION

Dye absorption and color measurement

For determining the color shade and dye absorption of dyed cotton fabrics the values of K/S were used. Results are shown in the Table 2 for the 4 types of dyestuff. Commercially, the dyestuffs of the best color fastness properties were recommended due to cheap price and availability.

Table 2 expressed the whole color shade of L*, a*, b*, c*, h* values and it specified that the higher values of L* expressed lighter shades and lower value of L* meant darker shades. The negative values of a* and b* denoted green and blue, where positive values of a* and b* denoted red and yellow. The highest K/S (3.97) values were obtained for henna/mehedy, where the lowest K/S (3.11) values were obtained for pomegranate color. It was also observed that, the highest K/S value had the lowest lightness values (L), which indicate the lightest color and vice versa. The highest K/S value with the lowest value of L, exhibit the best color fastness properties and vice versa.

Table 2 Values of K/S and values of CIE L* a* b* c* h* of dyed cotton fabric

Dyestuff	K/S	L	a*	b*	c*	h*
Henna/mehedy	3.97	42.91	0.33	1.27	1.29	83.83
Turmeric	3.68	55.89	2.21	3.63	4.05	81.99
Tea leaf	3.39	76.11	4.33	23.23	26.13	79.21
Pomegranate	3.11	79.11	4.69	25.77	27.18	77.39

Color fastness to light

It was seen from Table 3 that light fastness values (4-5) of the cotton fabric dyed with mehedy dye was the highest. Light fastness values (4) of the cotton fabric dyed with turmeric dye was the second. The 3rd and the 4th values of the color fastness properties of the cotton fabric dyed with tea leaf were (3-4) and pomegranate was (3).

Color fastness to wash

It was seen from Table 3 that wash fastness values (4-5) of the cotton fabric dyed with mehedy dye was the highest. Wash fastness values (4) of the cotton fabric dyed with turmeric dye was the second. The 3rd and the 4th values of the color fastness properties of the cotton fabric dyed with tea leaf were (3-4) and pomegranate was (3).

Color fastness to rubbing

It was seen from Table 3 that rubbing fastness values (dry 4, wet 3-4) of the cotton fabric dyed with mehedy dye was the highest. Rubbing fastness values (dry 4, wet 3-4) of the cotton fabric dyed with turmeric dye was the second. The 3rd and the 4th values of the color fastness properties were for the cotton fabric dyed with tea leaf (dry 3, wet 2-3) and pomegranate (dry 3, wet 2-3) dye.

Table 3 Color fastness values of the cotton samples

Cotton fabric dyed with	Light fastness	Wash fastness	Rubbing fastness		Perspiration fastness	
			Dry	Wet	Acidic	Alkaline
Henna/mehedy	4-5	4-5	4	3-4	4-5	4-5
Turmeric	4	4	4	3-4	4-5	4-5
Tea leaf	3-4	3-4	3	2-3	4	4
Pomegranate	3	3	3	2-3	3-4	3-4

Color fastness to perspiration

It was seen from Table 3 that perspiration fastness values (acidic 4-5, alkaline 4-5) of the cotton fabric dyed with mehedy dye was the highest. Perspiration fastness values (acidic 4-5, alkaline 4-5) of the cotton fabric dyed with turmeric dye was the same as turmeric dye. The perspiration fastness values of the cotton fabric dyed with tea leaf dye was 4 for acidic and 4 for alkaline. The 4th values of the color fastness properties were for the cotton fabric dyed with pomegranate dye was 3-4 both for acidic and alkaline medium.

FTIR observation

The colorfastness properties and the color intensity properties of the cotton fabrics were assessed using Fourier Transform Infrared spectroscopy. IR spectroscopy was taken after dyeing the fabric with natural selected dyestuffs. FTIR spectral observation was effortlessly detected the intensity of the color using IR spectrum with the facilities of a FTIR instrument and shown in Figures 6-9. The infrared rays can enter a few microns into the sample surface and shown the results with infrared radiation wave numbers. When the sample cannot grip infrared light a spectral scan was not achieved. IR radiation was used to detect the peaks connected to the sample from the spectral scan and then assessment of the enduring spectral scan was completed. The region of the infrared spectral was from 340 to 4600 wave numbers in the FTIR observation.

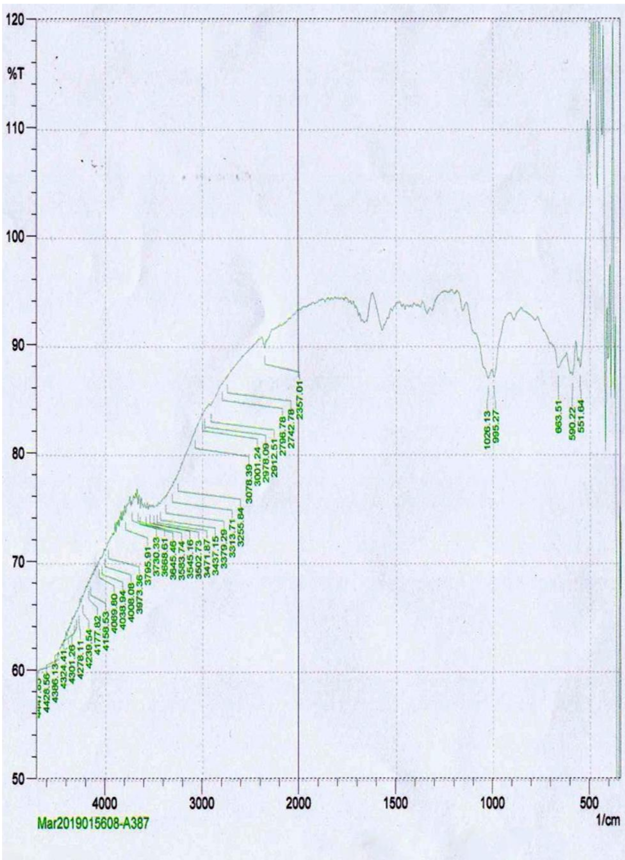
FTIR assessment of the anonymous materials was investigated using IR radiation with the IR highest peak points.

The lowest and highest peaks for the fabrics dyed with mehedy/henna were 362 cm^{-1} and 4609 cm^{-1} wave numbers. The lowest and highest peaks for the fabrics dyed with turmeric were 343 cm^{-1} and 4582 cm^{-1} wave numbers. The lowest and highest peaks for the fabrics dyed with tea were 405 cm^{-1} and 3541 cm^{-1} wave numbers. The lowest and highest peaks for the fabrics dyed with pomegranate were 516 cm^{-1} and 3363 cm^{-1} wave numbers. These peaks clarify the existence of the colorant in the perceptible spectral range and they were distinctive for detecting the chromophore present in the dyestuff those was responsible for specific colored shades on fabric.

The highest peak for the most intense color mehedy/henna was at 4609 cm^{-1} that confirms the existence of chromophore in fabric that increases dye fastness. That was why, the highest color fastness properties were obtained correspondingly in mehedy/henna dye stuffs (4609 cm^{-1}), then in turmeric dye stuffs (4582 cm^{-1}), then in tea leaf dye stuffs (3541 cm^{-1}) and finally in pomegranate dye stuffs (3363 cm^{-1}) that is shown in Table 4.

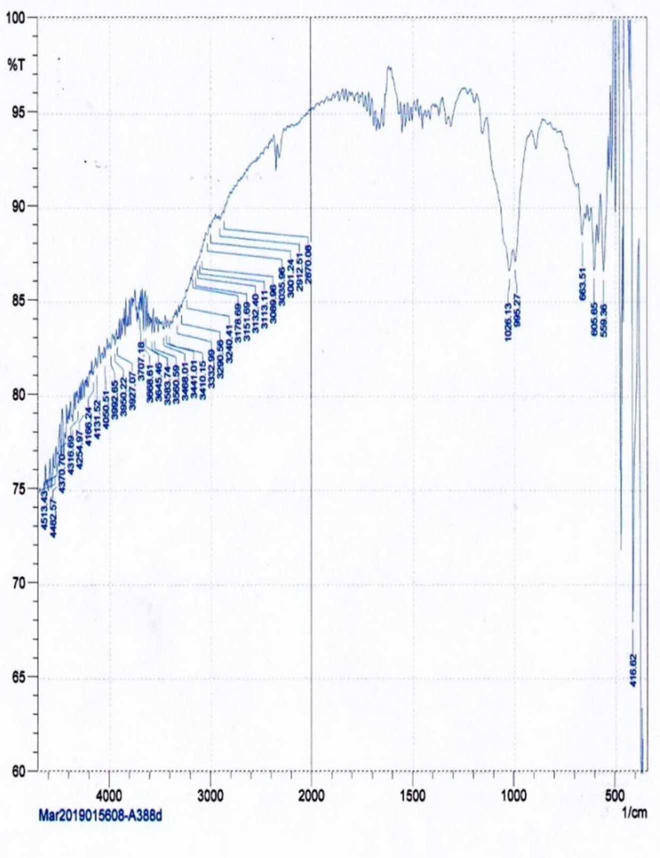
Table 4 FTIR highest wave numbers obtained from dyed cotton fabrics using different dyes

S.N	Fabric dyed with	Highest peak points (wave numbers) [cm^{-1}]
01	Henna/mehedy dye	4609
02	Turmeric dye	4582
03	Tea leaf dye	3541
04	Pomegranate dye	3363



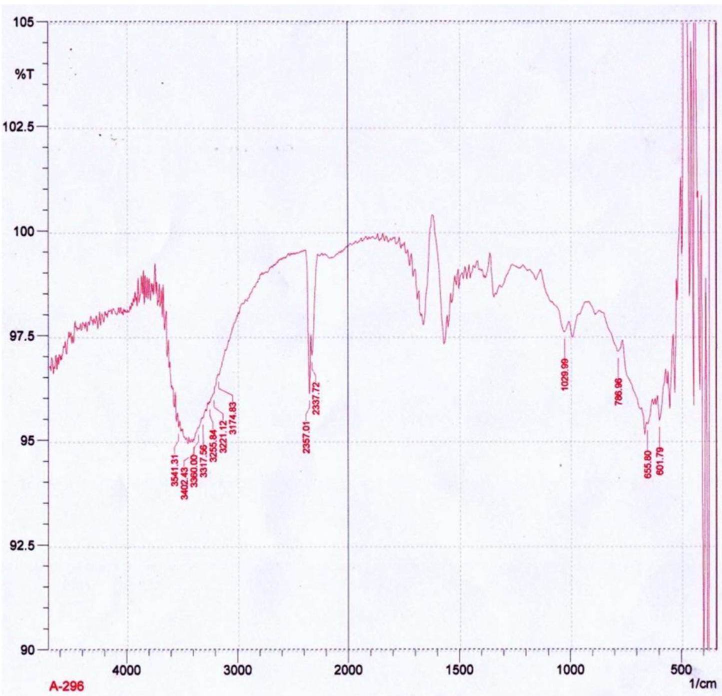
	Peak	Intensity	Corr. Inte	Base (H)	Base (L)	Area	Corr. Are
1	362.62	21.19	67.97	370.33	339.47	8.8	6.51
2	551.64	88.13	2.75	555.5	513.07	0.94	0.99
3	590.22	87.44	2.73	621.08	574.79	2.49	0.38
4	663.51	88.13	1.79	698.23	621.08	3.89	0.3
5	995.27	87.2	1.38	1006.84	918.12	3.79	0.12
6	1026.13	87.08	1.49	1138	1010.7	5.84	0.52
7	2357.01	89.95	0.73	2384.02	2345.44	1.71	0.08
8	2742.78	87.21	0.04	2746.63	2465.03	14.42	0
9	2796.78	86.6	0.08	2800.64	2754.35	2.82	0.01
10	2912.51	84.62	0.3	2924.09	2804.5	8.11	0.09
11	2978.09	84.13	0.06	2981.95	2931.8	3.68	0
12	3001.24	83.8	0.09	3005.1	2985.81	1.47	0.01
13	3078.39	82.15	0.08	3082.25	3005.1	6.23	0.01
14	3255.84	78.22	0.09	3259.7	3086.11	16.67	0.04
15	3313.71	77.22	0.09	3317.56	3263.56	5.93	0.02
16	3379.29	76.2	0.1	3383.14	3317.56	7.55	0.02
17	3437.15	75.57	0.2	3448.72	3402.43	5.56	0.02
18	3471.87	75.34	0.16	3479.58	3452.58	3.3	0.01
19	3502.73	75.22	0.23	3510.45	3483.44	3.32	0.02
20	3545.16	75.28	0.21	3549.02	3529.73	2.37	0.01
21	3583.74	75.12	0.51	3599.17	3572.17	3.32	0.04
22	3645.46	75.16	1.06	3653.18	3633.89	2.34	0.07
23	3668.61	75.47	1.23	3676.32	3657.04	2.3	0.06
24	3730.33	75.51	0.52	3738.05	3714.9	2.79	0.04
25	3795.91	74.68	0.87	3803.63	3753.48	6.14	0.12
26	3973.36	72.02	0.11	3977.22	3950.22	3.81	0.01
27	4008.08	71.28	0.21	4015.79	3992.65	3.38	0.02
28	4038.94	70.58	0.19	4042.8	4015.79	4.02	0.02
29	4069.8	70.2	0.11	4073.66	4062.09	1.76	0
30	4158.53	68.65	0.14	4162.38	4139.24	3.74	0.01
31	4177.82	68.27	0.16	4181.67	4162.38	3.18	0.02
32	4239.54	67.01	0.19	4243.4	4204.82	6.61	0.04
33	4278.11	66.02	0.2	4281.97	4266.54	2.75	0.01
34	4301.26	65.59	0.15	4305.12	4285.83	3.51	0.02
35	4324.41	65.15	0.18	4328.26	4308.97	3.56	0.01
36	4386.13	63.86	0.22	4389.99	4362.98	5.19	0.02
37	4428.56	62.95	0.19	4432.42	4413.13	3.84	0.03
38	4447.85	62.48	0.32	4455.56	4432.42	4.69	0.02
39	4548.15	60.39	0.13	4552.01	4490.28	13.26	0.11
40	4567.44	59.66	0.25	4571.29	4552.01	4.27	0.02
41	4609.87	58.73	0.28	4613.73	4594.44	4.39	0.02

Figure 6 FTIR observation of the henna/mehedy dyed fabrics



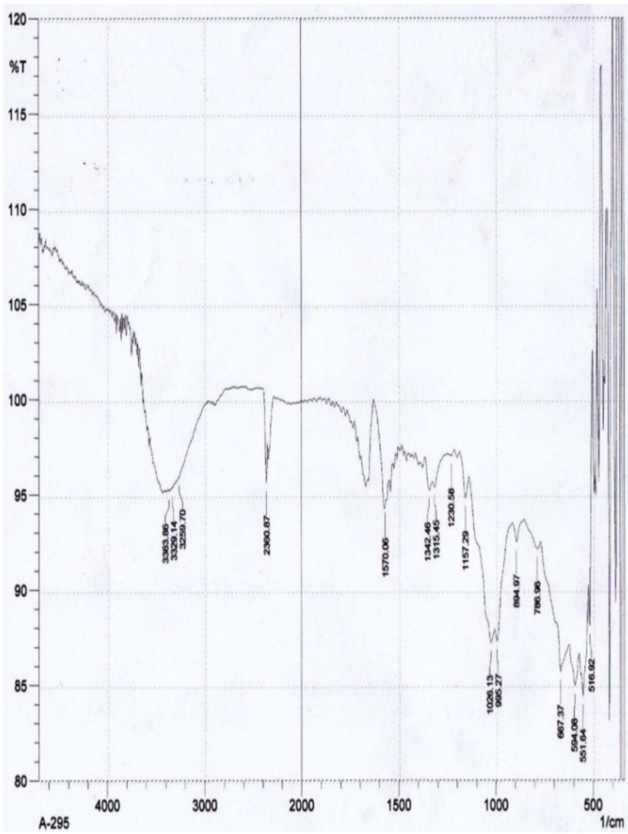
	Peak	Intensity	Corr. Inte	Base (H)	Base (L)	Area	Corr. Are
1	343.33	24	15.24	347.19	339.47	4.7	0.71
2	358.76	12.02	40.61	366.48	351.04	8.3	4.06
3	416.62	68.06	27.01	424.34	389.62	3.36	2.05
4	559.36	86.62	4.32	570.93	540.07	1.59	0.38
5	605.65	86.71	2.68	617.22	594.08	1.29	0.16
6	663.51	88.6	1.5	682.8	655.8	1.31	0.11
7	995.27	87.18	1.6	1006.84	933.55	3.12	0.15
8	1026.13	86.68	1.94	1134.14	1010.7	5.69	0.69
9	2870.08	89.78	0.22	2877.79	2831.5	2.08	0.02
10	2912.51	89.4	0.25	2916.37	2877.79	1.84	0.03
11	3001.24	89.04	0.2	3008.95	2970.38	1.9	0.02
12	3035.96	88.6	0.22	3047.53	3012.81	1.79	0.02
13	3089.96	87.67	0.27	3097.68	3070.68	1.5	0.02
14	3113.11	87.4	0.1	3116.97	3101.54	0.89	0
15	3132.4	87.16	0.06	3136.25	3120.82	0.91	0
16	3151.69	86.75	0.28	3163.26	3140.11	1.41	0.02
17	3178.69	86.44	0.11	3182.55	3167.12	0.95	0
18	3240.41	85.57	0.18	3244.27	3201.83	2.81	0.03
19	3290.56	84.75	0.21	3298.28	3259.7	2.71	0.01
20	3332.99	84.23	0.47	3340.71	3317.56	1.7	0.03
21	3410.15	83.62	0.41	3425.58	3402.43	1.77	0.02
22	3441.01	83.7	0.5	3452.58	3429.43	1.77	0.04
23	3468.01	83.59	0.57	3483.44	3456.44	2.07	0.05
24	3560.59	83.4	1.11	3568.31	3549.02	1.48	0.06
25	3583.74	83.34	1.16	3599.17	3572.17	2.04	0.07
26	3645.46	83.54	2	3653.18	3633.89	1.41	0.1
27	3668.61	83.47	1.93	3676.32	3657.04	1.41	0.09
28	3707.18	84.63	0.56	3714.9	3695.61	1.36	0.03
29	3927.07	83.08	0.71	3934.78	3907.78	2.14	0.08
30	3950.22	82.75	0.6	3961.79	3938.64	1.87	0.04
31	3992.65	82.58	0.48	4004.22	3977.22	2.2	0.04
32	4050.51	82.08	0.71	4058.23	4027.37	2.58	0.07
33	4131.52	81.55	0.76	4143.1	4108.38	3	0.09
34	4166.24	81.18	0.7	4177.82	4146.95	2.74	0.07
35	4254.97	79.95	0.85	4266.54	4247.25	1.83	0.04
36	4316.69	79.65	0.6	4324.41	4305.12	1.89	0.04
37	4370.7	78.67	0.55	4374.55	4355.27	1.95	0.04
38	4482.57	76.31	2.74	4494.14	4474.85	2.14	0.17
39	4513.43	76.73	0.62	4517.29	4498	2.13	0.04
40	4544.29	76.22	0.92	4559.72	4536.58	2.69	0.08
41	4582.87	75.14	1.56	4590.58	4563.58	3.26	0.15

Figure 7 FTIR observation of the turmeric dyed fabrics



	Peak	Intensity	Corr. Inte	Base (H)	Base (L)	Area	Corr. Are
1	405.05	89.68	10.41	412.77	393.48	0.54	0.51
2	601.79	95.5	0.74	609.51	574.79	0.61	0.07
3	655.8	95.42	0.12	659.66	636.51	0.45	0.01
4	786.96	97.15	0.35	852.54	771.53	0.9	0.08
5	1029.99	97.62	0.37	1083.99	1010.7	0.66	0.05
6	2337.72	97.07	0.73	2345.44	2283.72	0.48	0.09
7	2357.01	96.15	1.61	2391.73	2349.3	0.42	0.12
8	3174.83	96.6	0.1	3182.55	3116.97	0.91	0.02
9	3221.12	96.15	0.04	3224.98	3182.55	0.67	0
10	3255.84	95.94	0.06	3263.56	3228.84	0.61	0
11	3317.56	95.58	0.04	3321.42	3298.28	0.45	0
12	3360	95.33	0.03	3363.86	3332.99	0.63	0.01
13	3402.43	95.04	0.05	3406.29	3367.71	0.83	0
14	3541.31	95.35	0.26	3549.02	3529.73	0.39	0.01

Figure 8 FTIR observation of the tea leaf dyed fabrics



	Peak	Intensity	Corr. Inte	Base (H)	Base (L)	Area	Corr. Are
1	516.92	88.09	6.57	524.64	505.35	0.59	0.31
2	551.64	84.39	2.09	559.36	528.5	2	0.22
3	594.08	84.94	1.86	621.08	574.79	3.09	0.24
4	667.37	85.66	3.04	767.67	624.94	7.6	0.85
5	786.96	92.14	0.55	852.54	771.53	2.65	0.11
6	894.97	92.52	1.02	914.26	856.39	1.77	0.1
7	995.27	87.3	1.05	1002.98	918.12	3.49	0.09
8	1026.13	87.23	1.87	1138	1006.84	5.56	0.64
9	1157.29	94.8	1.52	1184.29	1141.86	0.79	0.12
10	1230.58	97.03	0.2	1246.02	1215.15	0.39	0.02
11	1315.45	95.38	0.44	1323.17	1265.3	0.94	0.03
12	1342.46	95.26	0.96	1361.74	1327.03	0.67	0.09
13	1570.06	94.44	0.62	1627.92	1566.2	0.79	0.08
14	2360.87	95.64	2.74	2399.45	2349.3	0.4	0.21
15	3259.7	95.9	0.06	3263.56	3109.25	1.97	0.02
16	3329.14	95.36	0.06	3332.99	3309.85	0.47	0
17	3363.86	95.2	0.11	3371.57	3336.85	0.73	0.01

Figure 9 FTIR observation of the pomegranate dyed fabrics

4 CONCLUSION

It was seen throughout the research that mehedy/henna dye exposed the best colorfastness properties in all the experiments. This was because mehedy/henna dye reacted with cellulose of cotton in alkaline condition to form a covalent bond that formed a long lasting attachment between the dye and the cellulose; therefore it was not removed by frequent treatment with steaming water in neutral conditions and exposed excellent color fastness properties. Mehedy dye contained a reactive group that acted as an integral part of fiber and that covalent bond was formed between the dye molecules and the terminal reactive group. Mehedy was dyed in two phases, one was dye absorption and second was fixation where reaction occurred between fiber and dye stuffs. Electro negativity of oxygen atom had lead propensity of OH group for ionizing. Cellulose was therefore ionized in alkaline conditions and acted as a nucleophilic component which, showed succeeding reactions with acid halides. Mehedy dyes required alkaline catalyst for fixation with cellulose that was why mehedy dyestuff showed best color fastness properties those were ascertained by above experiments. This research was practice based and further study could enhance the possibilities of dyeing cotton fabrics with natural dyes.

5 REFERENCES

1. Kesornsit S., Jitjankarn P., Sajomsang W., Gonil P., Bremner J.B., Chairat M.: Polydopamine-coated silk yarn for improving the light fastness of natural dyes, Coloration Technology 135(2), 2019, pp. 143-151, https://doi.org/10.1111/cote.12390
2. Ford L., Rayner C.M.. Blackburn R.S.: Comparative sorption isotherms for colorants present in Dyers' madder (Rubia tinctorum L.) provide new insights into historical dyeing, Coloration Technology 134(1), 2018, pp. 3-12, https://doi.org/10.1111/cote.12327
3. Kabir S.M.M., Hasan M.M., Uddin M.Z.: Novel approach to dye polyethylene terephthalate (PET) fabric in supercritical carbon dioxide with natural curcuminoid dyes, Fibres & Textiles in Eastern Europe 27(3), 2019, pp. 65-70, DOI: 10.5604/01.3001.0013.0744
4. Jabeen S., Ali S., Nadeem M., Arif K., Qureshi N., Shar G.A., Soomro G.A., Iqbal M., Nazir A., Siddiqua U.H.: Statistical modeling for the extraction of dye from natural source and industrial applications, Polish Journal of Environmental Studies 28(4), 2019, pp. 2145-2150, https://doi.org/10.15244/pjoes/85125
5. Batool F., Iqbal N., Azeem M., Adeel S., Ali M.: Sustainable dyeing of cotton fabric using black carrot (daucus carota l.) plant residue as a source of natural colorant, Polish Journal of Environmental Studies 28(5), 2019, pp. 3081-3087, https://doi.org/10.15244/pjoes/93712

6. Shabbir M., Rather L.J., Bukhari M.N., Ul-Islam S., Shahid M., Khan M.A., Mohammad F.: Light fastness and shade variability of tannin colorant dyed wool with the effect of mordanting methods, Journal of Natural Fibers 16(1), 2019, pp. 100-113, https://doi.org/10.1080/15440478.2017.1408521
7. Adeel S., Rehman F.U., Rafi S., Zia K.M., Zuber M.: Environmentally friendly plant-based natural dyes: extraction methodology and applications, Ozturk M., Hakeem K. (eds), Springer, Cham, Plant and Human Health 2, 2019, pp. 383-415, https://doi.org/10.1007/978-3-030-03344-6_17
8. Rather L.J., Shabbir M., Li Q., Mohammad F.: Coloration, UV protective, and antioxidant finishing of wool fabric via natural dye extracts: cleaner production of bioactive textiles, Environmental Progress & Sustainable Energy 38(5), 2019, https://doi.org/10.1002/ep.13187
9. Rather, L.J., Khan M.A., Mohammad F.: Biomordanting potential of Acacia nilotica (Babul) in conjunction with Kerria lacca and Rheum emodi natural dyes, Journal of Natural Fibers 16(2), 2019, pp. 275-286, https://doi.org/10.1080/15440478.2017.1414657
10. Mir R.A., Adeel S., Azeem M., Batool F., Khan A.A., Gul S., Iqbal N.: Green algae, Cladophora glomerata L.–based natural colorants: dyeing optimization and mordanting for textile processing, Journal of Applied Phycology 31, 2019, pp. 2541-2546, https://doi.org/10.1007/s10811-018-1717-6
11. Barani H., Rezaee K., Maleki H.: Influence of dyeing conditions of natural dye extracted from Berberis integerrima fruit on color shade of woolen yarn, Journal of Natural Fibers 16(4), 2019, pp. 524-535, https://doi.org/10.1080/15440478.2018.1427172
12. Shahid M., Shahid-ul-Islam, Rather L.J., Manzoor N., Mohammad F.: Simultaneous shade development, antibacterial, and antifungal functionalization of wool using Punica granatum L. Peel extract as a source of textile dye, Journal of Natural Fibers 16(4), 2019, pp. 555-566, https://doi.org/10.1080/15440478.2018.1428846
13. Baig R., Hussain D., Najam-Ul-Haq M., Rajput A.W., Amjad R.: Eco-friendly route for dyeing of cotton fabric using three organic mordants in reactive dyes, Industria Textila 70(1), 2019, pp. 25-29, DOI:10.35530/it.070.01.1532
14. Shahid-ul-Islam, Rather L.J., Shabbir M., Sheikh J., Bukhari M.N., Khan M.A., Mohammad F.: Exploiting the potential of polyphenolic biomordants in environmentally friendly coloration of wool with natural dye from Butea monosperma flower extract, Journal of Natural Fibers 16(4), 2019, pp. 512-523, https://doi.org/10.1080/15440478.2018.1426080
15. Jiang H., Hu X., Meena B.I., Khan A., Hussain M.T., Yao J., Wang J.: Extraction of natural dyes from the stem of Caulis spatholobi and their application on wool, Textile Research Journal 89(23-24), 2019, pp. 5209-5217, https://doi.org/10.1177/0040517519853788
16. Günaydin G.K., Avinc O., Palamutcu S., Yavas A., Soydan A.S.: Naturally Colored Organic Cotton and Naturally Colored Cotton Fiber Production, Gardetti M., Muthu S. (eds) Organic Cotton. Textile Science and Clothing Technology. Springer, Singapore, 2019, pp. 81-99, https://doi.org/10.1007/978-981-10-8782-0_4
17. Patel B., Kanade P.: Sustainable dyeing and printing with natural colours vis-à-vis preparation of hygienic viscose rayon fabric, Sustainable Materials and Technologies 22, 2019, e00116, https://doi.org/10.1016/j.susmat.2019.e00116
18. Fan Y., Zhang Y.Q., Yan K., Long J.J.: Synthesis of a novel disperse reactive dye involving a versatile bridge group for the sustainable coloration of natural fibers in supercritical carbon dioxide, Advanced Science 6(1), 2019, p. 1801368, https://doi.org/10.1002/advs.201801368
19. Tiwari A., Srivastava M.: Colouration and UV protection properties of cotton khadi fabric dyed with galls of quercus infectoria dye extract, Man-Made Textiles in India 47(2), 2019, pp. 49-54
20. Zuber M., Adeel S., Rehman F.U., Anjum F., Muneer M., Abdullah M., Zia K.M.: Influence of microwave radiation on dyeing of bio-mordanted silk fabric using Neem Bark (Azadirachta indica)-based tannin natural dye, Journal of Natural Fibers, 2019, pp. 1-13, https://doi.org/10.1080/15440478.2019.1576569
21. Micó-Vicent B., Jordán J., Perales E., Martínez-Verdú F.M., Cases F.: Finding the additives incorporation moment in hybrid natural pigments synthesis to improve bioresin properties, Coatings 9(1), 2019, pp. 1-17, https://doi.org/10.3390/coatings9010034.
22. Wang L., Wang N., Jia S., Zhou Q.: Research on dyeing and ultraviolet protection of silk fabric using vegetable dyes extracted from Flos Sophorae, Textile Research Journal 79(15), 2009, pp. 1402-1409, https://doi.org/10.1177/0040517509338345
23. Sun J., Wang H., Zheng C., Wang G.: Synthesis of some surfactant-type acid dyes and their low-temperature dyeing properties on wool fiber, Journal of Cleaner Production 218, 2019, pp. 284-293, https://doi.org/10.1016/j.jclepro.2019.01.341
24. Kumbhar S., Hankare P., Sabale S., Kumbhar R.: Eco-friendly dyeing of cotton with brown natural dye extracted from Ficus amplissima Smith leaves, Environmental Chemistry Letters 17, 2019, pp. 1161-1166, https://doi.org/10.1007/s10311-018-00854-w
25. Sen A., Bhowal A., Datta, S.: Application of natural dye on polytrimethylene terephthalate fiber, Research Journal of Textile and Apparel 23(1), 2019, pp. 71-90, https://doi.org/10.1108/RJTA-06-2018-0041
26. Safapour S., Sadeghi-Kiakhani M., Doustmohammadi S.: Chitosan-cyanuric chloride hybrid as an efficient novel bio-mordant for improvement of cochineal natural dye absorption on wool yarns, The Journal of The Textile Institute 110(1), 2019, pp. 81-88, https://doi.org/10.1080/00405000.2018.1503384
27. Ayare N.N., Ramugade S.H., Sekar N.: Photostable coumarin containing azo dyes with multifunctional property, Dyes and Pigments 163, 2019, pp. 692-699, https://doi.org/10.1016/j.dyepig.2018.12.050

28. Abate M.T., Ferri A., Guan J., Chen G., Nierstrasz V.: Colouration and bio-activation of polyester fabric with curcumin in supercritical CO_2: Part I - Investigating colouration properties, The Journal of Supercritical Fluids 152, 2019, p. 104548, https://doi.org/10.1016/j.supflu.2019.104548
29. Su T., Han Y., Liu H., Li L., Zhang Z., Li Z.: The surface modification by O2 low temperature plasma to improve dyeing properties of Rex rabbit fibers, Journal of Engineered Fibers and Fabrics 14, 2019, pp. 1-12, https://doi.org/10.1177/1558925019854024
30. Jalali S., Rezaei R., Afjeh M.G., Eslahi, N.: Effect of vanilla as a natural alternative to traditional carriers in polyester dyeing with disperse dyes, Fibers and Polymers 20(1), 2019, pp. 86-92, https://doi.org/10.1007/s12221-019-8482-2
31. Velmurugan P., Vedhanayakisri K.A., Park Y.J., Jin J.S., Oh B.T.: Use of Aronia melanocarpa fruit dye combined with silver nanoparticles to dye fabrics and leather and assessment of its antibacterial potential against skin bacteria, Fibers and Polymers 20(2), 2019, pp. 302-311, https://doi.org/10.1007/s12221-019-8875-2
32. Patil S.P., Pandit P., Laddha K.S.: Eco-friendly single bath dyeing and ultraviolet protective finishing of proteinous fabric using loganin derived blue dye, Journal of Natural Fibers, 2019, pp. 1-9, https://doi.org/10.1080/15440478.2019.1598915
33. Wang Y., Tang Y.L., Lee C.H., Kan C.W.: A computer color-matching study of reverse micellar dyeing of wool with reactive dyes, Polymers (Basel) 11(1), 2019, pp. 1-16, doi: 10.3390/polym11010132
34. Shah M.R., George I.A.: Increased biomass and pigment production from Cassia alata L. callus cultures and their potential as a textile dye, Industrial Crops and Products 128, 2019, pp. 346-353, https://doi.org/10.1016/j.indcrop.2018.11.018
35. Sharma A., Kadam S., Mathur P., Sheikh J.: Re-using henna natural dyeing wastewater for coloration and multifunctional finishing of linen fabric, Sustainable Chemistry and Pharmacy 11, 2019, pp. 17-22, https://doi.org/10.1016/j.scp.2018.12.001
36. Benli H., Bahtiyari M.İ.: Combination of dyeing method and ozone after-treatment to apply natural dyes on to cotton fabrics, Ozone: Science & Engineering 40(1), 2018, pp. 44-53, https://doi.org/10.1080/01919512.2017.1336926
37. Rehman F., Adeel S., Hanif R., Muneer M., Zia K.M., Zuber M., Jamal M.A., Khosa M.K.: Modulation of marigold based lutein dye and its dyeing behaviour using UV radiation, Journal of Natural Fibers 14(1), 2017, pp. 63-70, https://doi.org/10.1080/15440478.2016.1146642
38. Kilinc M., Canbolat S., Merdan N., Dayioglu H., Akin F.: Investigation of the color, fastness and antimicrobial properties of wool fabrics dyed with the natural dye extracted from the cone of Chamaecyparis Lawsoniana, Procedia - Social and Behavioral Sciences 195, 2015, pp. 2152-2159, https://doi.org/10.1016/j.sbspro.2015.06.281
39. Jafari S., Izadan H., Khoddami A., Zarrebini M.: Investigation into the dyeing of soybean fibres with natural dyes and their antimicrobial properties, Progress in Color, Colorants and Coatings 7(2), 2014, pp. 95-104
40. Rehman F.U., Adeel S., Qaiser S., Bhatti I.A., Shahid M., Zuber M.: Dyeing behaviour of gamma irradiated cotton fabric using Lawson dye extracted from henna leaves (Lawsonia inermis), Radiation Physics and Chemistry 81(11), 2012, pp. 1752-1756, https://doi.org/10.1016/j.radphyschem.2012.06.013
41. Mongkholrattanasit R., Kryštůfek J., Wiener J.: Dyeing and fastness properties of natural dyes extracted from eucalyptus leaves using padding techniques, Fibers and Polymers 11(3), 2010, pp. 346-350, https://doi.org/10.1007/s12221-010-0346-8
42. Rahman M.: How Pad Steam Dyeing Machine Works Practically, Auto Garment, 2016, Available at: https://autogarment.com/pad-steam-dyeing-machine/

THE RESEARCH OF THE PROCESS OF FORGING A ROLLING ROLLER THROUGH THE PACK OF THE FINAL FORM OF REWINDING MACHINES

O.P. Manoilenko, B.S. Zavertannyi and O.O. Akymov

Kyiv National University of Technology and Design, Nemirovich-Danchenko st. 2, 01011 Kyiv, Ukraine
manojlenko.op@knutd.com.ua, botanuga@ukr.net, akimov.al.al@gmail.com

Abstract: *In the work a comparative analysis of the authors proposed the new design of the rolling roller in the form of segments [1] with the basic design of the rolling roller machine BP-340 [2] (Figure 1). It is established that the application of the segment roller achieves a uniform slip along the entire line of the coil forming cone, with the increase in the number of segments in direct proportion to the decrease in the maximum friction speed. The results of the study allow us to determine the optimal parameters of the segmental stiffening roller, which provide a qualitative process of forming the packing on the conical reel. They also provide a reduction in the heat and energy consumption of the friction roller in the steam, the roller, which leads to an increase in the life of the parts of the winding mechanism. Thread injury in the process of winding the conical reel is reduced.*

Keywords: *packing, bobbin, bobbin holder, rolling roller, slippage, rewinding of threads, winding mechanism.*

1 INTRODUCTION

In preparatory operations, the preparation of textile materials (yarns) plays a significant role in rewinding them into bobbins. In rewinding machines of basic design with direct drive in the winding mechanisms (Figure 1a); a continuous friction rolling roller 1 is used, which is mounted in bearings on a rigidly fixed axis 2, which is fixed to the rocker arm 3. Its main purpose is to secure the threads to the reel 4 in the process of winding it and adjusting its tension which provides the required packing density [3].

The clamping force is regulated by the counter-weight 5. In the process of work over time, wear of the stiffening roller is observed. The magnitude and nature of its wear is uneven in length. More intense wear is observed at its ends. Also, the process of winding the thread on the bobbin, accompanied by the release of heat, when slipping the rolling roller on the packaging at the point of contact. Wear of the rolling roller and its heating occur due to the loss of useful energy on the friction sliding of the kinematic pair of the rolling roller - packaging.

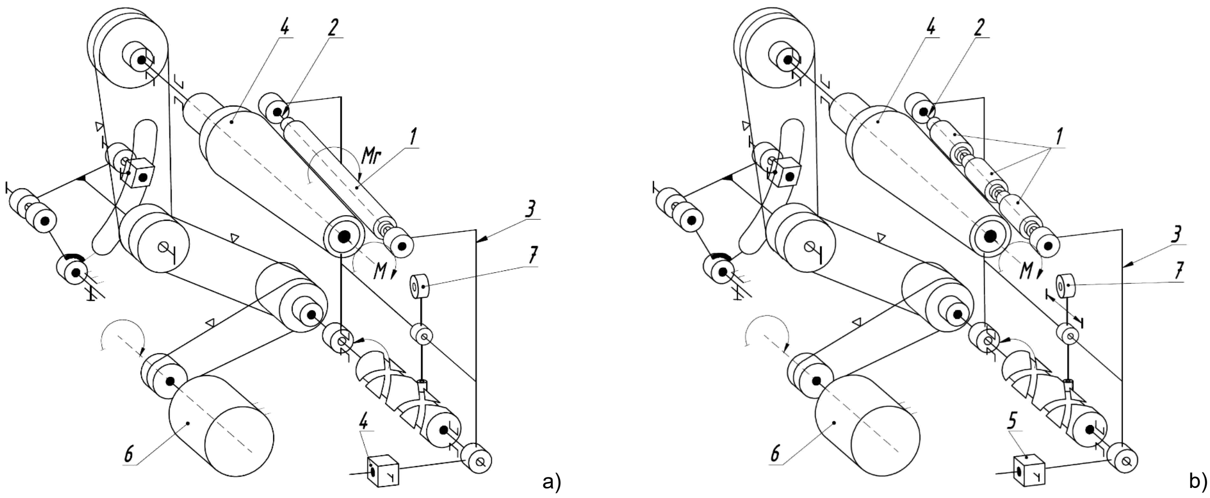


Figure 1 Kinematic-schematic diagrams of the winding mechanism of the rewinding machine: a) basic design of the BP-340 machine, b) new design [1]. 1 - the rolling roller, 2 - the axis, 3 - the rocker arm, 4 - the bobbin with packing, 5 – the counterweight, 6 - the electric motor, 7 - the mechanism of the distributor

References [4, 5] describe the constructions of winding mechanisms and rolling rollers using the rigid fastening of a single rolling roller. But the definition of its effect on packaging slippage has not been considered. At the same time, in [6], in addition to describing the winding mechanisms with a single rolling roller, the technological parameters of winding speed were determined, taking into account the position of the rolling pole. However, the authors do not take into account the effect of the rolling roller force on the displacement of its pole. Also, in the above works, the effect of displacement of the rolling pole on the slippage of the rolling roller relative to the packing has not been investigated.

Therefore, the urgent task is to determine the parameters that affect the slippage of the rolling roller in order to take them into account when developing a rational design of the rolling roller.

2 THEORETICAL SUBSTANTIATION

The reliable operation of the friction roller is due to several factors that influence the nature and magnitude of the rolling roller's slip on the package, which include:

1. A condition that ensures a secure friction connection of the rolling roller with the packing, which is determined by the balance of the friction force [4]. In this case, it is pure rolling friction, in the rolling pole, and rolling friction with slip (with sliding friction) at other points of contact of the rolling roller and packaging:

$$F_{tp} = F_n \cdot f = F_t \cdot \beta \quad (1)$$

   where F_{tp} – friction force [N]; F_n – the force of clamping the rolling roller to the pack [N]; f – coefficient of the materials friction of the rolling roller and packing; F_t – rotating effort [N]; β – clutch of the stock coefficient (chosen with such a calculation that the rolling roller will not slip on the pack in all possible operating modes).

2. Condition of stability work at change of speed modes. To reduce the energy consumption of friction under different modes of operation of the mechanism and reduce the tension of the contacting pair, the roller - packing, it is necessary that the ratio of the magnitude of the pressing force F_n and F_t are constant [10]:

$$F_n/F_t = const \quad (2)$$

3. Factors affecting the slippage should also include the geometric and mass-inertia parameters of the bobbin and the roller.
4. Factor of technological necessity of application of greasing solution. The process of rewinding textiles can be carried out, both with the application of a greasing solution and without it. In the first case, the coefficient of friction is less than in the second (f_1<f_2), therefore, to maintain the friction contact of the rolling roller with the packaging, it is necessary to increase the clamping force $F_{n1} = F_{n2}\frac{f_2}{f_1}$. At the same time, the use of a grease solution improves the heat removal and the packing of the textile material.
5. The factor of geometric slippage, which arises due to unequal change of the linear speed along the contact length of the rolling roller and packing, and depends on the geometrical and structural parameters of the reel and rolling roller.

Specified working conditions of a pair of the roller - packing should be taken into account both when selecting the material of the rolling roller and when calculating and designing the winding mechanism. Particular attention should be paid to the maximum reduction in the amount of slip can be achieved by determining the rational parameters of the mechanism.

3 THE SOLVING OF THE PROBLEM

One of the main factors influencing the work of the friction pair is the rolling roller - the packaging is a geometric slip. Geometric sliding results in uneven slippage of the rolling roller on the conical bobbin, which results in uneven wear over the entire length. Consider ways to reduce the value of geometric slip. The work of a kinematic pair of a rolling roller - packing with straight lines and linear contact can generally be considered as rolling of a cone and a cylinder with inordinate vertices: *O* - the top of a cone, O' - the top of a cylinder which is at infinite distance from the rolling pole *P* (Figure 2). The work of a kinematic pair is a rolling roller - the packing can be represented by the plots of the velocity distribution of the sliding velocities v_k and the friction forces F_f along the length of the contact line (Figure 2).

When rolling the rolling roller, the packing velocity along the contact line *AB* changes not uniformly v_{A1} < v_{B1} respectively at points *A* and *B*. On the driven rolling roller, the speed at the same points has the same value and is equal to the velocity in the rolling pole *P*– v_{A2} = v_{B2} = v . In the rolling pole *P* of the contact line *AB*, there is a pure rolling, at all other points - rolling occurs with sliding at velocities respectively v_{SA} and v_{SB}, while at the section *PA* the sliding occurs with a negative sign and at the section *PB* with the positive one.

In the complete absence of loads, the rolling pole *P* lies in the middle of the line of contact *AB*, and the moments of friction forces M_{f1} and M_{f2} between the surfaces of the rolling roller and the packing that occur respectively on the sections *PA* and *PB* are balanced. When the mechanism is loaded, the rolling pole *P* shifts. In this case, the friction force F_{f1} arising on the *PA* section plays a negative role - it slows down the driven roller, and the friction force F_{f2} arising on the section *PB*, on the contrary, accelerates it. Having started the coordinates in the middle of the contact line *AB* at point *C* (*AC* = *CB*). We consider the coordinate *x* to the vertex of packing p. *O* to be positive.

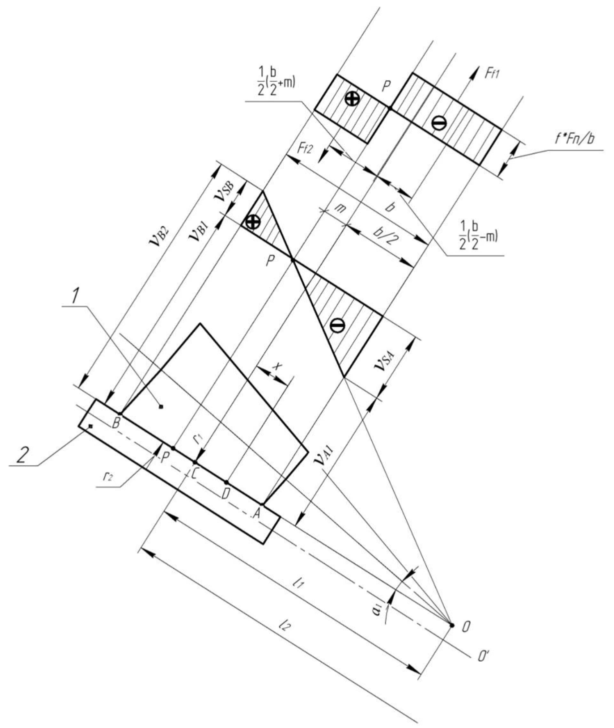


Figure 2 Scheme of distribution of velocity, slip and friction forces along the length of the contact line when using a continuous rolling roller: 1 - packaging; 2 - the rolling roller

We introduce the coordinate *m* which determines the position of therolling pole of p. *P* into all dependencies also with its sign: "minus" when moving from the middle to the base of the packing and "plus" when shifting the pole of rolling *P* to the vertex p. *O*. The difference between the moments of friction forces M_{f1} and M_{f2} arising from the friction forces F_{f1} and F_{f2} is balanced by the moment of resistance M_r on the rolling roller [8]. M_r is understood as the full moment of resistance to the rolling roller, including useful resistance, as well as the friction in the roller bearings and the rolling friction of the rolling roller.

$$M_r = F_{f1} \cdot \left(r_2 - \frac{1}{2} \cdot \left(\frac{b}{2} + m\right) \cdot \sin(\alpha_2)\right) - F_{f2} \cdot \cdot (r_2 + + \frac{1}{2} \cdot \left(\frac{b}{2} - m\right) \cdot \sin(\alpha_2)) \quad (3)$$

$$F_{f1} = q_n \cdot f \cdot \left(\frac{b}{2} - m\right); \; F_{f2} = q_n \cdot f \cdot \left(\frac{b}{2} + m\right);$$

$$r_2 = l_2 \cdot \sin(\alpha_2) = const; \; l_2 = \infty; \; q_n = \frac{F_n}{b}$$

where q_n – normally distributed load [N/m]; α_2 – the angle of inclination of the rolling roller ($\alpha_2=0$) [radian]; l_2 – the distance from the roller pole *P* to the top of the rolling roller p.*O´* ($l_2=\infty$); *b* – the length of the contact line of the AB rolling roller with the packing [m].

After substitution and transformations in general form:

$$M_r = -q_n \cdot f \cdot sin(\alpha_2) \cdot \left(m^2 - 2 \cdot m \cdot l_2 - \frac{b^2}{4}\right) \quad (4)$$

Since the rolling roller has a cylindrical shape in the bearings, the moment of resistance M_r including the resistance in the bearings of the rolling roller can be taken to be zero $M_r=0$.

Similarly to the previous difference of moments of friction forces M_{f1} and M_{f2} relative to the driving shaft of the packing gives the moment on the packing:

$$M = -q_n \cdot f \cdot sin(\alpha_1) \cdot \left(m^2 - 2 \cdot m \cdot l_1 - \frac{b^2}{4}\right) \quad (5)$$

where l_1 – the distance from the pole of the rolling p. *P* to the top of the pack p. *O* [m]; α_1 – the angle of inclination of the rolling roller [radian].

The coordinates of the rolling pole, taking into account the moment on the packing and the friction power when geometric sliding is determined from the expression (5):

$$m = l_1 - \sqrt{l_1^2 + \frac{b^2}{4} - \frac{M^2}{q_n \cdot f \cdot \sin(\alpha_1)}} \quad (6)$$

Assume that the rotational force F_t is applied in the rolling pole, then the moment of resistance:

$$M = -F_t \cdot (r_1 - m \cdot sin(\alpha_1)) = -F_t \cdot (l_1 - m) \cdot sin(\alpha_1) \quad (7)$$

Equating this to expression (4) and considering that:

$$F_t = \frac{F_n \cdot f}{\beta} = \frac{q_n \cdot b \cdot f}{\beta} \quad (8)$$

We get it:

$$m = [1 + \cdot \frac{1}{\beta} \cdot \frac{b}{2 \cdot l_1} - \sqrt{1 + \left(\frac{b}{2 \cdot l_1}\right)^2 \cdot \left(1 + \frac{1}{\beta^2}\right)}] \cdot l_1 \quad (9)$$

In order to reduce the slip ratio b/l_1 is taken as small as possible [9], so the terms with the factor $(b/2l_1)^2$ in formula (9) can be neglected. Then with sufficient accuracy it is possible to record:

$$m \approx \frac{F_t}{F_n \cdot f} \qquad m \approx \frac{1}{\beta} \cdot \frac{b}{2} \quad (10)$$

The instantaneous value of the gear ratio of a pair of roller - packing is determined by the expression [10]:

$$i(m) = \frac{r_1 - m \cdot \sin(\alpha 1)}{r_2} = \frac{\sin(\alpha 1) \cdot (l_1 - m)}{r_2} \quad (11)$$

In the winding mechanism at constant rotational force $F_t=const$, the rolling pole of the *P* is shifted depending on the force of the rolling roller along the contact line AB. For the boundary case, where $F_t = F_n \cdot f$ and $\beta = 1$, the coordinate $m \approx 0.5b$, i.e. the pole of p. *P* rolling coincides with p. *B*. Further reduction of the clamping force $F_t > F_n \cdot f$ and the clutch coefficient $\beta<1$ will result in complete slipping of the stiffening roller - slip.

The oscillation of the clamping force, which is differentially related to the time of packing, is accompanied by a change in the position of the rolling pole, p. P, and with it the estimated radius of packing r_1 (r_2 = *const*) and, accordingly, a change in gear ratio (11). With a constant pressing force F_n the pole p. P occupies a constant position, i.e. m = *const*.

One of the most important characteristics is the relative sliding speed ε_x of the rolling roller and packing.

The velocity of relative slipping v_s at an arbitrary point D with the coordinate x (Figure 2) is determined by the difference in the speed of the rolling roller and the packing v_1 and v_2:

$$v_s = v_1 - v_2 = -\frac{(l_2 - l_1)\cdot(x-m)}{(l_2-m)\cdot(l_1-m)}v \qquad (12)$$

The relative velocity of the geometric slip of the rolling roller in the packing in the General case:

$$\varepsilon_x = \frac{v_s}{v} = -\frac{(l_2 - l_1)\cdot(x-m)}{(l_2-m)\cdot(l_1-m)} \qquad (13)$$

Considering in expression (13) that $l_2=\infty$, it is possible to take $l_2-m \approx l_2-l_1$ then the expression of geometric slippage takes the form:

$$\varepsilon_x = -\frac{x-m}{l_1-m} \qquad (14)$$

Complete elimination of geometric slippage can be achieved provided $\alpha_1=0$. In this case, we get cylindrical packaging.

Partial reduction of slippage can be achieved by distributing the load on several rolling rollers – a segment roller. To analyze this, consider the design of the rolling roller with three segments proposed by the authors [1] (Figure 3).

The geometric slippage of a segmental stiffening roller will be equal to the sum of the geometric slippages of each segment according to (14) will have the following form:

$$\varepsilon_x = -\sum_{i=1}^{n}\frac{x_i-m_i}{l_i-m_i} \qquad (15)$$

where l_i – i - those distances from the rolling poles p. P_i to the top of the pack p. O [m]; x_i – i - those coordinates of arbitrary points for calculating the slip relative to the geometric mean of each segment [m]; m_i – i - those coordinates of the i-th poles of rolling of p. P_i of each i-th segment, relative to their geometric mean [m]; n – the number of segments of the rolling roller.

Consider the marginal case for $F_t = F_n \cdot f$ for a rolling roller made of three identical segments, when the linear speeds of the roller and the reels are equal at the right end of the roller.

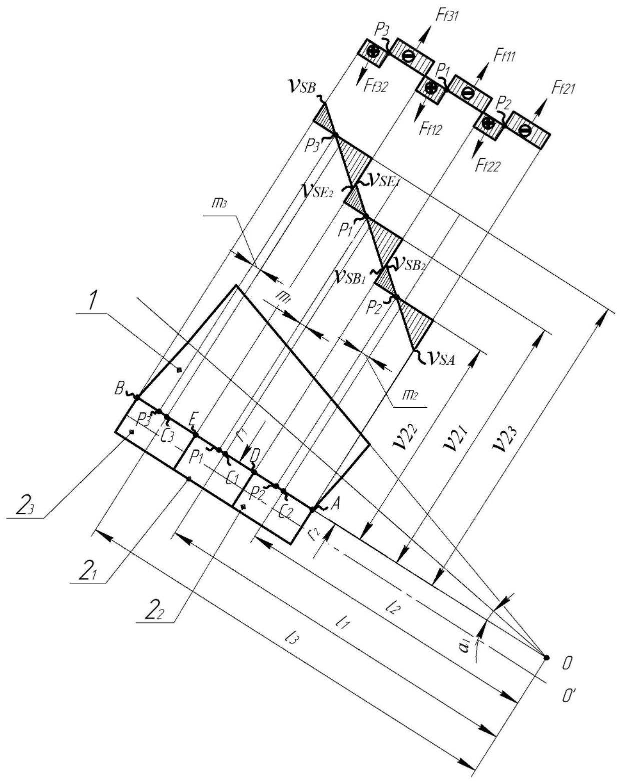


Figure 3 Scheme of distribution of velocity, slip and friction forces along the length of the contact line when using a segmental roller

The amount of slippage for a rolling roller of three segments with the same length is determined by the expression:

$$\varepsilon_x = -\frac{x_1-m_1}{l_1-m_1} - \frac{x_2-m_2}{l_2-m_2} - \frac{x_3-m_3}{l_3-m_3} \qquad (16)$$

where $l_2 = l_1 - \frac{b}{3}$, $l_3 = l_1 + \frac{b}{3}$, $x_1 = x$, $x_2 = x_1$, $x_3 = x_1$, $m_1 = m_2 = m_3 = \frac{m}{3}$

Then (15) taking into account the given coordinates in the limit case $m=b/2$ and $x=-b/6$ looks like:

$$\varepsilon_{x''} = \frac{\frac{b}{3}}{l_1 - \frac{b}{2}} + \frac{\frac{b}{3}}{l_1 - \frac{b}{6}} + \frac{\frac{b}{3}}{l_1 + \frac{b}{6}} \qquad (17)$$

Similarly, for the boundary case when, $m=b/2$ and $x=-b/2$ (14) for a one-component stiffening roller will look like:

$$\varepsilon_{x'} = \frac{b}{l_1 - \frac{b}{2}} \qquad (18)$$

Thus, by adopting the parameters of the rolling roller used on the BP-340 machine [2] at the beginning of the winding $b=0.25$ and $l_1=0.56$, we obtain the maximum slip value, respectively, for the basic design and the new rolling roller design with three segments ε_{x1}=0.797 and $\varepsilon_{x2}=0.649$.

Figure 4 presents a graph of the maximum total value of geometric slip ε_x as a function of the number of rollers *n*.

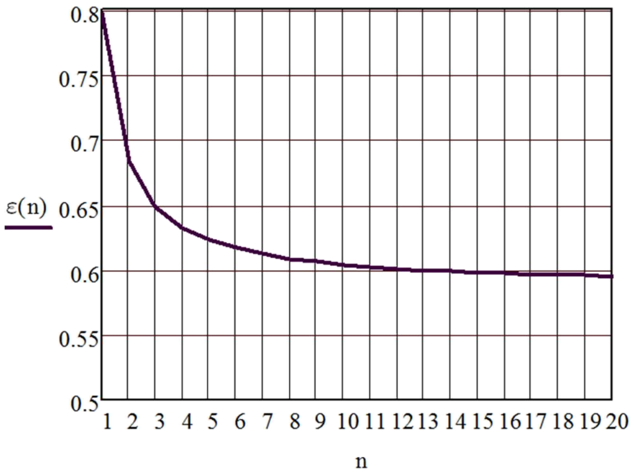


Figure 4 The dependence of geometric slip on the number of segments of the rolling roller

4 CONCLUSIONS

As a result of a comparative analysis of the new design of the rolling roller with the base structure, it is established that the value of geometric slip in the application of the segmental roller allows to reduce the value of maximum slip at the beginning of the winding process by more than 18.5%. It has also been found that an increase in the number of roller segments results in a decrease in the amount of slippage, which varies in law with a degree function. This reduces the injury of the thread during the winding process. The results of the calculations show a decrease in slippage when using a three-segment roller. The results obtained allow us to determine the optimal parameters of the winding mechanisms. The results can be used to design new winding mechanisms and upgrade existing equipment.

According to the results of the study, it is advisable to use a rolling roller with a number of segments from 3 to 5. With more segments, the effect of reducing the relative sliding is counterbalanced by friction in the bearing supports on which the segments are installed.

5 REFERENCES

1. Akimov O.O., Manoilenko O.P., Zavertanniy B.S.: Ukrainian Patent UA 136674 U, B65H 54/00. A device for winding threads into bobbins / No. u201902866, declared 03/22/2019, publ. 08/27/2019, Bull. No. 16/2019
2. Ivanova T.P.: Technology and equipment for the preparation of threads for weaving: educational-methodical complex, UO "VSTU", Vitebsk, 2008, 306 p.
3. Fishman K.E., Khruzin N.A.: Production of Kapron Fibre, (in Russian), Khimiya, Moscow, 1976, 312 p.
4. Singh M.K.: Industrial practices in weaving preparatory, Woodhead Publishing India, 2014, 295 p., ISBN: 978-93-80308-29-6, https://doi.org/10.1016/C2014-0-03945-7
5. Gandhi K.L. (Ed.): Woven Textiles: Principles, technologies and applications, Woodhead Publishing, 2012, 488 p., ISBN: 978-1845699307
6. Koranne M.: Package driving and yarn traversing, chapter in Fundamentals of Yarn Winding, Woodhead Publishing India, 2013, pp. 159-173, ISBN: 978-1-78242-068-2
7. Baldin V.A.: Machine parts and design fundamentals, (in Russian), textbook for undergraduate and specialty, V.V. Galevko (Ed), 2nd edition, Yurayt Publishing House, Moscow, 2019, 333 p.
8. Proshkov A.F.: Calculation and design of machines for the production of chemical fibers (in Russian), textbook for university students, Light and food industry, 1982, 402 p.
9. Targ S.M.: A short course in theoretical mechanics, (in Russian), textbook for technical colleges, 10th edition, 1986, 416 p.
10. Pronin B.A., Revkov G.A.: Stepless V-belt and friction drives (variators), (in Russian), 3rd edition, Mechanical Engineering, Moscow, 1980, 320 p.

TRAINING MODELS OF BATIK MOTIF DESIGN DEVELOPMENT FOR DESIGNERS IN MICRO ENTERPRISES

Mulyanto[1], Nadia Sigi Prameswari[2], Lili Hartono[3], Figur Rahman Fuad[4] and Ni Luh Desi In Diana Sari[5]

[1,3,4]Arts Education Department, Faculty of Teacher Training and Education, Sebelas Maret University, Jl.Ir.Sutami 36A, Surakarta, 57216, INDONESIA
[2]Visual Arts Department, Faculty of Languages and Art, Semarang State University, Jl.Sekaran Raya, Gunung Pati, Sekaran, Semarang, 50229, INDONESIA
[5]Visual Communication Design Department, Faculty of Visual Art and Design, Indonesian Institute of the Arts Denpasar, Jl.Nusa Indah, Denpasar, 80235, INDONESIA
mulyanto@staff.uns.ac.id; nadiasigi@mail.unnes.ac.id; liliart_ono@staff.uns.ac.id; figurrahmanfuad@staff.uns.ac.id: desiindianasari@yahoo.com

Abstract: *This participatory action study aims to develop a training model to develop designs of batik motifs for designers in small businesses in Indonesia. Partners of batik motif design at work are batik skippers and the batik motif design has been validated by expert of batik design. Research participants consist of 6 designers and a batik skipper in small busines of Dewi Ratih batik in Pilang village, Sragen regency, Central Java province, Indonesia. There are two processes of data analysis. The first process, qualitative descriptive method is used to explore and compile the draft model of design development training motif for the designer. The second process, the method of reviewing the participatory act of the designer and the skipper to test the draft of the model produced in the first process. The results of study show that the training model of design development motifs for designers in small business includes 4 stages, namely any design needs analysis, program planning, facility and engineering infrastructure, and training measures implementation The training plans programs includes compiling training objectives, materials, media, methods and facilities. The purpose of training is to improve the quality and number of design products. Training materials consist of batik motif patterns, types of batik motifs and the meaning of batik motifs. The prepared training media includes fabrics, patterns and master motif pictures. Training methods include demonstrations with some motif drawing strategies. Training facilities consist of tables, carbon and lighting. The training is conducted based on adult education and self-learning concept, the work process is directed to the designers' creativity development by adjusting the level of competence, and adapted to the socio-cultural environmental conditions of the society, in addition to natural environment of the local area.*

Keywords: *training, development, motif, batik, designer.*

1 INTRODUCTION

Indonesian batik has been recognized by the United Nations Educational, Scientific and Cultural Organization (UNESCO) of the United Nations (UN) as a world non-border heritage on October 2, 2009. Such recognition claims batik to meet 3 requirements of the 5 intangible cultural domains, among others: (1) oral tradition and expression, including language as the vehicle of the intangible cultural heritage, (2) social practices, ritual, and festival events, and (3) traditional craftmanship [1].

Batik is one of the Indonesia's export commodities. The value of Indonesian batik exports to foreign countries over the past four years has always been increasing. In 2011 the value of batik exports amounted to 43.96 million US dollars, in 2012 the exports rose to 46.16 million US dollars, in 2013 the value of batik exports rose again to 47.54 million US dollars and in 2014 rose again to 48.97 million US dollars [2].

In Indonesia, the business world is dominated by micro, small and medium enterprises (UMKM). In 2012 there are 99.99% MSMEs, and they are able to absorb the workforce as much as 97.22% [3]. Similarly, batik business is also dominated by micro, small and medium enterprises, i.e., Dewi Ratih's batik business in Sragen regency, Central Java province, although her business is considered small scale (Republic of Indonesia, 2008) but it has about 200 employees or craftsmen and 88% of them are local and home craftsmen. Similarly nDerbolo, batik business in Sragen regency has about 100 employees and 85% are home batik craftsmen [4].

One of the most facing problems by batik industries in Indonesia is minimum number of professional motifs designers [5]. Normally, batik designers are professionals of old ages, while young designers tend to having lack of ability in exploring creativity; they are just able to move the master motifs on fabrics. This condition apparently happening due to low wage offerred for designers, this generally occurs in the regeneration of designers in Batik industry, one of which occurs in Yogyakarta region [6]. In addition, motif designers in general do not have educational background on their design motifs. The wage for designer motifs in mass amounted to Rp 3.000 s.d. Rp 7.500, - per piece of cloth, surely it depends on levels of motif difficulty. Minimum wage agreed in Sragen regency, in 2013 amounted to Rp 864.000, - (information retrieved from Central Java Governor, SK No. 561.4/58/2012). The amount of batik craftsmen wage above the UMK (district minimum wage) is usually the main dye batik craftsmen, which is Rp 50.000 x 25 per-25 working days = Rp 1.250.000.

Batik is a creative product manufactured by local society [7, 8] and the batik design motif is one of the dominant factors in increasing the selling value of batik products. Thus, to increase selling value of batik products, there should be improvement made in term of the motifs design quality, in addition to improvement on the quality of motifs, which certainly requires focus on training design development motif for the designers. In addition, design training will improve the designer's skill, creativity, design and motif quality [9]. While the quality of the produced motifs highly integrated with the wage rate, for that reason training will increase the designer's wage [10].

Creative ideas, according to Kaufman [11] should inevitably meet three conditions, namely having different ideas, new and innovative; should be highly qualified, and appropriate to the task or relevant. The process of making batik, especially batik tulis (hand-written batik) is rich with the craftsmen's high senses of creativity. To create qualified batik products, the crafters' creativity should be grown in accordance with their respective characters. In a way to cultivate the artisans'creativity, it can be pursued in two ways, according to Rogers & Munandar [12, 13] is by creating both psychological security and psychological freedom. Psychological security means that produced creative products should be accepted as they are, there is no need further evaluation process which suppress or cause threat effects to the artisans. Psychological freedom means that the craftsmen are given the freedom to do their creativity during the batik making process.

Frese, et al [14] in a previous study revealed how important to initiate coaching to business owners to empower community resources and maintain the existence of SMEs in the midst of the influence of globalization which has extended to the industrialization and economic sectors. In his study, there was no specific mention the type of business in the training process because of the heterogeneity of paticipants. Hidayat, et al [15] explained in their research study that skills training can encourage product quality design and motif development at PT. Batik Trusmi Cirebon. This study focused on improving quality in limited liability companies, not on Small Business.

Some previous researchs only focused on the importance of conducting training to business owners in empowering community resources and maintaining the existence of SMEs. In addition, another previous researchs only focused on skills training to encourage product quality in the design and motives of limited liability companies. The novelty of this research was focused on training models for motifs design development for designers in small business.

2 REVIEW OF RELATED LITERATURE

2.1 Training

Training is as an addition of skills, knowledge or attitudes to improve performance in carrying out the work [16]. According to Leonard Nadler & Zeace Nadler [17], training is an activity designed to improve the ability of employees in performing a particular task or job that must be done immediately. According to Gilley and Eggland [18], training is a lesson learned to improve today's work-related skills. In line with this understanding, Hickerson and Middleton [19] define training as a learning process designed to improve the performance of people in doing the work. Training is a centralized activity to improve the ability of employees by increasing their knowledge and operational skills in running a job.

Thus, the definition of training in this study refers to the learning activities consciously in the self design of batik motifs that have the potential in improving the ability of knowledge, operational skills and their attitude in drawing (making batik) in order to produce qualified batik motifs and in the maximum amount.

Training on batik motif design development, as a system, consists of sub-system which includes input, process, output and outcome. Instrumental input, are all the instruments required in the training implementation process. These instruments include facilitators, training objectives, training materials, training media, training methods, training models, resources and evaluation systems. Input environment is the environment where training, natural environment resources, social environment resources, cultural environment, value system and the environment from which the trainee resides. Process, is the whole training implementation activities. Output / outcome is a change in the behavior of the participants of the exercise which include changes in knowledge, skills and attitudes. Outcome / impact is the impact of training activities, can be the improvement of motif quality, increasing the number of batik motifs and increasing the wages of designers.

There are several introduced models in training to design, five models of which are:

1. ADDIE (Analysis, Design, Development, Implementation and Evaluation) model,
2. ASSURE model (Analyze learner, State objective, Select media and material, Utilyze material, Require performance learners, Evaluation / revise),
3. Morrison model, Ross and Kemp,
4. Dick and Carey model, and
5. Job skill training model by Louis Genci.

The ADDIE training model consists of five components, namely analysis, design, development, implementation and evaluation.

The ASSURE training model is a model formulated for teaching and learning activities. This model consists of six steps, namely analysis leaner, stating objectives, select instructional method of media and materials, utilize media and materils, require learner response, and evaluate and revise.

The training model of Morrison, Ross and Kemp focuses on problem identification, analysis of participant characteristics, subject identification and task analysis, stating the training objectives to the training participants, sorting the contents in each training unit, designing the training strategies in order that each trainee can comprehensively master the material, and methods of delivery, developing evaluation tools, and selecting sources which further support learning activities in training.

Dick and Carey's training model is a result oriented and system one of procedural design model, which, so that by applying this model will produce learning materials that can be used to improve the quality of learning and applying the systematic steps. The steps of this model begin by identifying the training objectives, analyzing the training, identifying the input behavior and characteristics of the students, formulating the performance objectives, developing the benchmark reference tests, developing learning strategies, developing and selecting training materials, designing and executing formative evaluations, revising the training materials, and designing and implementing summative evaluations.

The training skill for the job model developed by Louis Genci includes four steps: reviewing the reasons and establishing an exercise program, designing the execution stage, selecting an effective presentation, and implementing and assessing the outcome of the exercise. The developed training model is more relevant to the skills training model. The model developed was assessed by the participants' needs and in designing the program added the required facilities and infrastructure required by the participants.

Suminar, et al [20] in previous studies have examined the empowerment of the Samin Tribe in economic improvement through batik training, although it is not specifically explained procedurally the stages in the training process. Ariefianto [21] said that in increasing impulsive offerings on the commodity of Batik, training was held by CLC Handayani for women craftsmen from Kemirian Tamanan Bondowoso. In this study focused on the role of CLC Handayani compared to the procedural training conducted.

2.2 Theory of behavioral learning

The batik motif design training development is proposed into a bottom-up manner, among others, based on the designers actual needs, the level of design knowledge, the condition of both facilities and infrastructure owned and used by the designers, the socio-cultural environment, and local natural environment. The structured training of batik motif designers is in line with the theory of people-centered development, in which a development should be oriented to improving human life' quality, which should not only rely on the economic growth through the market and strengthening the state [22]. The concept of people-centered development views people's creative initiative as the main development resource and views the material and spiritual well-being as the goal to be achieved through undergoing a development process.

The design development training is a typical learning which engages a lot of skills, so it includes motoric learning. Motoric learning is a learning process referring to the dimension of motion; learning is manifested through muscular responses expressed in body movements or specific body parts [23]. The motoric elements of skills include physical abilities, mental abilities and emotional abilities. Physical abilities include strength, endurance, agility, flexibility and sensory acuity. The ability of the mental function provides the desired movement of motion to the body's motoric system. Mental abilities include the ability to understand the decided movements, to understand the stimulus, to make decisions, to understand the spatial relationships, to assess moving objects, to assess the rhythm, to assess the movements of the past and to understand the mechanics of motion. Emotional ability is one factor supporting the occurrence of effective and efficient movement. There are several affecting factors to the motoric learning process, i.e. individual, environment, equipment or facility and learning facilitators.

There are two basic theories of learning, which is the Behaviorism (Watson, Thorndike, Pavlov, Skinner, & Hull) and the theory of Cognitivism (Gestalt, Piaget, & Norman). Each of these learning theories has implications for psychomotor learning such as design development training. Behaviorism is a theory of behavior changes as a result of experience. Behaviorism views individual only from his/her side of physical phenomena and ignores the mental aspects. The characteristic of this theory is to give priority to the elements and small parts, mechanistic like machine, emphasizing the role of environment, emphasizing the exercises, emphasizing reinforcement and emphasizing the mechanism of learning results.

Behavioral learning theory includes respondent learning, learning contingency, learning operant and observational learning. Skinner's operant conditioning theory of learning, focused on the relationship between behavior and its consequences, is the use of unpleasant and unpleasant consequences to change behavior. If a person's behavior is immediately followed by pleasant consequences, the person will, therefore, engage in that behavior more often. Thorndike's law of effect learning theory suggests that if an action is followed by a satisfactory change in the environment, it is likely to be repeated in similar situations and getting increased. On the contrary, if a behavior is followed by an unsatisfactory change in the environment, the likelihood of the behavior being repeated decreases. Thus one's behavior at some point plays an important role in determining the person's succeeding behavior. The implications of behaviorism theory in design development training, that is, good motor skills can be achieved by repetitive exercise, the participants are given a chance to try and fail, the participants are empowered, motivated and encouraged, and the evaluation on the results of exercise relies on the appearing products which consider the psychological aspect.

Mohan [24] in a Research Report conducted on Behavioral Learning Theory stated that the pattern of skills can be formed through training conducted, in this context through Coaching & Mentoring (C&M) as instructors in the development of motor learning. This study has not been in depth how the skills in producing batik products can be formed. In addition, in previous studies, Kumar, et al [25] explained that the skills of a skill can be achieved by habituation, such as human motor skills in biting and swallowing Gua Zi, will reflexively do so because of the habituation process.

2.3 Adult learning method

Based on characteristics of the studied participants, learning can be divided into two, namely learning for adults (andragogy) and learning for children (pedagogy). The definition of adults, in the context of designing of these motifs, is socially and psychologically mature, i.e. individuals who have had social roles such as job roles, husband-wife roles, parent roles, etc., in addition to being able to direct themselves like making their own decisions [26]. According to Mujiman [27], adult learning is built on four assumptions, namely:

1. Adults direct their own learning objectives,
2. Knowledge has been a source of learning for further learning,
3. Adults learn after he himself wants learning, learning activities were done to meet their life needs, and
4. Adults learn because they seek competence to meet their higher needs, such as the needs of potential self-development, they immediately feel the results of learning, what is learned should at least be usable.

According to Uno [26], the concept of adult learning is a non-authoritarian, more informal, lesson-oriented lesson that is generally aimed at finding understanding of experience and/or thought-seeking in order to formulate standard behaviors. Five keys to successful teaching of adults, namely:

1. Adult learning activities should be relevant to the needs and interests of participants learn, so as to provide satisfaction;
2. The orientation of an adult in learning is centered on his life, so the arrangement of learning should be relevant to his or her life situation;
3. Experience is the most important learning resource for adult learning process, hence the learning method is experience analysis;
4. Adults have a deep need to be self-regulating individuals. Thus, the teachers' role is more as a facilitator than as a transfer of knowledge or experience to the learners. It is suggested that the lecturer should be able to provide an evaluation of what the learners agree on;
5. There is a difference of personality between each individual participant learn, which is caused by the difference of age, educational background, social status, etc.

The use of a particular type of learning method in the training is largely determined by the learning objectives, the characteristics of the participants, the learning aids available, the state of the learning facility, the time available, the training venue, and so forth. Whichever method is chosen should be able to create a fun training atmosphere, be able to develop self-learning motivation. Some of the learning methods commonly used in the training include: lecturing methods, individual assignments, group assignments, demonstrations, class discussions, and panel discussions, in addition to simulation methods, games and comparative studies [26].

Lynne M. Celli & Nicholas D. Young [28] suggested that adult learning methods or andragogy have different ways of learning, where adult learning will be more effective through active experimentation, concrete, reflective experiences and parts of learning with auditory, visual and kinesthetic. This study does not specifically explain design skills training.

2.4 Designing process

According to Clipson, batik motif is part of textile; hence the development process of designing batik motif can be studied through textile design process theory [29]. The motif design process theory includes four activities, among others the problem identification, planning analysis of production, creative process and production process (Figure 1).

At the process of designing a textile, especially batik motif, the first step to be done is the preparation to identifying the problems in regard of designing the motifs; on how sort of design can meet the needs of a targeted community. In the world of small and medium scale batik industries, such problems indentification mainly observed by businessmen or skippers. The reason is, in marketing batik the skipper is the individual who would face consumers directly, so skipper understand the true tastes of consumers with various backgrounds. The results of the identification of motif problems undertaken by the skipper are then submitted to the designers.

The second stage is the stage of production planning analysis. In production planning, the industry aspect focuses on paying attention to potential customers such as potential users, consumer purchasing power, competition with other products, and so forth. While from the perspective of the environment it should be noted the social aspects of society, community culture, the economic levels of community, in addition to emerging technologies. On the basis of such mentioned steps, it leads to compiling the initial idea of motif design.

The third stage is the stage of the creative process. According to Tabrani [30], the creative process begins with the stage of the development of ideas, namely what happens until the maturation of an idea. This is followed by the stage of implementation, i.e. follow-up phase of the idea that includes eight stages namely: preparation, material gathering, empathy, incubation, hatching, external aspects of implementation, integral aspects of implementation and the highest level of creation. All levels of the execution phase are not always consecutive, but may jump to each other, change their order.

Creative products according to Besemer and Treffinger [5] are classifiable into three categories: 1) novelty, 2) resolution and 3) elaboration and synthesis. Creative products on "batik design" are produced by employers and their employees through four stages of the creative process, namely: preparation, incubation, illumination or inspiration and verification or elaboration [9, 10].

The fourth stage, the production process is a process of drawing motif design on the paper, the transfer of motif images on the media cloth, cap or screen. It is adapted to the technique used. The next process of batik making is coloring process.

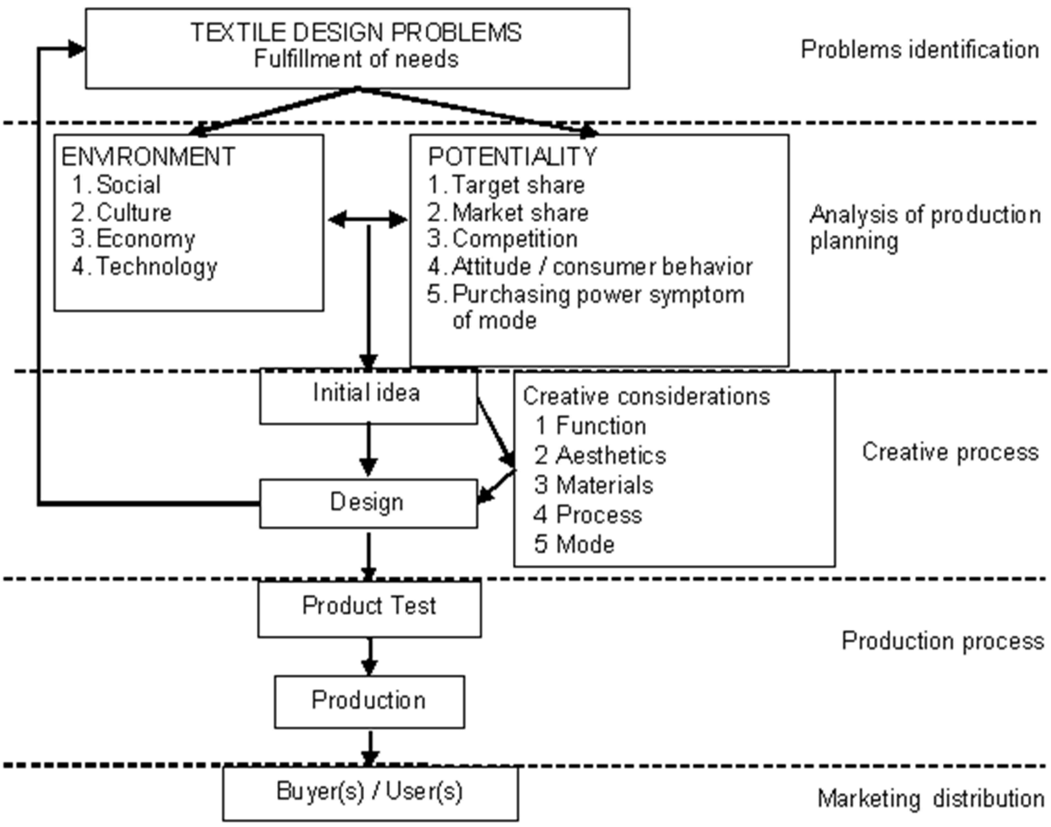


Figure1 Clipson's textile design process [29]

According to Rizali [31], several important factors in designing process towards industrial products is usability (useable or not), producapability (marketable), aesthetics (showing aesthetic appeal), profitability and reflects a social impact. In designing a product, there are several aspects which deserve consideration, among others; functional, technical, ergonomic, economical, environment, social culture, and visual aesthetics aspects.

2.5 Batik motif theory

Batik is a *wastra* or cloth that is made traditionally and is mainly used in traditional dimensions of a variety of ornamental patterns that make use of dye technique with the night batik 'candle wax' as a material of color barrier [31]. Katura [32] states that batik is a work of art on cloth that uses the technique of staining that uses night / wax heat as the color barrier. Minister of Manpower and Transmigration through *Standar Kompetensi Kerja Nasional Indonesia* (SKKNI) 'Indonesian National Competency Standards' 314 of 2013, states that batik is Indonesian textile whose motif is made by dyeing technique. In the process of making, batik using *malam* (hot wax) as a color barrier attached by using canting and or stamp tool. Thus, a *wastra* or cloth may be called batik when it contains at least three basic elements, namely: (1) obstacle technique using *malam* or hot wax as a color barrier; (2) how to embed or incise the candle using canting and/or stamp, and (3) patterns that vary in typical batik. In the development of the process of batik to date, based on the technique, batik can be divided into three, namely batik tulis, batik cap and batik combination of both technique.

Motifs or patterns are frame images that embody batik as a whole [33]. Indonesian batik decoration pattern is quite diverse. Hoop has documented the ornamental designs of Indonesia in the form of visual in a book which can illustrate a picture of batik motifs under today's development. Batik patterns or Indonesian batik motifs have been classified in several classes. Pringadie [34] classifies batik motifs into two, namely geometric motifs and cement motifs, while geometric motifs include *banji, ceplok, ganggong, kawung*, woven, and machete motifs. Tirtamidjaja [35] distinguishes batik motifs into two, namely geometric motifs and nongeometric motifs. Susanto and Hamzuri [36, 37], classify batik motifs based on the composition and forms of decoration into four, namely geometric batik motifs, cement, buketan and modern. Additionally, Roojen [38], distinguishes the motifs into two batik, classic batik motifs and coastal. Classic batik motif includes banji, kawung, ceplok, slash, nitik, plants and animals, cimukiran, and isen. Coastal motifs include Indo-Europe, Chinese coastal batik influences, pattern and style combinations, morning-afternoon batik, Hokokai batik and Cirebon batik.

3 RESEARCH METHODS

This research was a case study in small business of Dewi Ratih batik which consists of 6 motif designers and a skipper, and they are the respondents in this study. Dewi Ratih batik is located in Pilang village, Sragen regency, Central Java province, Indonesia. Batik products were produced the most of the Solo's classical batik motifs through the technique of writing, stamp and the technique of combining the two [39]. The data were collected through observation techniques [40], in-depth interviews [41]. In order to obtain correct data and research results during the data collection process, it was applied the techniques of triangulation on data sources, peer-debriefing, and reviewing key informants, and then the data were analyzed under the flow model [42].

Table 1 Research participants

No	Names	Age [year]	Working period [year]	Education	Information
1	Wartitik	55	-	SMA	Skipper
2	Sutarto	75	23	SD	Designer
3	Darman	71	18	SD	Designer
4	Maryoto	58	13	SD	Designer
5	Mardadi	58	13	SD	Designer
6	Daryono	51	13	SMP	Designer
7	Marsudi	40	6	SMA	Designer

This research was undertaken through qualitative descriptive approach and participative action study. The first stage, qualitative descriptive method is used to explore and compile the draft model of design development training motif for the designer. The collected data concern about conditions of the facilities and infrastructure design including motifs, the process of designing motifs the pattern of working relationship between the designers and skipper, backgrounds of the designers, master, the resulting motif images, the batik product, wage and the wage system, the socio-cultural condition of the society, the natural environment. The data were then analyzed to be drafted into a draft model of motif design development training. The second stage, the method of reviewing the participatory act of the designer and the skipper to test the draft of the model produced in the first stage. The results of the experiment were analyzed and made recommendations, based on the recommendation of the draft revision, then the revised draft was re-tested and then the draft was refined to further enable standardizing model.

4 RESULTS AND DISCUSSION

4.1 The socio-cultural condition and natural environment of the society

This research was conducted in Pilang village, Sragen regency, Central Java province, Indonesia, which is typical rice field area located along the river of Bengawan Solo. Agriculture is the dominant sector which absorbed most workers (56%), while the industrial sector absorbed 6.5% workforce or 38.498 people. Most of the rice fields in the area receive technical irrigation, allowing the area to be planted twice a year. In the rice planting season, the batik craftsmen who have both rice fields and gardens and those who do no normally cultivating other people's rice fields.

The socio-cultural life atmosphere of the community in the environment around the batik center is a traditional agrarian society [37] and people still uphold the culture of mutual help. Almost all of Pilang Village residents embraced Islam [43]. According to batik Rofiah and Mulyani, who actively joined religious activities, informed that: "In the village of Pilang there is a religious gathering (Islam) for housewives and fathers. Religious teachings for fathers, held at citizens' hoiuses alternately twice a week on every Wednesday night, and at mosque on Thursday night".

Problems arising in the design work related to the social and cultural activities of the local community, which includes social activities, customary activities, religious activities, and so forth. The value system that develops around the designing area includes the values shared by the surrounding community, beliefs and superstitious myths held by the community, and knowledge possessed and developed in the community. The people of Java in general and the people of Sragen in particular used to hold traditional ceremonies, such as wedding ceremonies or *mantenan*, upacara *mitoni* or *tingkeban* which is the ceremony at the first age of 7 months pregnancy, babaran or the baby birth ceremony, *selapanan* is a ceremony held at the time baby reaches at the age of 35 days, ceremonial circumcision, and death ceremony.

In the area around the artisans, mutual help activities among residents who are having *gawe* (performing traditional ceremonies) are still running well, for example if there are villagers who have *gawe mantu* (marriage), the neighboring surround residents shall help each other. Residents of the women community usually help contributing with materials for the *gawe* such as rice, sugar, oil, cigarettes, and so on. While the people from the men usually provide assistance in the form of energy, such as joining kajang, participate in making tarup, arranging chairs, and so forth. Teenage-age residents usually help to serve as a *sinoman* 'one who serves dishes to the guests'. At the time there is a resident who is building a house, other people around it also do mutual helping *'sambatan'*. In this case the society among women helped contribute material to the residents who built the house, while the men help the power (splice) to build a house. Thus, at the time part of the people who are stating gawe, such as setting up a house, wedding receptions, the birth of babies, aqiko han, circumcision, death, and others, batik motif designers proved to prioritize activities to help residents who are in it, they leave the batik activity.

4.2 Motif designers and skipper

Dewi Ratih's batik industry has about 200 artisans, 25 craftsmen working inside the factory and 175 others working outside the factory, and 6 motif designers who all working outside the factory or working at their own homes. The working relationship between the designers and the skipper is direct (Figure 2).

Table 2 Participants and motif picture characters

No	Name	Age [year]	Working period [year]	Educataion	Status / Character image motif
1	Wartitik	55	-	SMA	Skipper / batik entrepreneur
2	Sutarto	75	23	SD	Classical Javanese batik motif, plants, animals, complicated, small, soft, alusanJava classical batik motif, geometric, stripes, *alusan*/fine
3	Darman	71	18	SD	Classical Javanese batik motif, plants, animals, complicated, small, soft, alusanJava classical batik motif, geometric, stripes, alusan
4	Maryoto	58	13	SD	Large, simple, spread motifs on all fronts, long lines
5	Mardadi	58	13	SD	Spread motif in all fields, repeted
6	Daryono	51	13	SMP	Animal motif, simple
7	Marsudi	40	6	SMA	Geometric, abstract, simple, rough motif

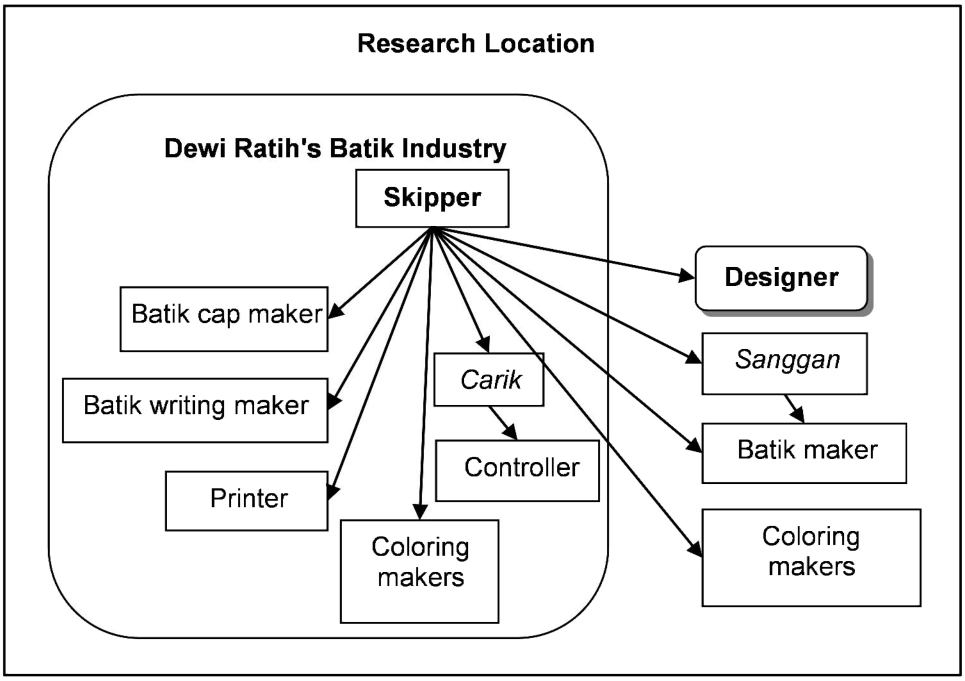


Figure 2 Working relationship between designers with skipper in direct confrontation

Each designer has a different motif picture character, and the skipper is able to distinguish each drawing made by the designer. Motifs made by Sutarto (75 years old) in the form of classical batik motif of Javanese grip, is complicated, shaped small fields, fine, and many use elements of plants and birds, which is made on making a *jarit* pattern. Darman's fine motif reflects many elements of geometric fields, lines, and fine 'alusan'. Darman often makes batik motifs on long-sleeved shirt patterns. Maryoto's motif takes the element of animals made them in simple ways. Daryoto's motifs are large-shaped simple, long lines and spread on all surfaces of the fabric. Mardadi's motif is often repeated and spread on the surface of the fabric. Marsudi motifs are mostly simple abstract shapes made on the pattern of short-sleeved shirts. The six designers of the motif none of which have a formal education background in the field of artistry or in the field of design batik motifs. The formal education level of the designer consists of four people graduating from elementary school (SD), a graduate of junior high school (SMP), and only one graduated from high school (SMA). The youngest designer is 40 years old and the oldest is 75 years old.

4.3 Problems and solutions in design

Batik skipper in this case is a woman whose name is Hj.Wartitik, the business owner of batik Dewi Ratih in Sragen regency. The skipper's role is associated with batik motif designers since her needs concerning the motifs will be served by designers in accordance with their abilities to meet the consumers' needs. To the designers, batik motifs are normally done at the home of each designer. In addition to dealing with the designer, skipper is also associated directly with other craftsmen such as *sanggan*, batik tulis makers, batik cap makers, printed batik maker and coloring makers.

The primary task of designing the motif is to draw batik motifs on white cloth in accordance with the skipper's expected designing plan. The definition of batik motif falls into two, the first - batik motif already exists, designers just move the motif from paper to fabric by reducing or adding a certain motif. Secondly, the motifs given by the skipper to the designer are still in abstract concepts and rough description forms, then the designer visualizes the image. As long as the designer develops the motif pictures, there is a discussion between designer and skipper until the motif is approved by the skipper.

The work of drawing batik motif is done in the picture room at the designer's house by using the drawing table. The drawing table is usually placed near a glass window with curtains fitted to illuminate the sunlight. On the table the picture also mounted the lights. The size of the drawing table used by various designers is: 120x100 cm, 120x170 cm and 120x150 cm.

Batik motifs are exemplified by designers to be drawn on various fabrics, among others (1) in the form of colored batik cloth products, (2) batik motif image only in the contour of black lines on tracing paper, and (3) batik motif picture on color print media. It means that artisan of the image is being exposed to examples of "batik motif models", for that reason he can directly see the visual model being constructed. The designer observes batik motif model samples, while listening to the oral instruction of the skipper about the main part of the motif which should be drawn and developed on the fabric.

During the process of developing the motif design, interpersonal dialogue takes place personally between master and designer(s). The designers are given familial directions, given the freedom to be creative, develop the supporting motifs in accordance with the basic motifs drawn. Based on the example of batik motif model, the designer develops batik motif design on tracing paper media with actual size (70x110 cm). If the created motif applied to fabric shirt patterned, then the drawn motif remains only on the back. Such motifs development can be undertaken by enlarging or minimizing certain motifs, adding or reducing certain motifs. Draft drawing the batik motif and let the skipper appreciated which then to be perfected by the designer to produce a master motif.

The master motif was then moved over the fabric as it is, or further developed into motifs patterned fabric, such as the left and right chest, left and right arm, collar, cuff and the pocket. Making a batik motif ruptured pattern on the fabric, done by means of back motif part with carbon fabric. To produce good quality scratched images and the lines which show high precision, the motif picture undetaken each piece of fabric or two pieces of fabric. To produce more scratched images at the same time, the drawing motif was undertaken by applying the technique of *ngemblak* on some pieces of the fabric with carbon cloth. Scratches made on cotton fabric, every stracth of the fabric is caught 5 strands, while scratches on the silk fabric made by non-machine loom (ATBM) then the cloth is only doubled in 2 strands. Whatever the motif form, the produced images by the designer has never been reproached by the skipper, it is worried that it can lead the designer to feel afraid of being creative. For skipper, the important is the produced batik motif is acceptable by consumer society.

Problems faced by the designer(s) related to the process of drawing motifs on white colored fabric is as follows: The first problem is - the drawing table used by motif designer was sized 100x120 cm with a flat surface, thus this shape can be set the slope. If the table is used to draw patternless motifs, the size of the table becomes less widespread. The second problem - drawing batik motif on cloth patterned shirts is harder than drawing on an un patterned fabric. Picture motif on cloth patterned shirt, motifs must be *sanggit* (well and tidy stretch patterned) when fabric was made into a shirt. To draw a *sanggit* motif, it is much easier to do on a fabric little by little. In case a fabric was doubled, then the results of the images motif can be shifted, thus the motif can no longer be a *sanggit* (less effective). In fact, to increase the products quantity (efficient) one way the fabric must be double. Third problem - drawing motif on silk fabric is harder than that the cotton fabric. To draw a motif on silk fabric it should be done on one by one fabric, if it was forced to be doubled then it should be a maximum of 2 fabrics only. The fourth problem - drawing new motifs that have not been understood the meaning more difficult than the usual motifs drawn. In general, the designer of the learning motif is autodidact, so they do not understand the meaning of the motif in which she/he draws. The designer develops motifs based only on the example of the batik motif model a designer is facing, given by the skipper. The fifth problem is that the light-dark volume temperature of drawing room facility is unadjustable. Good motif picture space has a low temperature so that the carbon fabric to be used for copying or motion does not dry quickly, otherwise the image space should be well lit.

On the basis of such elaborated problems, there are generated three solutions, among others is to artificially make up the working facilities, conduct training and working pattern relationships. The first solution, on the aspect of the means, is that the drawing table used to draw a patterned fabric should be 100x120 cm in size, while the table for drawing a patternless motif should have the same surface area as the size of the drawn fabric (115x250 cm). Desk surfaces are made using translucent glass material under which lamps are given. The purpose of making the lamp available is so that the image of the master motif is absorbed or drawn, it can still be seen even though the cloth is being doubled. By using the table, the amount of fabric drawn more and at the same time it enables the motifs pattern were drawn in *sanggit*. The drawing room facility needs to be made up artificially with windows and curtains, on top of a glass towel, and lights. At the time of drawing, the air temperature should be kept too hot then the curtains can be closed, and vice versa, when the cloudy room is less bright then the lights can be turned on. The second solution, the aspect on the training materials, the designer is given a well-training on making motifs patterns, understanding the motifs of classical batik along with their various areas of origin, to understand the meaning of the drawn motifs are often done, and trained techniques to draw motifs to fit with *sanggit* pattern. The third solution is on the aspect of employment relationship, namely the skipper: (1) he/she should provide a batik motif in accordance with the designer(s)' competence and interests. If the job given is a new introduced motif, the skipper should explain and give a clear description of the motif; (2) the skipper is required to encourage the development of the artist's creativity by providing a psychological security [11].

Psychological freedom means that the designer is given a freedom in terms of developing the motif concepts instructed by skipper. Psychological security means that the skipper should not easily show his/her criticism on the motif images embodiment produced by the designer, and he/her should not be angry at the designer.

4.4 Training models

On the basis of such elaborated research results was proposed the model of training on batik motif design development for designers in small businesses, which can be developed through four stages: (1) designing needs analysis, (2) training program planning, (3) working infrastructure planning and (4) implementation of training activities. The training phase is in accordance with model of skill training for the job. The stages of training model design of home batik motifs are shown in Figure 3.

4.4.1 Analysis of problems in designing work

This first phase is to explore and analyze the designers' needs or problems. The information is obtained through setting up interview and using the technique of observation. The analysiswas focused on issues related to the designing process of a work, such as conditions of given facilities and their availablity, and which of the facilities should be provided at the working place, the competence level of the designer related to the work, the material done, the pattern of working relationship or the learning system between the designer with the skipper, the amount of rewards or wages, and the produced works. The analyzing the designers' facing problems with regard to their family background, social environment condition of society culture, and socio-natural environmental circumstances. Based on these analyzes, then it is drawn up conclusions about the real needs of craftsmen in terms of the work of drawing motif designs.

4.4.2 Program planning and equipment manufacture

Based on the aforementioned analysis results of problems in design, the training plan programs and work infrastructure facilities were compiled. Aspects of the training program formulated cover the determination of training objectives, training materials, the creation of training media, training methods, preparation of management pattern between designer(s) and the skipper, the determination of place and time of training.

In relation to designers of the batik design, training objectives should refer to the needs of the designer, i.e. the designer has his/her own ablity in understanding the technique of drawing on fabrics. These individuals are able to understand the meaning of classical batik motifs, able to visualize the design concept instructed by skipper and able to create a well-decorated pattern which is termed as *sanggit* on fabric patterned shirts and jarit-shirts patterned.

Training materials are designed based on the targeted goals. Training materials for the designer include:

1) drawing techniques on various types of fabrics (*mori* / cotton, silk, dolby);
2) pictures of classical batik motifs and their meanings;
3) types of batik motif patterns;
4) techniques of developing design concepts; and
5) techniques of drawing the *sanggit* motifs on patterned fabrics.

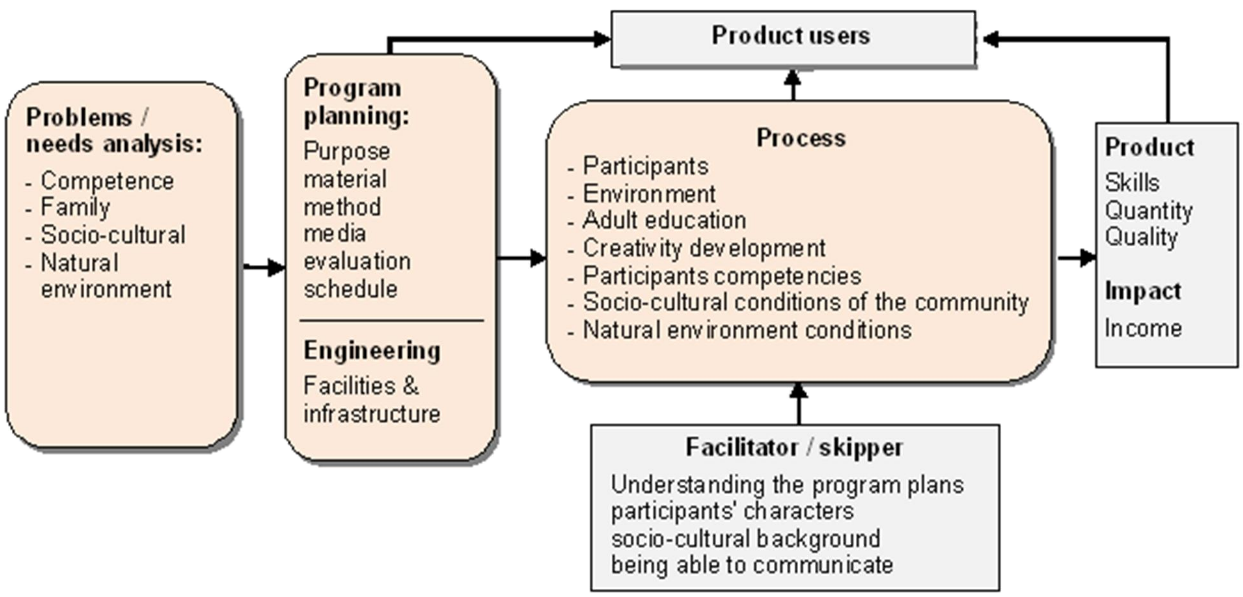


Figure 3 Training model for batik motif designers

The training method is chosen according to the designer(s)' qualifications, i.e. they should have experienced adult education, that the delivery of material is done individually according to the level of the designer's capability. Batik motif design training is a learning behavior, for that reason, the learning should be repeated and the designers should get the opportunity to try and fail [44].

During the process of delivering the material, the concrete learning media is being exploited; visual that contains elements of dots, lines, fields, colors, objects and symbols [45]. In line of that, the designer needs more visual stimulus rather than the audio or motion stimulus. In this training, the instructional media used include examples of classic batik motifs, examples of *sanggit* motifs, examples of various patterns of batik motifs, examples of batik motifs that have 3 dimensions and examples of *isen-isen* motifs. The evaluation system is designed for all phases, ranging from evaluation of design problem analysis, program planning evaluation, program implementation evaluation, to evaluation of training outcomes. Training schedule is selected at the right time according to designer condition and at designer place room or skipper.

Working facilities and design infrastructure such as drawing room and drawing table need to be ergonomically designed and prepared in training. The drawing room is designed to be clean enough, sufficient lighting lights and sunlight, not too hot, and having sufficient ventilation. When is the rainy season, the weather is usually often cloudy, so the drawing space needs lighting lamps. Conversely, in the dry season, the weather is subsequently very hot, it can cause the carbon used to draw dries quickly, therefore, it is highly suggested that the room temperature needs to be conditioned into more cold. The wide of drawing table should be 120, 150 or 250 cm in accordance with the regular type of the drawn motifs, while the height of the table is adjusted according to the height of the designer. Thus the required image space size is about 200x300 cm. If the designer often draws a motif by tracing the master motif, then the table top should be clear glass.

4.4.3 Training proces

Training implementation should as much as possible refer to these aspects:

- it is undertaken at the designing environment in which the designer works,
- the training refers to adult education,
- it is directed at the development of creativity of the designer,
- the material is adjusted to the level of the designer's ability,
- the training is adjusted on socio-cultural, and natural-environmental conditions of the society.

Most of the designers are lowly educated (Primary School), usually they feel more comfortable when doing their own learning environment and thus the training should be in the designers' environment. The designers are adults, both legally, psychologically and socially 20 to 60 years old [26]. Adult learning process is influenced by physiological internal factors such as hearing, vision, physical condition as well as psychological factors such as need, intelligence, motivation, attention, thinking, remembering and forgetting. It is also influenced by external factors such as the natural environment, social and presentation systems [46]. Thus, the training process should be adjusted to the needs, level of ability and based on experience. Batik is a creative product, produced through creative process of the designers. Thus the training process should be able to living up the designers' spirit of creativity, namely through the provision of both psychological freedom and psychological security [11, 12].

Batik motifs training is a matter if learning behavior and a well-maintained motoric skill can be achieved by regular practice, participants are given probability of trial and error, they are motivated and rewards accordint to standardized evaluation on such tangible products [47, 48]. According to the theory of learning, Skinner's behavior-operant conditioning [23, 46, 48], learning is focused on the relationship between behavior and its consequences. This is in accordance with the findings, that when the image of batik motif produced by the designer is accepted by the market, then the designer is flattered by the skipper and he will be rewarded with an incentive. Thus, this leads into pleasant consequences for the designers; they are driven into having more earnest and more creative developing batik motifs. Likewise, according to Thorndike's theory of learning [23, 48, ,50], if an action, like drawing a batik motif, is followed by a satisfactory change in the environment (the resulting batik motifs by the market), then the action of drawing batik motifs on that sense will be repeated again in similar situations and frequency will getting more increased. The technical methodology used in batik motifs training is dialogue, inter-personal four facilitator-participants, in a kinship to discuss the relevant batik motifs to be developed, then followed by the assignment. The method of dialogue between entrepreneurs and image artists includes Newcomb's communications model [48], in symmetrical inter-personal communication 2 people communicating ideas or concepts (batik motif). Methods of demonstration are undertaken to revise draft-draft drawing batik motif produced by the designer [26].

Designers are social beings; they have a need to affiliate with their fellow human beings around them. Space for affiliation in the community, among others, Islamic religious teaching activities and ceremonial activities (marriage, circumcision, training, and others). In addition, the designer's life is in the environment of traditional agrarian society, which means that in the wet season and steady season, the community mutual helping *(gotong royong)* at rice fields well-preserved. Thus, the training process should be adjusted to the socio-cultural conditions of the natural environment.

Facilitator(s) in batik motif training for designers played by the skipper or other party. In performing their working duties, skipper should understand the plan of the training program such as preparing for the motif design, designing the use or application of the motif, designing the batik product, preparing the material, managing the program, designing the evaluation system, monitoring and evaluating the drawing, and maintaining the continuity of the program such as depositing the proceeds to the skipper and or to rewithdraw the works from the skipper [49, 50]. Similarly, the skipper should also be skillfully in managing communication with the designer, having the attitude and knowledge that can be accepted by the designer, and understood the socio-cultural characteristics of the local community [50, 51], and has a good relationship with the designers [52].

Thus, for the training process to run smoothly, the facilitator(s) should have at least four determining skills, among others mastering the program planning, understanding the characteristics and background of the designer(s), understanding the socio-cultural background of the community, and being able to set up communication.

4.4.4 Products and impact

The training process will produce products in the form of designers' improving skills, because of that the resulting product is increased and more qualified which satisfying the consumers' expectation. Since the designer wage rate depends on both quantity and quality of the drawing products, then if the resulting image product increases and, more qualified, these will have an impact on the increase of income (Table 3).

The development of training models and the design of batik motifs requires a validation process before being applied to be produced and deployed to the market. The following is a validation table for developing the training model and design of batik motifs by Prof. Dr. Nanang Rizali, MSD, who is an expert in textile design.

Table 3 Preliminary and development motifs design

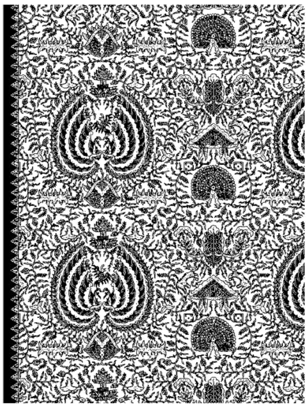
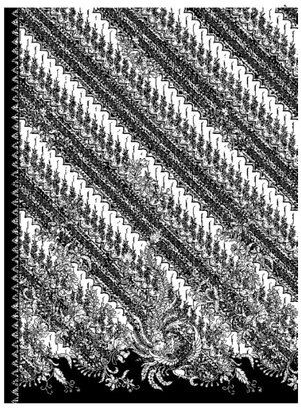
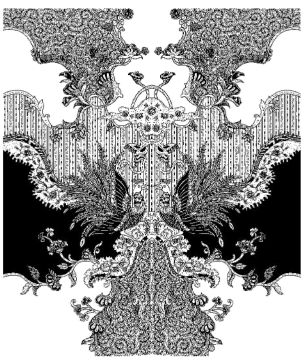
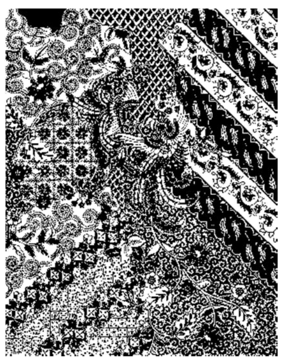
No.	Preliminary motifs design	Motifs design development	
1.	 Preliminary motif design of *jarit* cloth	 Motif 1 *Buketan* motif design for *jarit* cloth	 Motif 2 *Parang* motif design for *jarit* cloth
2.	 Preliminary motif design for apparel	 Motif 3 Symmetrical motif design for apparel	 Motif 4 Asymmetric motif design for apparel

Table 4 Validation model and design development

No.	Design	Training model assessment	Design assessment					Total
			Design principal	Aesthetic	Versatile use	Uniqueness	Originality	
1	Motif 1	This training model is very good because it can elaborate four components: 1) designing needs analysis, 2) training program planning, 3) working infrastructure planning and 4) implementation of training activities.	4	3	4	4	4	19
2	Motif 2		4	4	3	4	4	19
3	Motif 3		4	3	4	3	4	18
4	Motif 4		4	4	3	4	4	19

The assessment is measured by 5 scales (1 = very poor quality, 2 = poor, 3 = adequately, 4 = good, 5 = very good). The suggestion of the validator is that the designer must be careful in making the connection motif. The validation result showed that the training model and design motif development was eligible to be applied and did not need any improvement.

5 CONCLUSION

Based on the results and discussions, we can derive a conclusion that the model of batik design training to improve product quality and income is determined by several factors that are related as a system. These factors include raw inputs, input instruments, users, facilitators and processes. While the training model consists of four stages namely, begins by analyzing the problems faced by the designers, planning the program (including training objectives, materials, methods, media, evaluation and schedules), planning and engineering facilities needed in the training, and implementing training actions from the facilitator to the trainees.

The first stage, the design problems analysis, includes the background of competence, facilities and infrastructure used, the drawing process, the working relationship patterns between designers and skipper, the wage system, the designers' family background, socio-cultural environment of the local community and natural environmental conditions. The second stage is planning of the training program, which includes the determination of training objectives, materials, the making of instructional media, the determination of training methods, evaluation of the training program and the determination of the training schedule. In addition, training is required by the facilitator, which in this case may be played by the skipper or other party. A good facilitator should have four skills, namely mastering program planning, understanding the characteristics of the participants, understanding the socio-cultural background of the community around the participants and being able to communicate with the participants.The third stage, the planning and making of work facilities used by the participants, includes the drawing room and the drawing table. The fourth stage, the implementation of the action, should refer to six aspects consisting of training conducted in the workplace environment, the training should refer to adult education, and the process should be directed to the development of creativity, synergized based on the competency level of participants, socio-cultural conditions of the community and condition of the local natural environment. The process in question can produce products such as increased skills of participants, increased quantity and improved image quality *(design quality)* of batik motif. Because the wage rate of the craftsmen depends on the quality and quantity of the products produced, the product of the image affects the increase in revenue of the designer.

6 REFERENCES

1. Nurhayati S.: Indonesia's batik credit strategy through the formulation of a policy of harmony in the code system after the inauguration of batik as an intangible cultural heritage, Research report, Pekalongan University, 2012
2. Kompas Newsletter, 30 September 2015, Director General of Micro and Medium Industry, the Indonesian Ministry of Industry
3. Kompas Newsletter, 6 Oktober 2012, Intellectual Property Rights: Export SMEs Prioritized
4. Mulyanto: Batik design development training as an effort to empower businesses, Disertation, UNS Surakarta, 2013
5. Indarti, Rahayu I.A.T., Peng L.H.: Sustainable batik production: review and research framework, Series: Advances in Social Science, Education and Humanities Research 390, Proceedings of the International Conference on Research and Academic Community Services (ICRACOS 2019), pp. 66-72, https://doi.org/10.2991/icracos-19.2020.14
6. Sulaiman A.I., Djawahir F.S., Sugito T., Weningsih S.: Empowerment management model of batik craftsman entrepreneurship development empowerment management model of batik craftsman entrepreneurship development, Journal of Economics and Management Sciences 2(3), 2019, pp. 14-25, https://doi.org/10.30560/jems.v2n3p14
7. Besemer S.P., Treffinger D.J.: Analysis of creative products: review and synthesis, The Journal of Creative Behavior 15(3), 1981, pp. 158-178, https://doi.org/10.1002/j.2162-6057.1981.tb00287.x
8. Zaman B.A.: Batik-creativity-economy: Respond to the role of batik in the creative economy, World Batik Summit 2011: Indonesia "Global Home of Batik", Jakarta, Indonesia, 28 September 2011

9. Suliyanto, Novandari W., Setyawati S.M.: Training program evaluation on batik micro small medium enterprises (MSMEs): An analytical hierarchy process (AHP) method, International Business Management 9(3), 2015, pp. 251-257,

DOI: 10.36478/ibm.2015.251.257
10. Syahputra R., Soesanti I.: Design of automatic electric batik stove for batik industry, Journal of Theoretical and Applied Information Technology 87(1), 2016, pp. 167-175
11. Kaufman J.C., Sternberg R.J.: Creativity, Change: The Magazine of Higher Learning 39(4), 2007, pp. 55-60, DOI: 10.3200/CHNG.39.4.55-C4
12. Rogers E.M.: Diffusion of Innovations, New Yok: Free Press, 1983, 453 p.
13. Munandar U.: Gifted Child Creativity Development, Jakarta: Rineka Cipta, 2009
14. Frese M., Hass L., Friedrich C.: Personal initiative training for small business owners, Journal of Business Venturing Insights 5, 2016, pp. 27-36, https://doi.org/10.1016/j.jbvi.2016.01.001
15. Hidayat A.S., Alwi M., Setiawan Y.: The Training and competence effect of PT. Batik Trusmi Cirebon'semployee performance, Journal of Applied Management 15(2), 2017, pp. 346-354, http://dx.doi.org/10.21776/ub.jam.2017.015.02.19
16. Setjoatmodjo P. (Ed): Selected Readings on Aesthetics, Jakarta: P2LPTK, Ditjendikti, Depdikbud, 1988
17. Nadler L., Nadler Z. Designing Training Programs: The Critical Events Model, London: Routledge, 1994
18. Gilley J.W., Enggland S.A.: Principle of Human Resource Development, Massachusetts: Addison-Wesley publishing Company, 1991
19. Hickerson F.J., Middleton J., Helping People Learn: Module manager's guide, Honolulu: East-West Center, East-West Communication Institute, 1975
20. Suminar T., Budiartati E., Anggraeni D.: The Effectiveness of a Women's Empowerment Model Through Social Entrepreneurship Training to Strengthen a Tourism Village Program, International Journal of Innovation, Creativity and Change 5(5), 2019, pp. 324-338
21. Ariefianto L.: Role of Community Learning Center (CLC) "Handayani" Batik Training Program in Eradicate Extreme Proverty (Case Study of the Batik Craftsmen Woman Kemirian Tamanan Bondowoso Regency), Jurnal Empowerment 9(1), 2020, pp.12-21
22. Korten D.C., Sjahrir (Ed): Community Based Development, Jakarta: Yayasan Obor Indonesia dan Pustaka Sinar Harapan, 1993
23. Rahyubi H.: Learning Theories and Applications of Motoric Learning, Bandung: PT Nusa Media, 2012
24. Mohan K.P.: Coaching and Mentoring for Educators: Investigating the Cognitive-AffectiveBehavioral Learning Outcomes of Training, Research Report, Bangkok: Srinakharinwirot University, Bangkok, Thailand, 2018
25. Kumar A., Koullia N., Jongenburger M., Koutris M., Lobbezoo F., Trulsson M., Svensson, P.: Behavioral learning and skill acquisition during a natural yet novel biting task, Physiology & Behavior 211, 2019, pp. 1-6, https://doi.org/10.1016/j.physbeh.2019.112667
26. Uno, Hamzah B., Learning model, Jakarta: PT Bumi Aksara, 2011
27. Mujiman H. Training Managemant Independent Learning Based, Yogyakarta: Pustaka Pelajar, 2007
28. Celli L.M., Young N.D.: Contemporary pedagogy for the adult learning, Pupil: International Journal of Teaching, Education and Learning 1(1), 2017, pp.86-96
29. Clipson C. Design for a Coming Age, Nagoya, Japan: Acid, 1989
30. Tabrani P.: The Process of Creation, Appreciation, Learning, Bandung: ITB, 2000
31. Rizali N.: Overview of Textile Design, Surakarta: LPP UNS, 2006
32. Kina Karya Indonesia Magazine: Batik Nusantara: Batik of the Archipelago, Jakarta: Ministry of Industry Indonesia, 2013
33. Doellah S.: Batik: Influence of Times and the Environment, Surakarta: PT Batik Danarhadi, 2002
34. Pringadie M.: De Inlandsche Kunstnijverheid in Nedherlandsch Indie Door III, De Batik Kunst. Van Regeeringsweg Gedrukt En Uitgegeven Te S-Gravenhage Door de Boek & Kunstdrukkrij V/H. Mouton & Co, 1916
35. Tirtamidjaja: Style, Pattern and Motif, Jakarta: Djambatan Utama, 1966
36. Susanto S.S.K.: Indonesian Batik Art Craft, Jakarta: Balai Penelitian Batik dan Kerajinan, Departemen Industri, 1980
37. Hamzuri: Classic Batik, Jakarta: Djambatan, 1981
38. Roojen P.: Batik Design, Amsterdam: The Pepin Press, 2001
39. Pratiwi A., Riani A.L., Harisudin M., Rum S.H.P.: The development of market-oriented batik products based on customer buying intention (Industrial Center of Batik Sragen Indonesia), International Journal of Management (IJM) 11(3), 2020, pp. 373-389
40. Spradley J.P.: Participant Observation, New York: Holt, Rinehart and Winston, 1980
41. Bogdan R.C., Knopp Biklen S.: Qualitative research for education: An introduction to theory and methods, USA: Allyn and Bacon, 1982
42. Miles M.B., Huberman A.M.: Qualitative Data Analysis: A Sourcebook of a New Methods, Beverly Hills, California: Sage Publication, 1984
43. Hadi S., Wibowo M.: Development of Potency Village Pilang Village, Masaran District, Sragen towards Tourism Area, Jurnal Inovasi dan Kewirausahaan, 3(3), 2014, pp. 170-184.
44. Sztompka P.: Sociology of Social Change, Translation by Alimandan. Jakarta: Prenada Media, 2004
45. Dahar R.W.: Learning Theories, Jakarta: Ministry of Education and Culture, Directorate General of Higher Education, Educational Workforce Institution Development Project, 1988
46. Sardiman A.S., Rahardjo R., Haryono A., Rahardjito: Educational Media: Definition, Development and Utilization, Jakarta: Rajawali, 2009

47. Mappa, Syamsu dan Anisah Basleman: Adult Learning Theory. Jakarta: P3MTK, Ditjendikti, Depdikbud, 1994
48. Gredler M.E.B.: Study and Learning, Translated by Munandir. Jakarta: Rajawali Press, 1991
49. Mardikanto: Communication Development, Surakarta: UNS Press, 2010
50. Kamil M.: Non-formal education, Bandung: Alfabeta, 2009
51. Abiddin N.Z., Ismail A.: Building excellent workforce through effective coaching for coachees' development, International Journal of Education 4(1), 2012, pp. 101-111, DOI:10.5296/ije.v4i1.1503
52. Berlo D.K.: The Process of Communication, New York: Holt, Rinehart and Watson, 1961

RESEARCH INTO THE USE OF ENERGY EFFICIENT PRESSES FOR CUTTING TEXTILE MATERIALS

Mykola Skyba[1], Dmytro Prybeha[1], Oleg Synyuk[1], Anatolii Dombrovskyi[1], Halyna Lobanova[1], Oksana Mykhailovska[1], Inna Soltyk[1] , Valentyna Burak[2], Natalya Novikova[2] and Dzmitry Karneyenka[3]

[1]*Khmelnytskyi National University, Instytutska str. 11, Khmelnytskyi, Ukraine*
[2]*Kherson State Agricultural University, Sretenskaya str. 23, Kherson, Ukraine*
[3]*Vitebsk State Technological University, Moscow Av. 72, Vitebsk, Belarus*
ukraine_kyiv@i.ua

Abstract: *The research of features of the use energy efficient presses for cutting textile materials was conducted in the article. The experimental drive, main features of which are use of a frequency converter, microprocessor technics, sensors of control parameters of equipment work, tracking system and experimental measuring unit, was developed. The degree of power consumption of cutting presses and their maximum values of energy consumption was established. The coefficient of energy efficiency equipment for one-layer, multilayer and combined fabrics was calculated. The researches, allowed to determined coefficient of efficiency use of equipment for decks of different fabrics, were conducted. A comparison of existing and developed equipment, determined their economic efficiency and economic effect from the use of developed equipment was carried out.*

Keywords: *textile materials, cutting, experimental drive, cutting press, energy efficiency, tracking system.*

1 INTRODUCTION

The current state of the industry is characterized by rapid development of its various branches. Each of them has its own specific features. One of such branches is light industry. Today energy factor occupies one of the most important places in the development of not only light industry, but also the international economy as a whole. Engineers that create equipment go through the effective improvement of existing models and development of new, more economical and technological [1-3]. This provide to a new level of development for all branches of industry.

Electro-hydraulic press equipment in the light industry is used to cut artificial and genuine leather parts by dipping the cutter into the cutting plate [4]. Today the companies of light industry use a large number of modern cutting presses. However, number of new modern presses is insufficient to meet the needs of industry. Especially for small enterprises that are unable to rivalry with the world's giants and also growing crisis in the world economy. Therefore, modifying such equipment and improving its technical and economic indicators is relevant task.

Many technologies are used in the world to cut different materials. Technology of hydrojet forming [5-7] and hydrojet cutting [8] of different materials are widely known and used many years. But there are a number of significant drawbacks of such technology, which prevents its widespread use especially in cutting textiles materials.

Laser cutting is one of the most modern and progressive in terms of innovation and prospects of use [9-10]. This technology is used for cutting different materials but is characterized by high energy consumption. This has a negative impact on the cost of final product and its quality. The edges of cut-off parts are exposed to the laser beam (local thermal action of the beam) and lose their characteristics and aesthetic appearance. It is also worth to say, that this technology is still too expensive for mass use.

Automatic cutting complexes are very popular at various enterprises [11]. They are one of the most modern robotic complexes with a wide range of functional opportunities. This makes it possible to simplify the cutting process as much as possible in the complete technological cycle [12]. The complex of technical solutions of such equipment meets the modern requirements and allows to produce details of complex shapes with high quality of their processing. However, one of the main disadvantages of such cutting complexes is high cost. This is a significant disadvantage for small businesses where the annual volume of manufactured products does not ensure high profits.

The ratios of different indicators that are taken into account when cutting parts from different materials are described in [13]. Parametrization of various equipment and application features are considered. However, one of disadvantages of this work is that it does not taking into account the cutting of textile materials. This does not allow to determine the advantages and disadvantages of such equipment when interacting with textile materials of single and multi-layer decks.

One of the modern requirements in manufacture of textile materials is harmonization of material with the shape and feature of manufacturing on equipment [14]. In this regard, design aspects of manufacture of clothing [15] plays a significant role, as it directly affects on choice of constructive execution, materials and design features of products. Functional purpose of clothing is essential [16], especially if products put forward higher requirements to wear resistance, chemical resistance, radiation resistance and other important characteristics.

The most optimal of above equipment by criterion price-quality, simplicity of technical service and exploitation is the use of electro-hydraulic cutting presses. Their use is relevant for small enterprises where it is possible to make fuller use of their potential. This has a positive effect on the value of the final product, reducing it.

One of the major disadvantages of such equipment is its high power consumption during cutting. This worsens economic efficiency and increases the cost of finished products.

Therefore, there is a need to increase economic efficiency of cutting textile materials on such equipment. To do this, it is necessary to conduct research into the use of modern energy efficient presses and identify ways to improve their energy efficiency.

2 DEVELOPMENT OF EXPERIMENTAL EQUIPMENT FOR INVESTIGATING THE ENERGY CONSUMPTION OF CUTTING PRESSES

2.1 Experimental equipment

The experiments were carried out on Italian cutting press Atom SE20C, which is widely used in many enterprises of different industries. Its main advantages are high reliability, stability of work, low cost of operation and qualitative cutting of parts from various materials including textile. Fabrics are difficult to cut through a specific structure. The interlacing of threads of most fabrics is strong, so the cutting force should be 15-40% greater than when cutting, for example, leather or cardboard. Especially difficult is cutting down the fabrics with a total number of more than 3. This is due to the complication passage of the cutter between threads and their fibers, which in multilayered decks form a complex reinforced surface with high strength. If interlacing of each fabric in deck is difficult, then the overall strength is significantly increased and cutting efficiency is reduced.

Experimental research is based on the goal of improving the economic effectiveness of cutting presses by improving energy efficiency. This provides significant cost saving on implementation technological process of cutting. In general, this contributes to reducing energy consumption and unit cost of finished product, which is a positive factor.

For conducting researches developed experimental drive that used in cutting presses and which is activated only during cutting. The main drive elements are: frequency converter, microprocessor technique, sensors to control parameters of equipment work, tracking system and experimental measuring unit.

For conduct research was used frequency converter Altivar 340 Schneider Electric firm. The specified converter is a component of the drive that performs a number of specific and very important functions that directly affect on its work:

1) reducing electricity consumption;
2) smooth start of the engine;
3) increase reliability work of the engine;
4) smoothing of maximum load on drive during cutting;
5) compensation of failures in engine work at maximum load;
6) improving overall energy efficiency the work of press;
7) improving the quality of manufactured products.

The developed experimental drive has a special construction. Its main advantage is to operate only when performing a technological cutting operation. The starting currents at the engine start are extinguished by frequency drive in a fixed time interval. Another advantage of developed drive is automated work and change of various parameters of functioning drive-press in real time system. Such system is adaptive and allows during the work adjust any features of press and watch them on a PC monitor. This combination makes it easy to adjust the parameters of drive-press system and make adjustments to eliminate disadvantages.

Experimental equipment consists of the following components: cutting press, experimental drive, measuring equipment (tracking system, measuring unit, PC, automated system of control of set parameters of equipment work, system of information collection and processing, system of indicators of effective operation of the drive, system of control energy consumption of equipment). This set of different systems provides complete control over all processes of equipment work. The drive construction is located in a special place in lover part of press. Developed experimental drive provides energy efficiency and reduces the final cost of finished products through the rational use of electricity through a complex of set decisions.

Before cutting into computerized system entered data, which take into account all necessary cutting parameters: physical properties of material, cutting power, number of material layers, type of material, energy consumption parameters, characteristics of measuring systems, connection of all necessary sensors and test equipment. To obtain the necessary experimental data of equipment used measuring unit WB-1 [15-16]. This unit is an element of measuring equipment and works on the principle of analog-to-digital signal conversion of equipment work and obtaining accurate data of measurement values (Figure 1).

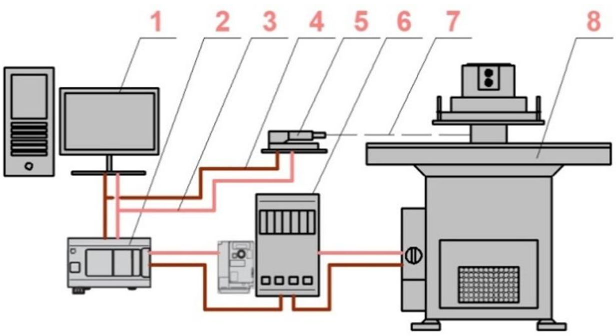


Figure 1 Scheme of experimental equipment work: 1 – personal computer; 2 – measuring unit VB-1; 3 – direct connection line; 4 – feedback connection line; 5 – tracking system; 6 – experimental drive; 7 – line control of the movement of drummer and cutting quality; 8 – cutting press Atom SE20C

Experimental equipment uses various sensors that control entire cutting process – from immersion of the cutter into material to control of oil level in the hydraulic press system. Another feature is the use of a special laser tracking system. It provides control of impactor movement and cutter in the space with high precision, which allows to control the quality of cutting. Particularly useful specified system in available minor errors in cutting various materials. At the same time displaying the characteristics on the PC screen, it is possible to control the quality of cutting down and to harmonize the different characteristics of the equipment in order to reduce power consumption and improve the quality of cutting. Under real conditions, knowledge of these indicators is a great advantage in production, as it allows to immediately correct certain inaccuracies in the work of cutting equipment. When using new material this system greatly simplifies the process of debugging of equipment work.

2.2 Methodology of conducting researches

For conducting experimental research were used different fabrics. The cutting efficiency for single-layer, multilayer and combined decks of textile materials, leather, cardboard and rubber, was checked. However, in case of significant deviation of indicators the average values of experimental data were selected.

During the experimental studies, the press worked as follows.

When the press was turned on, the engine did not work – it was in a state of calm. All functional systems work without load on power grid. The panel on control unit set required operation mode of experimental drive.

The VB-1 measuring unit is a key link and receives signals from the drive, monitoring system and all sensors and displays them on a personal computer. Then necessary software is configured to collect and processing experimental data. Before research press was set up on fixed technological parameters, special monitoring system, sensors and measuring unit VB-1.

The tracking system operates on the principle of controlling a movement of striker (video fixation) and the quality of cutting (control was carried out on the principle of contact change with a laser beam in real time). The laser beam was fixed on special photosensitive sections with feedback. Simultaneously with laser work on the PC screen simulated the process of cutting and moving striker, and also dipping the cutter into material. At the same time, there is opportunity to coordinate video and graphics of different characteristics of equipment.

Before cutting was selected desired mode of operation which depends on the following parameters:

1) material;
2) detail shape;
3) number of material layers.

Pressing the control buttons of the press it turns on appropriate electrical equipment, electric motor and hydraulic pump are switched on. The oil from hydraulic pump enters the working cylinder of press through pipelines. After turning the drummer into working position under the action of oil pressure, the drummer drops down, cutting a material. At same time according with cutting, an experimental drive is triggered. That provides stable work of equipment without overloading. After cutting the actuator is unlocked.

Due to use developed drive it is possible to save a considerable amount of energy, reduce the load on electric motor and equipment, improve the quality of the cut parts. The studies were conducted for fabrics in the following combinations: single-layered, multi-layered, combined (Table 1).

Table 1 Technical characteristics of the equipment

Technical equipment parameter	Textile materials		
	one-layer	multilayer	combined
Average value of cutting effort N_{vr},[kH]	61	147	135
Cutting time t [s]	0.002	0.0027	0.0025
Quality of cut line of the parts k	0.99	0.97	0.98
Maximum power of engine W_{max} [kW]	0.42	0.70	0.64
Efficiency coefficient of equipment use α_{eq}	0.81	0.78	0.79
Total energy consumption for 1 hour W_{Σ} [kW]	0.35	0.41	0.38
Efficiency coefficient of energy consumption e^N	0.89	0.83	0.85

During research, developed drive provided a significant improvement of equipment energy characteristics. At turn on, peak loads were smoothed out, which reduced engine overload.

During cutting, was provide reliability work of the press and its protection from possible breakdowns through the use of various drive safety functions (in accordance with IEC 61508 and ISO/EN 13849-1-2 standards), namely:

1) protective moment shutdown;
2) protective speed limitation;
3) protective stop;
4) safe maximum speed;
5) security door lock.

In addition to standard features used developed, designed to provide dual protection from drive overloading. This protects it from overload, stabilizes the work, and also provides reliability work during cutting multilayered decking of fabrics, especially in the final stages of cutting when highest loads on equipment are observed.

Thus, provides reliable motor work and its protection from possible stops, breakdowns and failure. And this, in the future, provided improved quality of cutting parts.

3 RESULTS AND DISCUSSION

Conducted experiments allowed to establish economic effect from the use of developed drive in the cutting presses, that used for textile materials cutting.

The first stage of the work was to check efficiency of developed drive. To do this, it was loaded to the maximum and at the same time perceived increased pressure from all systems (Figure 2).

It is investigated, that the use of developed drive provides its protection from overload in wide range of values (Figure 2). Drive overload adversely affects on all indicators of cutting process. In the case of emergency stop of engine, the key role is smooth and uniform reduction of drive torque reduction. If such stop is extended over time, it is an overload and possible failure of equipment. The points A1, A2 and A3 (Figure 2) characterize the process of drive stopping during overload – beginning of the stop, beginning of smoothing the overload and the end of overload protection function, respectively. Installed, that compared to conventional drive on 15-21% improves equipment reliability and its failure.

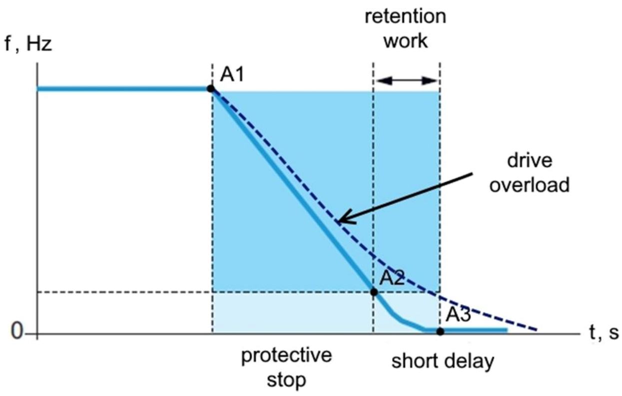


Figure 2 Features of the work of developed drive with overload protection

It is established, that use of developed drive promotes protection from exceeding the preset speed of the engine (Figure 3).

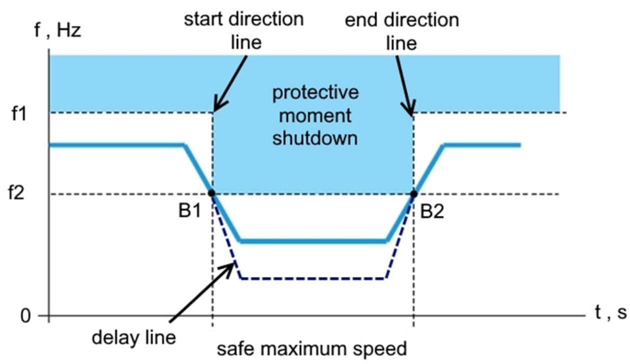


Figure 3 Overload protection from exceeding a set speed of drive motor

When entering amplitude of speed characteristics of the drive, motor speed is great importance. If at fixed points of drive work B1 and B2 do not set the required parameters of operation (Figure 3), then a break is possible between required and operating speeds. This critically affects on the engine dynamics and contributes to its rapid deterioration. The optimal motor speed makes it possible to use qualitatively its power in the fixed sections of technological process of cutting textile materials.

It is investigated, that the use of developed drive provides protection from exceeding speed by reducing rotation speed motor drive (Figure 4).

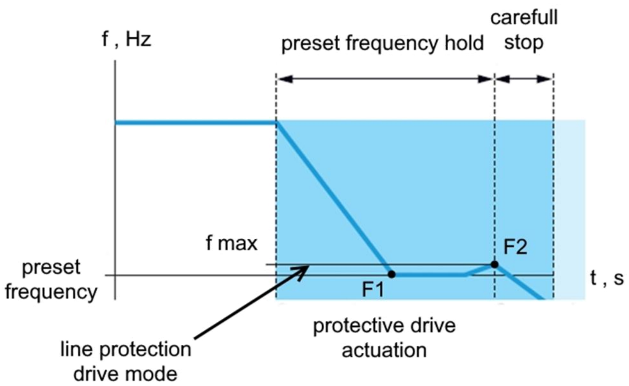


Figure 4 Protection from exceeding speed by reducing rotation speed motor drive

Frequency control of the drive along with motor contributes to quality control of press as a whole. The transition from point F1 to point F2 shows the dynamics of changing the load on motor with protection from critical overload (Figure 4). In this case, F1 is the point of beginning of dynamics change and F2 is the end point of dynamics change of before unlocking.

Another component of the experimental studies was to establish the energy consumption of press equipment, depending on the number of textile materials decks. The results of experiments are presented in the corresponding graphical dependences (Figures 5 and 6).

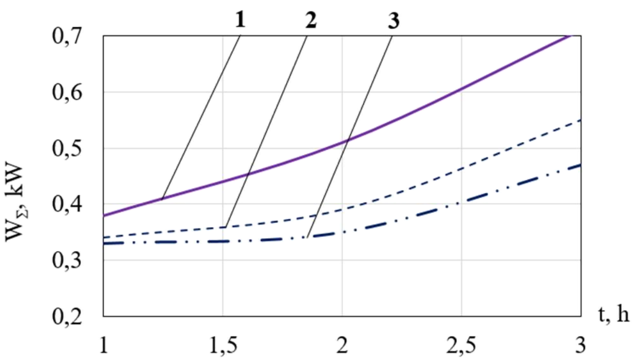


Figure 5 Graphical dependence of changing the maximum amount of energy consumption W_{max} on time t, which takes into account the number of decking material n: 1 – multilayer; 2 – combined; 3 – one-layer

The experimental researches made it possible to establish the nature of a change of consumed energy from the grid using a developed drive. It is established that the number of decks of textile material significantly influences on the nature of energy consumption by equipment. With increasing a number of material layers the level of energy consumption increases to a great extent.

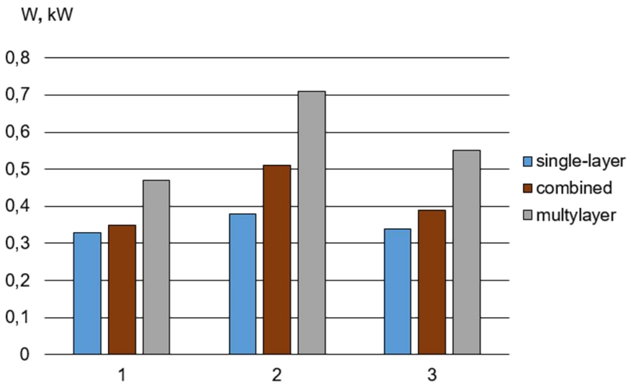


Figure 6 Graphical dependence of changing energy consumption W on number of decks of textile material and coefficient, which takes into account the type of material k: 1 – fabrics with a simple weave; 2 – fabrics with difficult weave; 3 – combination of fabrics with different materials

This is due to the occurrence of additional forces of resistance in the drum-cutter-material system. They complicate the cutting process and deteriorate a quality of cutting parts. Conducted researches are consistent with the work, described above [1-5].

Compared to cutting single-layer flooring fabrics, energy consumption is 15.5% higher for combined and 43.6% higher for multi-layer flooring fabrics. In turn, when cutting multi-layered materials, electricity consumption from the grid increases by 28.1%. At the same time, maximum energy consumption values for fixed materials are set, which are: 0.71 kW for multi-layered fabrics; 0-55 kW for combined fabrics and 0.47 kW for single-layer fabrics.

It is calculated coefficient of efficiency use of equipment α_{eq} for flooring of different fabrics: 0.81 for single-layer; 0.78 for multilayer and 0.79 for combined. Such values are consistent with previous energy consumption experiments for different materials.

Considering the total energy consumption of cutting equipment, calculated coefficient of energy efficiency e^N: 0.89 – single-layer, 0.78 – multi-layer and 0.79 – combined. Thus, according to this coefficient, the highest energy consumption characteristics are when cutting single-layer textile materials, and the worst – multi-layer. That is, when cutting single-layer fabrics, there is the least energy consumption, which has a positive effect on the cost effectiveness of cutting equipment.

The percentage difference between multi-layered and combined is insignificant – 5%. In general, the whole complex of conducted investigations has allowed to establish economic efficiency of cutting presses with the use of developed drive. In comparison with existing equipment, the economic effect is 35.4%. With continuous work of equipment such savings are significant. It is also important to take into account disadvantages of conducted researches.

A limited number of materials used in research should be noted. This is due to determination of power consumption of equipment in the range of basic fabrics. However, taking into account the behavior in cutting down a large number of tissues will identify ways of further research and establish the features of interaction of different tissues during cutting. However, consideration behavior of a large number of fabrics during cutting will identify the ways of further researches and to establish features of interaction of different fabrics at cutting. At the same time developed drive is experimental and cannot be used for prolonged exploitation. Therefore, there is a need to develop an industrial sample of experimental drive. These disadvantages need to be addressed in the next studies.

4 CONCLUSIONS

It was conducted a study of energy efficient presses for cutting textile materials, as a result of which determined features of their energy consumption and advantages over existing equipment.

A new experimental drive has been developed for use in cutting presses. Its main features are the use of a frequency converter, microprocessor technics, sensors to control parameters of equipment work, monitoring system and experimental measuring unit.

The degree of power consumption of cutting presses has been established. The maximum power consumption is: 0.71 kW for multi-layered fabrics; 0.55 kW for combined fabrics and 0.47 kW for single-layer fabrics. In comparison with cutting one-layer flooring of fabrics, in combined fabrics was energy consumption higher on 15.5% and in multi-layer on 43.6%.

Calculated coefficient of energy efficiency of cutting equipment for fabrics, which is: 0.89 – one-layer, 0.78 – multilayer and 0.79 – combined. Conducted researches have allowed to establish the coefficient of efficiency application of equipment for decks of different fabrics: 0.81 for one-layer; 0.78 for multi-layer and 0.79 for combined.

Comparison developed equipment with existing allowed to establish their economic efficiency. It is determined that economic effect of using developed equipment is 35.4%.

5 REFERENCES

1. Karmalita A.K., Yakymchuk D.M.: Experimental study of impact the mechanism of drummer rotation on the efficiency work of electro-hydraulic press equipment, Herald of Khmelnitskyi National University 3, 2013, pp. 106-109, (in Ukrainian)
2. Yakymchuk D.M.: Increasing the efficiency of cutting presses of light industry, Herald of Khmelnitskyi National University 1, 2011, pp. 46-50, (in Ukrainian)
3. Karmalita A.K., Yakymchuk D.M.: Investigation of energetic parameters of electro-hydraulic press equipment, Herald of Cernihiv State Technological University 42, 2010, pp. 265-269
4. Miller R.K.: Waterjet Cutting: Technology and Industrial Applications. Fairmont Press, 1991, 154 p., ISBN 978-0881730685
5. Yakymchuk D., Yakymchuk O., Chepeliuk O., Myrhorodska N., Koshevko J., Orlenko O., Nosova I.: Study of cutting presses in designing a women's costume for hospitality industry, Eastern-European Journal of Enterprise Technologies 5(1) Engineering technological system, 2017, pp. 26-36, https://doi.org/10.15587/1729-4061.2017.110962
6. Yakymchuk O., Yakymchuk D., Kushevskiy N., Chepelyuk E., Koshevko J., Myrhorodska N., Dzyundzya O., Burak V.: Prerequisites for the development of hydro-jet technology in designing women's headgear at hospitality establishments, Eastern-European Journal of Enterprise Technologies 1(1) Engineering technological system, 2018, pp. 36-46, https://doi.org/10.15587/1729-4061.2018.121507
7. Yakymchuk O., Yakymchuk D., Kovalska N., Shvets I., Shvets Y.: Economic effect of hydro-jet forming womens headwear details of hospitality establishmenst, Vlakna a Textil (Fibres and Textiles) 25(3), 2018, pp. 84-88
8. Orel V., Shchetinin V., Salenko A., Yatsyna N.: The use of controlled cracking to improve the efficiency of waterjet cutting, Eastern European Journal of Enterprise Technologies 1(7), 2016, pp. 45-56, https://doi.org/10.15587/1729-4061.2016.59907
9. Li M., Li S., Yang X., Liang Z.: Fiber laser cutting of CFRP laminates with single- and multi-pass strategy: A feasibility study, Optics & Laser Technology 107, 2018, pp. 443-453, https://doi.org/10.1016/j.optlastec.2018.06.025
10. Cenna A.A., Mathew P.: Analysis and prediction of laser cutting parameters of fibre reinforced plastics (FRP) composite materials, International Journal of Machine Tools and Manufacture 42(1), 2002, pp. 105-113, https://doi.org/10.1016/S0890-6955(01)00090-6
11. Phakphonhamin V., Chudokmai M. Optimizing the performance of the LECTRA automatic fabric cutting machine, In: Proceedings of 2018 5th International Conference on Business and Industrial Research (ICBIR), Bangkok, 2018, pp. 282-287, doi: 10.1109/ICBIR.2018.8391207
12. Krowatschek F., Nestler R.: Automatic cutting machines for single- and multiple-ply lays, Knitting Technology 20(6), 1998, pp. 266-267

13. Volkova A.N., Toroptseva E.L., Ambrosimov S.K.: The relationship between the change in the conditions of discontinuous cutting, the structure, and microhardness of the cut layers, Fundamental and Applied Problems of Textile Technologies 3(299), 2013, pp. 61-65b (in Russian)
14. Yakymchuk D., Dzyundzya O., Burak V., Shvets I., Shvets Y., Myrhorodska N., Polishchuk O., Karneyenka D., Krasner S.: Economic efficiency of textile materials cutting designer costumes of hospitality facilities, Vlakna a Textil (Fibres and Textiles) 25(4), 2018, pp. 90-93
15. Artemenko M., Yakymchuk O., Yakymchuk D., Myrhorodska N., Zasornova I.: Costume designin for hospitality establishments staff on the basis of analysis the Slavic snakes ornamentation, Vlakna a Textil (Fibres and Textiles) 25(1), 2018, pp. 3-7
16. Diachok T., Bereznenko S., Yakymchuk D., Aleksandrov M., Bakal V., Budzynskyi M.: Development of equipment for complex man protection from artificial non-ionizing EMR, Vlakna a Textil (Fibres and Textiles) 26(2), 2019, pp. 9-13.

PETROCHEMICAL POLYMERS AND TECHNICAL TEXTILE INDUSTRY IN THE KINGDOM OF SAUDI ARABIA

Zakiyya Abdulrazak Halawani and Maha Abdullah Al Dabbagh

King Abdulaziz University, Faculty of Human Sciences and Design, Jeddah, Saudi Arabia
zhalawani0005@stu.kau.edu.sa; Maldabag@kau.edu.sa

Abstract: *This paper aims to explore the industrial environment of petrochemicals and technical textile in the Kingdom of Saudi Arabia, where it links the abundant availability of synthetic polymer, as a "national wealth" of high quality and sustainability standards, with its importance in the technical textile industry. The paper discusses the future trend and economic relevance of polymers and technical textile, as well as the challenges that face this industry in Saudi Arabia. Findings of this research, have pointed out that abundant availability of raw polymers in the Kingdom contributes to accelerating the manufacturing process of technical textile. In addition, it has also indicated that the Kingdom has natural and economic environment, favorable to the technical textile industry that relies on cutting-edge technology which eliminated the need to hire great number of technicians. In addition, the manufacturing process of technical textile now relies on thermal processes instead of water as an alternative to preserve the water wealth, thus, making the Saudi natural and economic environment favorable to this industry. The research has also highlighted the Kingdom's development plans as well as its future vision that aims to promote the petrochemical industries and enhance various respective products, given their economic and investment strength that contributes to the growth of non-oil industries in the Kingdom of Saudi Arabia.*

Keywords: *Petrochemical industry, synthetic polymers, technical textile, sustainability.*

1 INTRODUCTION

The world has experienced a significant transformative revolution in petrochemical industries, which has become today's industrial tool. Thus, the entire world has shifted from the Iron and Stone ages to the age of chemistry, with petrochemicals being utilized in the manufacture of various products that we use in daily lives, including furniture, clothes, devices, vehicles, and even in the construction of bridges, roads and buildings.

Today, the Kingdom of Saudi Arabia has emerged as one of the world's largest producer of petrochemical industries, due to abundant availability of stockpiles of crude oil and natural gas. Moreover, the Saudi petrochemical industry has seen increasing growth rates in recent years, and the country's total production of petrochemical materials, chemicals and polymers is projected to increase to 115 million tons in the coming years [1].

The Kingdom's Ministry of Energy has aimed at achieving sustainable development for the integrated industry of oil, gas and mining, in order to achieve the highest added value to the national economy [2]. Thus, the petrochemical materials industry has outweighed that of non-oil industries in terms of investment volume, with an investment value of approx. SAR 532 billion, i.e. 50% of the total investments of producing factories [3].

Nowadays, Saudi Arabia produces various petrochemical products in addition to fertilizers, including the five main plastic polymers, which are polyethylene (both low-density and high-density polyethylene), polypropylene fibers, polystyrene, plastic and polyester [4-6]. Moreover, the year 2018 has shown further innovations, including the introduction of special portfolio of textile polymers, as well as innovative sustainable solutions for synthetic polymers [7].

The demand for technical textile-based products is constantly increasing. In 2017 alone, the volume of technical textile market (both woven and non-woven) was estimated at USD 165.51 billion, and it is likely to reach USD 220.37 billion by 2022, at a CAGR of 5.89% from 2017 [8-10]. Moreover, reports on global textile market and its future expectations have predicted an increase in the market value of technical textile to reach USD 220.37 billion by 2022 [11].

This increased demand on technical textile may be attributed to its physical, mechanical and dynamic characteristics, which are utilized in heavy and light industries. In addition, the increased use of technical textile in many end-uses industries (such as aggrotech, buildtech, mobiltech and geotech) has further increased the demand on it [8, 12].

Both technical fiber and textile are also utilized in the production of variety of clothes and products, including protective, functional, meditech and health, sporttech and smart clothes. Consequently, the shirt we wear is made of polyester, shoes and bags are made of polyvinyl [13], flame- and fire-resistant clothing, and military clothing are made of nano and synthetic polymers [14-16]. Additionally, the carpets and bedspreads are made of polypropylene, while the fabric used in the manufacture of fire- resistant tents that are commonly found at the sacred sites during pilgrimage, is a sort of highly effective fire-resistant petrochemical-based polymers [17, 18]. Currently, the world's is trending towards clothes, furnishings, leather and nylon that are made of petrochemical-based synthetic textiles [17]. The textile industry is an important segment of the Kingdom's industrial sector. It plays an important role in creating job opportunities for Saudi citizens, diversifies their sources of income, and helps overcome the problem of unemployment. Moreover, this industry contributes to increased production rates, leads to economic independence and provides some local needs of clothing and textile [19, 20].

In light of the research's exploratory study which has included field visits to Saudi petrochemical and technical textile factories, as well as face-to-face interviews with concerned staff, it was found out that there is a need to pay attention to technical textile industry in Saudi's market, which is known for its global competitive strength, thanks to the abundant availability of crude oil stockpiles on the Kingdom's soil as a "national wealth" and the possibility to transform quantities of this oil into non-oil transformative industries, in line with the Kingdom's 2030 vision.

2 PETROCHEMICAL AND POLYMERS - FUTURE VISION

The Kingdom's petrochemical industry constitutes a vital component of Saudi non-oil economy. It also supports the transformative industry and international investments, helps leverage the country's economy, supports the industry sector, and provides job opportunities for the citizens [21, 22].

In the meantime, petrochemical industry has the potential to open the local markets to some new products, while, at the same time, reduce reliance on imports. Moreover, studies have indicated that the government has already taken steps to encourage the inflow of foreign direct investment in the petrochemical industry. However, these studies have also noted that several measures related to infrastructure and security factors need to be taken [23]. These facts were highlighted by the National Transformation Program 2020 (a.k.a., the Kingdom's Vision 2030), given the prominent role of petrochemicals industry in the non-oil economy, being one of the important sectors that achieve the aspired objective to diversify resources of national income away from reliance on oil [2, 24]. As per annual reports of the Ministry of Energy, total exports of the Kingdom's petrochemical and plastic amounted to $ 30 billion in 2017, while petrochemicals accounted for a large proportion of the total non-oil exports, amounting to 60%. The reports have also predicted that the petrochemical industries sector will help increase the production capacity so as to produce specialized chemicals and end-uses products. This will not only achieve growth in the Kingdom's non-oil exports, but will also create job opportunities for Saudi citizens [3]. Planning the future of petrochemical industry, the Ministry of Energy, in collaboration with the Saudi Industrial Development Fund, has aimed to achieve sustainable development for the integrated industry of oil, gas and mining, in order to achieve the highest added value to the national economy, and work towards discovering and exploiting more resources of oil, gas and minerals in the Kingdom, in order to generate the highest returns from these resources, especially as the production capacity of the petrochemical sector is constantly growing and increasing as shown in Figure 1 [24].

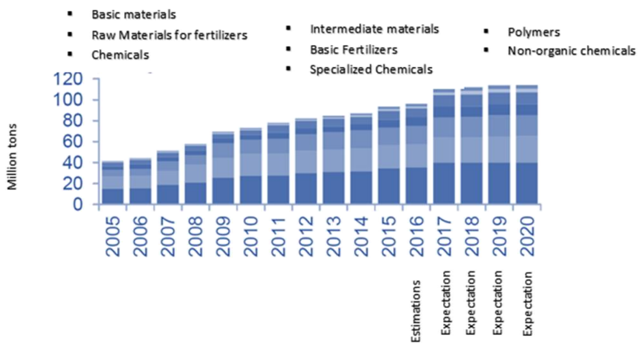


Figure 1 Production capacity of the Saudi petrochemical sector (2005-2020) [24]

3 PETROCHEMICAL PRODUCTS: POLYMERS

Saudi Arabia produces many petrochemical products such as plastic polymers, which are polyethylene (both low-density and high-density polyethylene), polypropylene fibers, polystyrene, plastic and polyester. It does also produce more than 2 million tons of methanol and a similar amount of MTBE (Methyl tert-butyl ether) which are widely used as additives in gasoline. Recently, a new project was launched with the aim to produce 140,000 metric tons of polyester fibers and PET pellets, which are used in the manufacture of bottles and textile [4-6].

In 2017, a project proposal was presented to convert quantities of oil into chemicals, with the aim to produce 9 million tons of petrochemical materials per year through treatment of 400,000 barrels of crude oil per day, and with an optimal integration between plants and petrochemical refineries. Moreover, polymeric materials have gained the interest of industrial consumers over the past 70 years, resulting in an increased production of polymers portfolios, and addition of demand-driven characteristics, including viscosity, conductivity, shielding, thermal management, flame resistance, and the overall aspect that enhances the performance of its multiple uses [7].

The Kingdom's petrochemical companies manufacture the building blocks for chemicals that are utilized in several industrial activities, including but not limited to packaging industry, and manufacturing of health care devices and household necessities. Moreover, the year 2018 has witnessed further innovations with the introduction of the premium portfolio of textile polymers [7]. In an interview held within the exploratory study of this research, a representative of the most famous petrochemical companies in the Kingdom has valued the quality of Saudi polymers, citing its high quality and conformity to standard international specifications as well as its similarity to products of Europe and other foreign countries. This can be attributed to the fact that most companies in Saudi Arabia are associated with partnerships with peer companies in Europe and other foreign countries, and therefore employ the same technology used by those foreign countries.

4 POLYMERS AND TECHNICAL TEXTILES

The exploratory study has shown that the Kingdom manufactures polymers that are used in the textile industry, including acrylic fibers, nylon, elastane (a.k.a. spandex), polyester fibers among others, which are all available in the Kingdom's factories and are also exported. As per the study’s exploratory interviews, the most important countries to which the Kingdom exports textile polymers are China, India, Vietnam and Bangladesh, while it exports less to Europe, America and Turkey. However, in terms of local demand on petrochemical polymers, the exploratory study has shown that local demand on textile polymers, such as polyester, is weak compared to a stronger external demand. However, this was attributed to lack of textile factories in the Kingdom. These findings were verified by global reports and statements, including the announcement by the International Energy Agency during its International Conference on the Future of Petrochemistry, during which statistics of countries that use the most synthetic threads in the textile industry, such as polyester, polyamide and acrylic, were revealed. As per these statistics, the USA, Europe, China and India have had the highest consumption rates between 2002-2014. Meanwhile, the organization has revealed that future global trend in the textile and clothing industry demands polyester over other types of threads [25]. This was further confirmed by another study in which it was maintained that the global demand for polyester exceeds that of natural threads such as cotton and wool, at an average of 60% of the total global demand for threads that are utilized in production.

The results of the exploratory study have shown that various technical types of textile polymers are being produced in the Kingdom’s petrochemical factories. Figure 2 illustrates the production stages of polymers, starting with treatment of crude oil and natural gas, to the production of ready-to-use petrochemical-based synthetic polymers. These production stages include specialized refining and manufacturing processes along with various chemical treatments, and are supervised and managed by industry-experienced, and specialized technical team throughout the whole production process, until the delivery of the product in its final form. Thus, it can be concluded that the availability of local petrochemical-based textile polymers can support derivative transformative industry, such as textile industry (including technical textile). Moreover, availability of polymers at the local level can promote production, while utilizing crude oil for the manufacture of polymers can help improve the rates of national productivity.

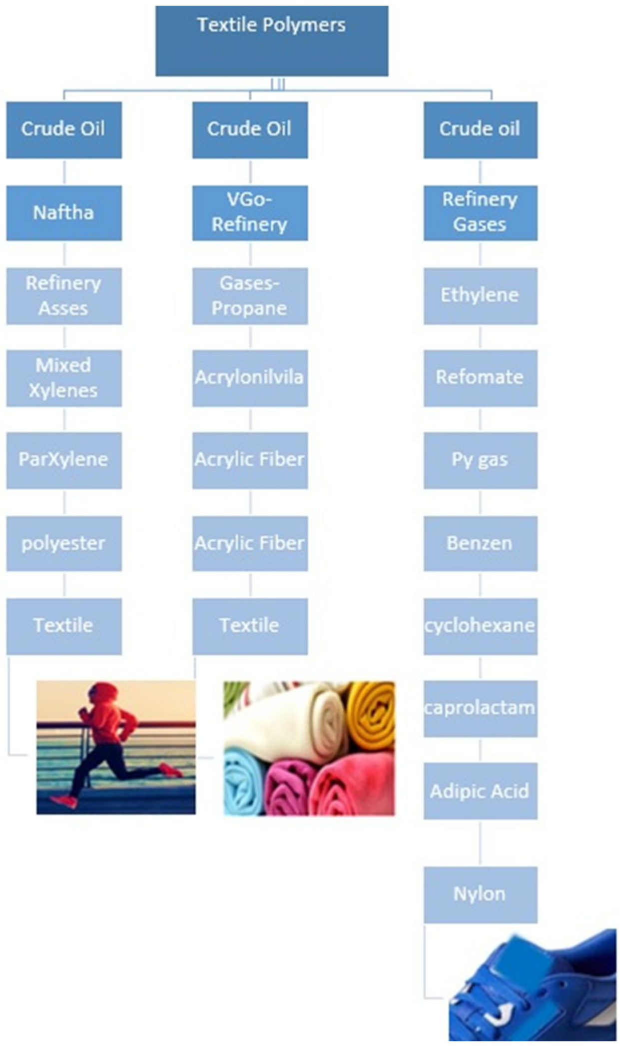


Figure 2 Production stages of textile polymers in Saudi Arabia petrochemical factories

5 POLYMER INDUSTRY'S CONTRIBUTION TO SUSTAINABILITY

The concept of global sustainability is closely linked to the petrochemical industries in the Kingdom of Saudi Arabia, and some Saudi petrochemical companies have conducted researches and studies that link sustainability to petrochemical products. Moreover, sustainability helps Saudi petrochemical companies realize their future orientations towards achieving the economic, environmental and social pillars of sustainability. In addition, sustainability promotes financial performance by achieving efficiency that reduces operating costs, as well as by developing innovative sustainability solutions for products, in order to increase profitability [23].

The Kingdom is striving to invest in research and development initiatives to achieve sustainability for its products, and convert plastic waste into feedstock and chemicals. In this regard, a Saudi company was ranked the third best petrochemical company for the year 2018 in FORBES Classification for its operations in more than 50 countries to make positive impact on the communities where it operates through sustainability. The company has implemented a successful experiment to convert plastic waste into feedstocks as shown in in Figure 3.

Building on this success, the Kingdom issued a decision to build a plant in the Netherlands to produce raw material from recycled plastic waste, thus ending the previous practice of incinerating waste materials or burying them in landfills. Thus, the Kingdom has become the first country to implement such a project [28]. The research sample has indicated that the Kingdom's companies pursue several aspects of developments in the sustainability processes, including the reduction of carbon footprint of waste and production processes, through the application of alternative environment-friendly solutions. On this regard, sustainability reports have confirmed that the Kingdom's companies registered 11,738 patents in the petrochemical sector and its sustainability [26].

6 SYNESTHETIC TECHNICAL TEXTILE INDUSTRY IN THE KINGDOM OF SAUDI ARABIA

The Saudi local market produces petrochemical-based textile products, according to the study's exploratory interviews with officials in the technical textile sector. Given the importance of the technical textile industry as being one of the promising sectors, a number of textile factories that produce different products were established. These factories produce fibers as well as other textile threads that are used in manufacturing different industrial products (such as bags that are used for packaging of onion and rice; special textiles that are utilized in construction of bridges and roads; as well as textiles used for manufacturing of umbrellas, tents, (especially tents that are commonly used in the sacred sites during time of pilgrimage) and furniture. These textile factories use raw materials that are utilized in the manufacture of petrochemical-based synthetic textiles (such as propylene, polyethylene, polyester and nylon) and others.

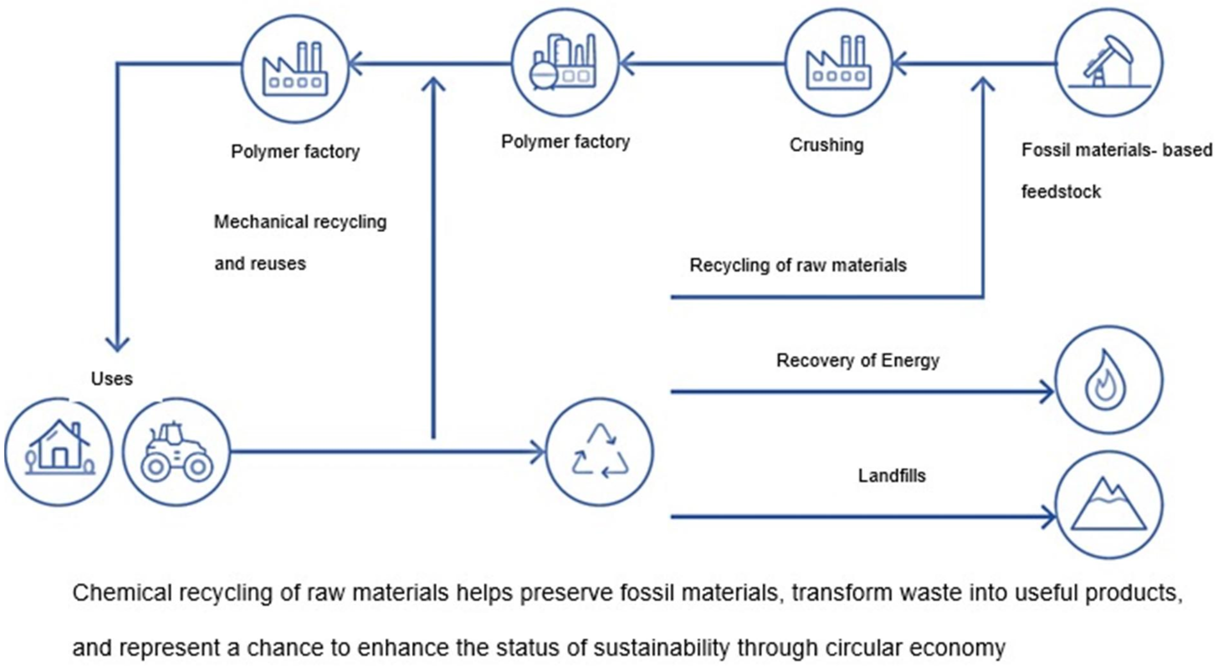


Figure 3 Transforming plastic materials into raw materials for the production of chemicals [26]

7 GOVERNMENT INDUSTRIAL SUPPORT FOR PRODUCTS MADE OF PETROCHEMICAL-BASED TEXTILE IN THE KINGDOM OF ARABIA

Saudi government impose laws that stipulate the sale of all kinds of local polymers to Saudi national factories at a low price [2]. In addition, the Kingdom's 2030 vision avails its support to the petrochemical sector, considering it as one of the sectors that will help boost the non-oil exports. As per the vision, the Saudi petrochemicals industry has been designated as one of the seven national industries selected for concentrated support. Specifically, the Vision emphasizes the need to build a unique logistical hub in the Kingdom, in which the enhancement of logistical services, state-of-the-art infrastructure, and streamlined trade exchanges are sought. Additionally, the vision also emphasizes support for national companies, including petrochemicals, in helping them gain market share in both regional and international markets [24].

Consistent with government decisions, the research's exploratory study has shown how the government avails its support to polymer products, including by imposition of laws that encourage petrochemical companies to avail special prices to local companies that produce polymer-based products, and stipulate the sale of polymer-based products in the local market at a lower prices compared to export prices.

Additionally, national factories of various industrial activities have confirmed receipt of supplies of all types of petrochemical materials and their derivatives, including the chemically treated polyesters that are used for the manufacturing of carpets as well as for tents that are commonly used in the sacred sites during time of pilgrimage.

Thus, it is clear that government support for local polymers and availability of raw materials in the local market at a competitive price can save a lot of time and effort, contribute to the development of local industries, and accelerate the production process of technical textile-based products.

8 OUTPUTS OF TECHNICAL TEXTILE SECTOR IN THE KINGDOM OF SAUDI ARABIA

The study's exploratory interviews have indicated that 30% of factories that manufacture technical textile cover the needs of government projects at the local market, including factories that rely on government projects (such as factories that manufacture tents for sacred sites and provide materials for construction of airports), while 20% of factories cover the consumers' needs of functional textiles, (such as medical masks and carpets), and 50% export their products.

The Kingdom's petrochemical companies focus their attention on the production of new groups of technical textile products. In 2018, the Kingdom launched UDMAX™ GPE 46, a unidirectional fiber-reinforced thermoplastic composite tape that can be used to reinforce industrial oil pipes, boilers and storage tanks. This can significantly increase strength performance while reducing weight and corrosion in the most demanding environments.

In the health and medical textiles sector, new fibers were introduced in 2018 as an innovative new product made of polypropylene resins, and engineered to enable manufacturers produce non-woven fabrics of light thickness and different characteristics, including air permeability and thermal insulation. In addition, this material meets the rigorous standards of hygiene and consumer protection, which makes it highly candidate for use in a wide range of medical and health applications, including diapers, sanitary napkins, to patient gowns and medical clothing [26].

Resin can be easily designed according to specific requirements as per customer demand, and can help manufacturers produce fabrics that combine unique advantages, including excellent processing features, high performance, control over costs and manufacturing requirements, and sustainability, while observing customers' safety and comfort [26].

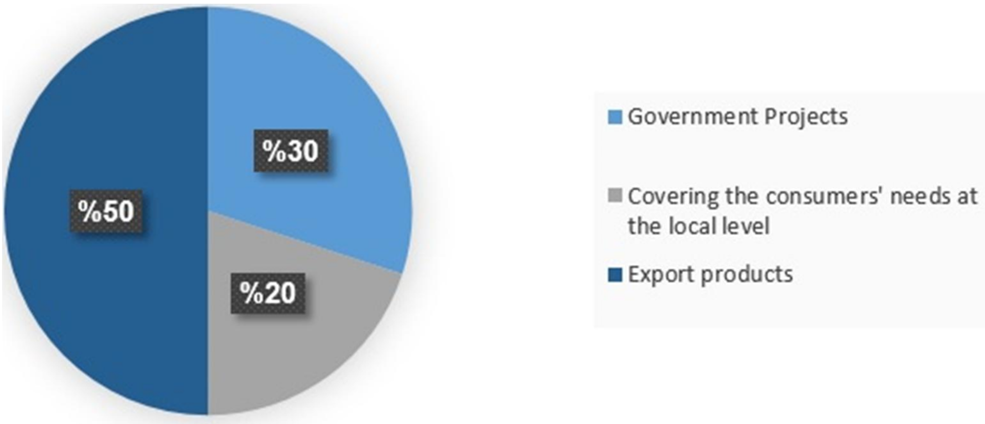


Figure 4 Outputs of technical textile sector in the Kingdom of Saudi Arabia

Reflecting on the research's exploratory study, the Kingdom was found to have many effective technical textile factories that use locally-manufactured textiles polymers (such as propylene and polyester used for the manufacturing of carpets, medical tissues and flame-resistant tents that are specially made for the sacred sites). In addition, these factories have proved its capacity to cover both local and global needs, as well as its ability to deal with the challenges that face the textile industry in the Kingdom. These findings can encourage the implementation of more industrial activities (similar to the industry of petrochemical-based technical textile), that are manufactured and produced using cutting-edge technological machines which have proved its capability and effectiveness in current factories.

9 CHALLENGES FACING THE TECHNICAL TEXTILE INDUSTRY IN THE KINGDOM OF SAUDI ARABIA

The Kingdom's natural and economic environment is considered favorable to the technical textile industry, as there are no major technical or natural problems hindering the manufacturing of polymer-derived textile. This can be attributed to the industry's reliance on advanced technological machines that have overcome many technical and natural problems, such as the need to use huge amounts of water for manufacturing of natural textile. Most of these new machines are powered by energy and heat, and no longer need abundant water.

The manufacturing of polymers-based technical textile relies on advanced machines as demonstrated by the research's exploratory interviews, and the factor of human manpower does no longer represent an obstacle to this industry, thanks to the advanced machines that are run by only few operators and technicians. Thus, it can be concluded that the manufacturing of all kinds of technical textile can be smoothly managed in the industrial environment of the Kingdom.

On a different note, excessive reliance on non-Saudi manpower represents a key challenge in Saudi labor market according to JADWA Investment reports [24]. Manufacturing is one of the sectors that contribute to improving the overall Saudization process and employment rates. However, the main challenge lies in the low number of graduate technicians, with a remarkable drop of enrollment in technical specialty in the Kingdom in recent years. However, this problem has been touched upon in the 2030 transformation program, which underscored the need to increase the numbers of mining and petroleum graduates so as to cope with changes, and have qualified persons for the industry.

10 GLOBAL CHALLENGES FACING THE INDUSTRY OF PETROCHEMICAL-BASED TEXTILE IN KSA

The most important external challenges facing manufacturers of petrochemical-based textile are the economic fluctuations, in light of the Kingdom's accession to the World Trade Organization [24]. Another remarkable challenge lies in competitiveness among leading manufacturing countries of technical textile-based products and clothing fabrics, which greatly affect the Saudi productivity and exports, as they offer lower competitive prices due to availability of low-paid manpower and low prices of their products. Hence, it is necessary to provide protective systems for the national technical textile-based products and clothing fabrics [27].

Figure 5 Global challenges facing the industry of petrochemical-based textile in KSA

11 CONCLUSION

Current global reliance is oriented towards achieving sustainable development for synthetic polymers and technical textile industry, given their respective high value that promotes civil and economic progress. The Saudi petrochemical industries have seen increasing growth rates in recent years, and the country's production of synthetic polymers is projected to increase to 115 million tons in the coming years. It is crucial to make use of the Kingdom's synthetic polymers for the development of Saudi technical textile industries, given the Kingdom's natural and economic environment which is favorable to textile industry, thanks to the industry's reliance on advanced machines that eliminated the burden to hire big numbers of foreign technicians, as well as its reliance on high heat and pressure processes instead of excessive and wasteful use of water resources. This sector has a promising future in the Saudi market and has been touched upon by the Kingdom's development plans and future vision as an area that provides investment opportunities in the sector of petrochemical products and respective derivatives. Thus, this industry can help reduce reliance on oil, and oil's revenues can instead be invested in the industrial development [24].

12 REFERENCES

1. Saudi Industrial Development Fund, Annual Report, 2017, https://www.sidf.gov.sa/ar/MediaCenter/AnnualReport/SIDF-2017.pdf
2. Ministry of Energy, 2018, https://www.meim.gov.sa/arabic/Energy/Pages/petroleum.aspx
3. General Authority for Statistic, Industrial Sector, 2017, https://www.stats.gov.sa/sites/default/files/industrial_survey_report_ar_0.pdf
4. Boon M.: Multinational Business and Transnational Regions: A Transnational Business History of Energy Transition in the Rhine Region, 1945-1973, Routledge, New York, 2018, 250 p., https://doi.org/10.4324/9781315455976
5. Cetin E., Odabasi M., Seyfioglu R.: Ambient volatile organic compound (VOC) concentrations around a petrochemical complex and a petroleum refinery, Science of The Total Environment 312(1-3), 2003, pp. 103-112, https://doi.org/10.1016/S0048-9697(03)00197-9
6. Yuan Z., Qin W., Zhao J.: Smart manufacturing for the oil refining and petrochemical industry. Engineering 3(2), 2017, pp. 179-182, https://doi.org/10.1016/J.ENG.2017.02.012
7. SABIC, Annual Report, 2018, Transformation to continue growing, file:///C:/Users/USER/Downloads/SABIC-AR-Arabic-Web_tcm12-18629%20(1).pdf
8. Alagirusamy R., Das A. (Eds): Technical Textile Yarns, Woodhead Publishing, 2010, 632 p., ISBN: 9781845695491
9. Kumar R.S.: Textiles for Industrial Applications, CRC Press, 2016, 406 p., ISBN: 9780429187353, https://doi.org/10.1201/b15338
10. McCarthy B.J.: 1 - An overview of the technical textiles sector, In: Horrocks A.R. & Anand S.C. (Eds.), Handbook of Technical Textiles (2nd ed.), Woodhead Publishing, 2016, pp. 1-20, https://doi.org/10.1016/B978-1-78242-458-1.00001-7
11. Market and market, Annual Report, 2018, https://www.marketsandmarkets.com/search.asp?search=technical+textile+market
12. Horrocks A.R., Anand S., Anand S.C.: Handbook of Technical Textiles, CRC Press, 2000, 5959 p., ISBN: 9781855733855
13. Gupta B.S.: Manufactured Textile Fibers, Chapter 12 in: Kent and Riegel's Handbook of Industrial Chemistry and Biotechnology, Kent J.A. (Ed), Springer US, 2007, pp. 431-498, eISBN: 978-0-387-27843-8, https://doi.org/10.1007/978-0-387-27843-8_12
14. Du D., Tang Z., Ouyang J.: Highly washable e-textile prepared by ultrasonic nanosoldering of carbon nanotubes onto polymer fibers, Journal of Materials Chemistry C 6(4), 2018, pp. 883-889, https://doi.org/10.1039/C7TC05179D
15. Gokarneshan N., Chandrasekar P.T., Suvitha L.: Advances in Nanotextile Finishes - An Approach Towards Sustainability, In: Textiles and Clothing Sustainability, Textile Science and Clothing Technology, Muthu S. (Ed), Springer, Singapore pp. 1-56, 2017, eISBN: 978-981-10-2188-6, https://doi.org/10.1007/978-981-10-2188-6_1
16. Zhou J., Xu M., Zhang X., Leng Y., He Y., Li B.: Preparation of highly efficient flame retardant unsaturated polyester resin by exerting the fire resistant effect in gaseous and condensed phase simultaneously, Polymers for Advanced Technologies 30(7), 2019, pp. 1684-1695, https://doi.org/10.1002/pat.4599
17. Castano L.M., Flatau A.B.: Smart Textile Transducers: Design, Techniques, and Applications, Capter in: Industrial Applications for Intelligent Polymers and Coatings, Hosseini M., Makhlouf A. (Eds), Springer, Cham, 2016, pp. 121-146, eISBN: 978-3-319-26893-4, https://doi.org/10.1007/978-3-319-26893-4_6
18. Fai T.J., Mark J.E., Prasad P.N. (Eds): Polymers and Other Advanced Materials: Emerging Technologies and Business Opportunities, Springer US, 2013, 791 p., eISBN: 978-1-4899-0502-4, doi: 10.1007/978-1-4899-0502-4
19. Al-Subiani N.A.-H.: Factors affecting production in the ready-made garment industry in Jeddah, College of Education, Umm Al-Qura University, 2011
20. Nader K., Hamdan N.: Ready-made garments industry in the Kingdom of Saudi Arabia, Makkah Al-Karma, King Fahd National Library, 2010
21. Rehman M.Z., Khan M.N., Khokhar I.: Select financial ratios as a determinant of profitability evidence from petrochemical industry in Saudi Arabia, European Journal of Business and Management 6(6), 2014, pp. 187-196
22. Yamada M.: Gulf-Asia relations as “post-rentier” diversification? the case of the petrochemical industry in Saudi Arabia, Journal of Arabian Studies 1(1), 2011, pp. 99-116, https://doi.org/10.1080/21534764.2011.576054
23. Aljarallah A.: Analysing the Impact of the World Trade Organisation (WTO) on the Sustainability of Competitiveness of the Petrochemical Industry in Saudi Arabia, Doctoral thesis, Durham University, 2010, http://etheses.dur.ac.uk/303/
24. JADWA Investment, Saudi petrochemical sector and the Kingdom's vision 2030, 2017, file:///C:/Users/USER/Downloads/20170221_Petrochemicals-and-the-Vision-2030-Arabic%20(1).pdf
25. International Energy Agency, World Energy Outlook 2018, 661 p., https://doi.org/10.1787/weo-2018-en
26. SABIC, Annual Sustainable Report, Our Business Makes the Difference, 2018 file:///C:/Users/USER/Downloads/Sustainability-Report-Executive-Summary-Ar_tcm12-18599.pdf
27. Al-Muhammadi, Ibrahim Muhammad Nur: The Impact of Petroleum Production Strategy on Industrial Development in the Kingdom of Saudi Arabia 1995-2000 AD, Doctoral dissertation, Sudan University of Science and Technology, 2006

INSTRUCTIONS FOR AUTHORS

The journal „**Vlákna a textil**" (**Fibres and Textiles**) is the scientific and professional journal with a view to technology of fibres and textiles, with emphasis to chemical and natural fibres, processes of fibre spinning, finishing and dyeing, to fibrous and textile engineering and oriented polymer films. The original contributions and works of background researches, new physical-analytical methods and papers concerning the development of fibres, textiles and the marketing of these materials as well as review papers are published in the journal.

Manuscript

The original research papers are required to be written in English language with summary. The advertisements will be published in a language according to the mutual agreement.

The first page of the manuscript has to contain:

The title of the article (16 pt bold, capital letters, centred)

The full *first name* (s) and also *surnames* of all authors (11 pt, bold, centred).

The complete address of the working place of the authors, e-mail of authors (9 pt, italic, centred)

Abstract (9 pt, italic)

Key words (9 pt, italic)

The manuscript has to be written in A4 standard form, in **Arial, 10 pt**.

The text should be in ***one-column format in single line spacing***.

Page margins: up and down 2.5 cm; left and right 2.0 cm.

Do not number the pages and do not use footnotes. Do not use business letterhead.

Figures, tables, schemes and photos (centered) should be numbered by Arabic numerals and titled over the table and under the figure or picture.

Photos and schemes have to be sufficiently contrastive and insert in text as pictures.

Mathematical formulae should be centred on line and numbered consecutively on the right margin.

Physical and technical properties have to be quantified in **SI units**, names and abbreviations of the chemical materials have to be stated according to the IUPAC standards.

References in the text have to be in square brackets and literature cited at the end of the text. References (9 pt), have to contain names of all authors.

[1] Surname N., Surname N.: Name of paper or Chapter, In Name of Book, Publisher, Place of Publication, YYYY, pp. xxx-yyy, ISBN

[2] Surname N., Surname N.: Name of paper, Name of Journal Vol. (No.), YYYY, pp. xxx-yyy, doi number

[3] Surname N., Surname, N.: Title of conference paper, Proceedings of xxx xxx, conference location, Month and Year, Publisher, City, Surname N. (Ed.), YYYY, pp. xxx-yyy

[4] Surname N., Surname N.: Name of Paper, Available from http://www.exact-address-of-site, Accessed: YYYY-MM-DD

The final template of manuscript is available on **http://www.vat.ft.tul.cz**

Authors are kindly requested to deliver the paper (in Word form) to be published together with information about at least 3 recommended reviewers from institutions others than the parent (name, e-mail, institution and department) by e-mail: marcela.hricova@stuba.sk

After successful review procedure there is charged fee (article processing charge) of EUR 100. All articles after review process are freely available online and this fee helps to cover the costs of taking a manuscript and turning it into a finished article.

Address of the Editor Office:

Marcela Hricová

Faculty of Chemical and Food Technology,

Slovak University of Technology in Bratislava

Radlinskeho 9

812 37 Bratislava,

Slovakia