VLÁKNA A TEXTIL

FIBRES AND TEXTILES

2

Volume 26.
June
2019

STU FCHPT

TECHNICAL UNIVERSITY OF LIBEREC
Faculty of Textile Engineering

Trenčianska univerzita Alexandra Dubčeka v Trenčíne
Fakulta priemyselných technológií v Púchove

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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

- Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology
- Technical University of Liberec, Faculty of Textile Engineering
- Alexander Dubček University of Trenčín, Faculty of Industrial Technologies
- Slovak Society of Industrial Chemistry, Bratislava
- Research Institute of Man-Made Fibres, JSC, Svit
- VÚTCH – CHEMITEX, Ltd., Žilina
- Chemosvit Fibrochem, JSC, Svit

Vydáva

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(Redakcia a distribúcia časopisu)

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***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) 2019
Vlákna a textil (2) 2019
June 2019

Content

SHEEP WOOL CAN BE SCOURED SUFFICIENTLY WITHOUT ANY CHEMICALS

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Abstract: *In our search for an alternative method of scouring sheep wool without using any chemicals, we have tested various methods: a) wool scouring in ultrasonic bath filled with tap water at 40°C under different time modules and, b) simple maceration of wool in unheated tap water. Reference procedure was Soxhlet extraction by dichloromethane. The criteria applied to assess the efficiency of the selected procedures were the mass loss of the scoured sample and the 220 nm absorbance of aqueous extract obtained from the wool after individual scouring steps. Based on the obtained data, it was concluded that the chemical-free water scouring of 20 g wool in ultrasonic bath with the volume of 5 dm^3, at 38 kHz frequency, during 4x10 min and combined with a water exchange every 10 min, provides a very good result. A comparable effect was observed using a simple unheated tap water maceration during 2x7 day intervals with a water exchange after 7 days. Both procedures are more environmentally friendly than the conventional method. Depending on the intended use and required level of wool purity, it is possible to reduce the total time of ultrasonic scouring. While the maceration requires a minimal handling and technical equipment, it is a lengthy process. On the other hand, the scouring with the ultrasonic support takes only few minutes, however, it requires an initial investment, but with a quick economic return. Both methods share a common advantage of the reduced environmental impact.*

Keywords: *sheep wool, ultrasonic scouring, maceration, Soxhlet extraction.*

1 INTRODUCTION

Sheep wool is decreasingly used in the traditional textile production and becomes an unwanted hardly marketable by-product for sheep farmers. In recent years, several studies have appeared focused on examination of this material to be a potential biosorbent [1-3]. Sheep wool belongs to the group of fibrous biosorbents of keratin-type [4, 5] containing a whole range of acidic and basic functional groups that are potentially active sites for binding various substances from the environment [1]. A crude sheep wool contains various types of impurities and grease on the fibre surface and their amount depends on the manner and the region of sheep breeding [6, 7]. Several technological procedures are used to eliminate them. In the textile industry, the sheep wool scouring is usually accomplished in Leviathan, a machine consisting of a series of five tanks. The scouring medium is a slightly alkaline solution of soap or detergent [8, 9]. The laboratory studies describing the removal of greasy impurities from the fibre surface utilize organic solvents, e.g. dichloromethane [2, 10, 11], 1,1,1-trichloroethane and trichlorotrifluoroethane [12], petroleum spirit [13] or carbon tetrachloride [14]. The sheep wool scouring process is accomplished in three steps. First, the fibres are mechanically cleaned, then greasy components are extracted by a solvent and, at the end, washed with water. The solvent is subsequently regenerated by distillation [5]. A newer and cheaper alternative is the utilization of an ultrasonic device which not only reduces the consumption of chemicals, time and energy but, above all prevents felting or knots [15-17]. Although several published articles point to the benefits of the ultrasound utilization [18, 19], so far only few works have been devoted to the study of wool scouring in an ultrasonic bath without the use of any chemicals. Bahtiari and Duran [20] scoured crude sheep wool in five steps consecutively with and without the ultrasound utilization. They found that after the third scouring in an ultrasonic bath, the same results were achieved as by the five-step conventional scouring. The comparison of the ultrasonic scouring efficiency in pure water with the scouring in water containing chemicals showed that the ultrasonic scouring in water at 35°C provided the wool with a good whiteness index value and sufficient impurity removal.

Provided that sheep wool can be a potential sorbent, the application of detergents and other auxiliaries in the bath may have a negative effect on sorption properties of the fibres by occupying the active sites. Regarding the wool potential sorption, our work was focused on the examination of some possibility to remove impurities from the wool without any chemicals including organic solvents.

2 EXPERIMENTAL

2.1 Materials

A sheep wool sample was obtained from a spring cut of the Suffolk-Tsigaya sheep bred in Banská Belá. After the shearing, the wool was cleared of crude impurities (feed, dung, plants) by washing in tepid water until the water was clear. After the pre-cleaning, it was freely dried and stored in a well-ventilated place with minimal access of light and moisture.

2.2 Equipment

The wool samples used for the scouring (à 20 g) were weighed nearest to 0.01 g (scale Kern 440, Germany). The ultrasonic bath with the volume of 5 dm^3 (Kraintek, K5LE, Slovakia, 350 VA, output of 450 W, 38 kHz frequency, tempering from 20 to 80°C, timer from 0 to 90 min, applied intensity level 9) was used for the ultrasonic scouring. The samples were dried in a laboratory oven (Binder ED/FD, Germany). The scoured samples taken for the control of aqueous extracts (à 0.2 g) were weighed on analytical scales with the readability of 0.0001 g (Radwag AS/C/2, Poland) and shaken on a laboratory shaker (Witeg SHR-2D, Germany) at 100 rpm. The corresponding filtrates were centrifuged using a laboratory centrifuge (T23, Czechoslovakia) and the filtrate absorbance was measured by a UV-VIS spectrophotometer (Specord® 50 Plus, Analytikjena, Germany) with a quartz cell of 1 cm path against distilled water as a reference.

2.3 Scouring procedures

The manually pre-cleaned wool of 20 g was taken for each scouring procedure. The following methods were applied to remove the remaining grease from the fibres:

a) Scouring in 40°C warm tap water in an ultrasonic (US) bath in four repeated cycles of various time lengths (US1, US2, US3, US4 see Table 1) and the water exchange after each time interval; the whole procedure was tested thrice.
b) Simple wool maceration in an enclosed container with 5 dm^3 of tap water at room temperature during four consecutive seven-day scouring cycles, with the water exchange every seven days; regarding the minimal mechanical manipulation and the risk of the fibre damage, the experimental deviations were considered as negligible and the experiment was performed in one repetition.
c) Soxhlet extraction with dichloromethane (bp 39°C) used as a comparative method; the sample of 20 g divided into five extraction cartridges and each part extracted separately in 14 overflows (4 h) taken as one cycle.

After every scouring cycle, the samples were washed in 5 dm^3 of distilled water when scoured in water, while twice with 5 dm^3 of distilled water after Soxhlet extraction and evaporation of a residual solvent in a digester. The all washed samples were spread on filter paper and dried freely at room temperature and humidity during 24 h. Then they were post-dried in the oven at 40°C within 24 h and weighed. The applied conditions are summarized in Table 1.

2.4 Scouring process efficiency control

Efficiency of the scouring procedures was checked as follows:

a) directly through the mass loss of the wool. The relative mass loss L_{rel} [%] was calculated using the following equation:

$$L_{rel} = \frac{m_1 - m_2}{m_1}.100 \quad (1)$$

where m_1 and m_2 are the masses of the wool [g] in the dry state before and after the scouring, respectively.

b) indirectly using the measurement absorbance A_{220} nm for the aqueous extracts obtained from the scoured samples after every finished scouring cycle. The aqueous extracts were prepared from 0.2 g of the dried fibres cut into small 3-5 mm pieces, placed in small glass cups and 20 ml of distilled water was added to each sample. The fibres were in contact with water for 24 hours, while during the first 6 hours the cup contents were shaken on a horizontal laboratory shaker (100 rpm) and the rest of the time, they were in static mode. Then, the liquid fraction was decanted and centrifuged (60 seconds, Level 1) to sediment microparticles causing a mild turbidity. The transparent filtrates were used to measure the absorbance at 220 nm against the distilled water as a reference. Data obtained were treated using statistical methods [21].

Table 1 Scouring methods overview

Scouring method identification	T [°C]	Time design of one scouring cycle	Solvent	Number of scouring cycles applied	Water volume used per 1 scouring cycle [litres]
US 1	40	2x10 min	tap water	4	10 TW + 5 DW
US 2	40	3x10 min	tap water	4	15 TW + 5 DW
US 3	40	1x20 min	tap water	4	5 TW + 5 DW
US 4	40	1x30 min	tap water	4	5 TW + 5 DW
Maceration	23	1x7 days	tap water	4	5 TW + 5 DW
Soxhlet extraction	39	240 min	dichloromethane	1	undefined TW to cool extractor + 10 DW

Legend: US – ultrasonic scouring, TW – tap water, DW – distilled water

3 RESULTS AND DISCUSSION

Design of the experiments was based on supposition that the aqueous extracts from the wool scoured by dichloromethane extraction should contain especially low-polar components and, the extracts from the water processes should consist mostly of polar substances. However due to ultrasound, also low-polar substances can be present in the aqueous extracts.

3.1 Effectivity of scouring procedures evaluated by mass loss

The mass loss within the water scouring was assigned to the removed grease and other impurities contained in the wool. After the scouring, a measurable mass loss was recorded only after the first two scouring cycles, while the mass loss was negligible for the following two cycles. The results of the relative mass loss for the individual methods are summarized in Table 2. When measured the mass loss, we did not expect large figures compared to other published works since this depends on level of the wool pre-treatment. Regarding our initial material was pre-treated in the same way; mutual comparison within the used procedures is justified. As could be seen in Table 2, the lowest mass loss was recorded for the seven-day maceration in water (6.2%). The order of the mass loss after the first scouring cycle was as follows: US2 (3x10 min) ~ US4 (1x30 min) > US1 (2x10 min) > US3 (1x20 min) > maceration (7 days). The comparison of the ultrasonic scouring processes showed that the scouring efficiency increased with the duration of ultrasound application. In the second scouring cycle, the measured mass loss in all scouring procedures was almost the same, ranging from 4.8-5.1%. Again, the US2 ultrasonic scouring process (3x10 min) was the most effective.

Regarding the number of scouring cycles, the comparing the dichloromethane Soxhlet extraction with the ultrasonic scouring is debatable. Although the extraction was performed in only one cycle, but with a considerable number of the solvent exchanges for smaller sample portion, the removal of the wool grease itself may be considered as the most efficient. However, from a time, ecological and financial point of view, it is the least effective. In our case, the result of the 10% mass loss after the extraction was a good basis to conclude that a good result may also be achieved by the repeated ultrasonic scouring in water. Even higher mass loss than in the Soxhlet scouring indicates that ultrasound may remove other substances than grease admixtures as well.

3.2 Effectivity of scouring procedures evaluated by aqueous extract absorbance

The using UV-absorbance of aqueous extract from the scoured wool is based on supposition that grease (lanoline) is the only low-molecular component able to pass into solution. While higher grease concentrations in water can be observable as milky emulsion unsuitable to scan transmission spectrum, the scoured wool containing a low remaining amount of the grease, if any, already provides a transparent solution absorbing within UV-spectral region only (Figure 1). The more thoroughly scoured wool, the lower absorbance of the extract. Then absorbance of aqueous extract from the scoured wool can be an indicator of the grease removal rate.

Measured absorbance values for the aqueous extracts from wool scoured in individual procedures are summarized in Table 3.

Table 2 Relative loss of the wool mass during scouring methods

Scouring method	Relative loss of wool mass [%]			
	1st cycle	*2nd cycle*	*3rd and 4th cycles*	*Total loss*
US1 (2x10 min)	6.80 ± 0.07	5.02 ± 0.07	negligible	11.82 ± 0.14
US2 (3x10 min)	7.11 ± 0.07	5.08 ± 0.32	negligible	12.19 ± 0.39
US3 (1x20 min)	6.71 ± 0.02	4.83 ± 0.16	negligible	11.54 ± 0.18
US4 (1x30 min)	7.09 ± 0.07	4.92 ± 0.10	negligible	12.01 ± 0.17
Maceration (7 days)	6.21 ± 0.05	4.85 ± 0.03	negligible	11.06 ± 0.08
Soxhlet extraction	10.00 ± 1.46	-	-	10.00 ± 1.46

Table 3 Absorbance data ($A_{220\ nm}$, 1 cm quartz cell) for aqueous extracts from wool after being scoured; for non-scoured wool $A_{220\ nm}$ = 0.637±0.013

Scouring procedures	Absorbance after repetition of the scouring cycles			
	1st	*2nd*	*3rd*	*4th*
Soxhlet extraction	0.275 ± 0.007	-	-	-
Ultrasonic scouring with 2x10 min cycle (US1)	0.175 ± 0.009	0.115 ± 0.009	0.146 ± 0.048	0.128 ± 0.013
Ultrasonic scouring with 3x10 min cycle (US2)	0.169 ± 0.048	0.124 ± 0,045	0.122 ± 0,002	0.148 ± 0.034
Ultrasonic scouring with 1x20 min cycle (US3)	0.180 ± 0.021	0.174 ± 0.019	0.142 ± 0.004	0.124 ± 0.012
Ultrasonic scouring with 1x30 min cycle (US4)	0.164 ± 0.030	0.147 ± 0.017	0.110 ± 0.080	0.115 ± 0.022
Maceration with 7 days cycle	0.175 ± 0.040	0.106 ± 0.014	0.140 ± 0.015	0.136 ± 0.021

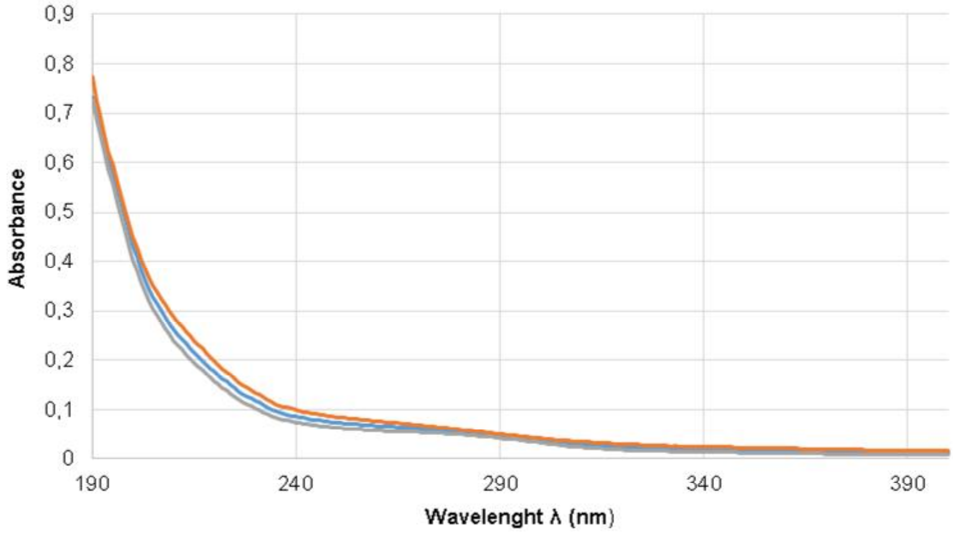

Figure 1 UV spectrum of three parallel aqueous extracts obtained from the scoured wool applying the ultrasonic scouring processes US3 (second cycle)

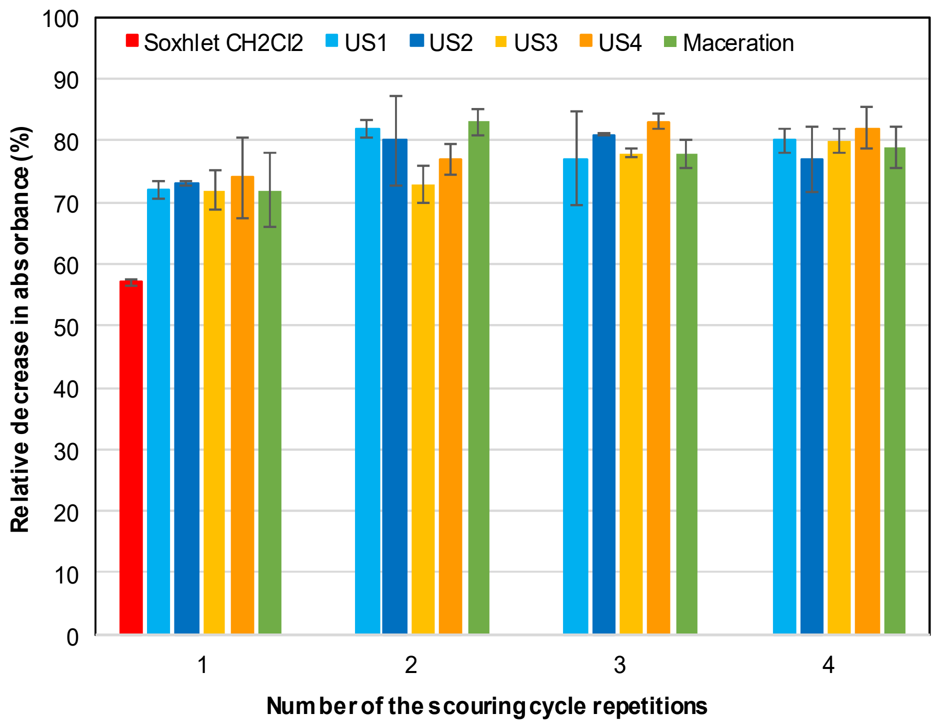

Figure 2 Relative decrease of absorbance $A_{220\ nm}$ for the aqueous extracts from the scoured wool compared with the non-scoured sample after using individual procedures and cycle repetitions. Detailed legend is provided in Tables 1 or 3

Except for the Soxhlet extraction, the absorbance differences between the individual scouring procedures for the first cycle are relatively small in all cases (Table 3). The percentage decrease in the absorbance compared to the non-scoured wool was in the range of 74-71% as displayed in Figure 2.

We expected the lowest absorbance values to be measured for the reference sample. However, the opposite was observed; while the sample after the Soxhlet extraction showed higher mass loss of 10% compared to the first cycle of all water scouring procedures (Table 2), the measured absorbance regarded as a residual grease in the water extracted sample was higher (0.275), even higher than that for the sample macerated (0.175). We have assumed that, while the organic solvent removed grease admixtures, other constituents more polar than the grease went into the aqueous extract. These are better soluble in water and should correspond to higher absorbance.

Analyzing the absorbance results it was concluded that, the most effective scouring procedure was two repetitions of 2x10 min cycle in US1 mode (i.e. 4x10 min including the water exchange after each 10 min) or two 7-days cycles of the maceration mode (i.e. 2x7 days with the water exchange after 7 days). In the mentioned cases the percentage of the absorbance decrease corresponds to 82-83% (Figure 2) compared with the unscoured wool. After completing the particular second repetitions of the scouring cycles and based on the absorbance decline within the range of 72-83%, the ranking of the method efficiency appears as follows: maceration > US1 > US2 > US4 > US3. It is remarkable that the maceration at room temperature showed the highest decrease in the absorbance overall overpassing the other procedures.

Moderate variations in the absorbance were observed after the third repetitions of the cycles following a mild increase for US1 and the maceration, while US2, US3 and US4 provided lower values. Considering application of the ultrasound we assume a partial damage of the wool fibres and possibly, consequently pass of some micro-fragments into solution. Those despite the centrifuge treatment contributed to higher absorbance. This idea is supported by observation of Li et al. [22] who, using electron microscopy, reported that ultrasonic treatment caused scale cracking/peeling in cuticle on some wool fibres. On the other hand, Kadam et al. [16] did not observe any cracks after ultrasonic scouring however, ultrasound was applied not longer than 15 min. Also Goud et al. [23] did not find any topographic changes or damage when scoured wool ultrasonically during 3 min. Anyway, when the demand on the wool purity is not too high, the total ultrasonic scouring time can be reduced to avoid some damage of the fibre surface.

Different reason for higher absorbance after the third maceration cycle should be considered. Negligible manual manipulation with the fibres compared with the ultrasound action excludes any damage in practice. Even integrity of the fibre surface scoured mechanically is documented in work of Li et al. [22], too. So that the higher absorbance should not be consequence of some micro-fragments in the aqueous extract. But probably, depending on time, progressive dissolution of other components from unimpaired fibre surface increased the absorbance.

As believed the variations of absorbance for the fourth repetitions of the cycles present a mixture several reasons participating at the former steps and it is difficult to differentiate them.

4 CONCLUSION

Looking for a way of sheep wool scouring to avoid any chemicals using, the following procedures were tested: a) scouring in ultrasonic bath filled with tap water at 40°C under different mode and, b) simple maceration of wool in unheated tap water. The efficiency of the tested procedures was assessed by the mass loss as well as by measuring the absorbance at λ=220 nm of the aqueous extract from the scoured sample. The comparison procedure was the grease extraction with dichloromethane in a Soxhlet extractor, considered to be the most effective way to remove grease. As shown by the results of both control methods, the use of water as a scouring medium with ultrasound support can provide good results depending on the choice of scouring-time intervals connected with water exchange. Very good result was achieved after four times 10 min ultrasonic scouring at 40°C with water exchange after every 10 min intervals. Prolonging the effect of ultrasound may lead to partial destruction of the fibres, what indicated increasing absorbance after the eighth 10-minute interval. Comparably satisfactory results were also obtained by the simply maceration of the wool in water for 2x7 days with water exchange after 7 days. The latter procedure is simple with minimal handling and technical equipment, but it is tedious. Despite the assumption, the wool extraction with dichloromethane did not achieve either the highest mass loss or the lowest absorbance of the aqueous extract from the scoured wool. This indicates that except wool grease other impurities are washed up by water, too. If it was applied the wool scouring in water without chemicals on a larger scale and with respect to the required purity degree, optimization will be necessary regarding the ration of wool amount to water volume, ultrasound performance, time-period and number of cycles with water exchange. The presented results of the laboratory testing provide a good starting point for process setup. Waste water from the chemical-free scouring will not need to burden any sewerage plant but, it can serve for agricultural purposes including irrigation of agricultural land and possible additional fertilization.

ACKNOWLEDGEMENT: *The authors thank Peter Godovič for spelling and grammar corrections.*

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DEVELOPMENT OF EQUIPMENT FOR COMPLEX MAN PROTECTION FROM ARTIFICIAL NON-IONIZING EMR

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***Abstract:** The main factors that influence on the process of artificial non-ionizing electromagnetic radiation on the man were determined. The method of obtaining nanoparticles of metals directly in the structure of textile materials by impregnating them with solutions of metal salts was developed. Experimental equipment for obtaining nanoparticles of metals by the method of their sputtering by means of an electric arc in a liquid environment is developed. The experimental researches with the modification of textile materials by nanoparticles of metals were carried out and the mechanism of influence of copper nanoparticles on the structure of fabric was determined. The ways of further research for complex man protection are offered.*

***Keywords:** textile materials, metal nanoparticles, non-ionizing EMR, fabric, protective properties, textile materials modification.*

1 INTRODUCTION

Today, scientific and technological progress is increasing day by day. We are surrounded by electronic devices, which have penetrated practically all areas of our business. However, the fee for their use is a permanent stay under the influence of electromagnetic fields which adversely affects on our health. The environment of human existence has always been under the influence of electromagnetic fields. These fields caused by nature are constant background radiation. There are natural and artificial sources of electromagnetic fields (EMF). Biological influence degree of electromagnetic fields on the human body depends on the frequency of oscillation, tension and intensity of the field, mode of its generation (pulse, continuous) and duration of influence. If the wavelength is shorter, then more energy it possesses. In our time, anthropogenic origin EMF significantly exceeds the natural background and it is the most unfavorable factor, which influence increases on the person from year to year. In essence, EMF sources can be any elements of electric circuit, through which passes the high-frequency current [1, 2]. The intensive development of electronics, radio and computer technology caused the pollution of the environment by electromagnetic radiation of different origins. EMF sources can be natural and technogene. The main sources generating EMF of anthropogenic origin are: television and radio broadcasting stations; radar and radio navigation equipment; high-voltage transmission lines; industrial equipment of high-frequency heating; devices providing mobile telephony; antennas and transformators.

Electromagnetic radiation of anthropogenic origin considered as one of the varieties of energy pollutants. They negatively affect on human body as well as on the other living organisms and have a harmful effect on the ecological systems of EMF. They also have energy and distributed in the form of electromagnetic waves. It is known that the main parameters of electromagnetic waves are the wavelength, frequency of oscillations and dissemination speed. The measure of pollution by electromagnetic fields is tension. Electromagnetic radiation by frequency divided into the following: low frequency radiation (LF): 0.003 - 30 kHz; high frequency (HF) radio waves: 30 kHz - 300 MHz; ultraviolet (UHF) radio waves: 30 - 300 MHz; ultrahigh-frequency microwave frequency: 300 MHz - 300 GHz. Such wide range of waves requires analysis and study of their effects on human and further possible protection from harmful radiation [3]. In last years, special attention of scientific community is attracted to the development of methods and means of protecting people from the harmful effects of electromagnetic fields (EMF). The degree of EMF biological effects on human body depends on many factors, especially frequency oscillations, tensions and modes of its generation (pulsed, continuous) and impact duration of exposure [4-6].

According to World Health Organization (WHO), the degree of exposure to EMF on human health exceeds the effects of radiation and therefore is particularly dangerous for the category of permanent users by electronic means. Among them, that especially dangerous, are children, young people (students). In this regard, greatest attention is devoted to development of protection against EMF, including personal protective clothing. An important role should be played a protective covers and other equipment for shielding the EMF sources by themselves [7-11].

With the development of nanotechnology in synthetic textile materials began to introduce different types of nanoparticles to obtain functionalized fibers with special properties. It is mainly inorganic, metal or metal oxides. The use of nanoparticles for the functionalization of textile materials provides the emergence of new properties, such as: protection against EMF, antibacterial activity, flame retardant property, super hydrophobicity and others [12-15]. Therefore, it is important to protect people who use modern electronic means from the influence of EMF by proper shielding clothes. Modern textile materials with applied nanoparticles have significant protective properties [16-20], so they are becoming more widespread. The purpose of the work is to develop equipment for the complex protection of people from artificial non-ionizing electromagnetic radiation (EMR).

2 EXPERIMENTAL

2.1 Experimental equipment

The method of obtaining nanoparticles of metals directly in the structure of textile materials by impregnating them with solutions of metal salts is developed [18]. The essence of this method is the chemical renewal of metal ions to metals in the structure of textile material and on its surface. As a reducing agent are used: polyhydric alcohols, carbohydrates, ascorbic acid and others.

Developed experimental equipment for obtaining nanoparticles of metals by the method of their sputtering by means of an electric arc in a liquid environment is shown in Figure 1.

The glass cylinder 1 is filled with a dispersion environment. Electrodes 2 and 3 are connected through a rheostat to a DC power supply. The upper electrode is connected to the negative pole, the lower one is positive. The gap between the electrodes for the arc obtaining is controlled by the screw 4. The operating voltage on the electrodes is set in the range from 400 to 700 V with the help of power supply, depending on nature of dispersed material. Metal dispersion can be carried out in constant and pulse modes.

The presence of nanoparticles in a dispersion environment was controlled by appearance of opalescence and the "Tindal cone". The stability of dispersion system is achieved by the addition of surface active substance (SAS) OP-10 up to 0.1%. The size of nanoparticles in a dispersed environment did not exceed 200 nm (Figure 1).

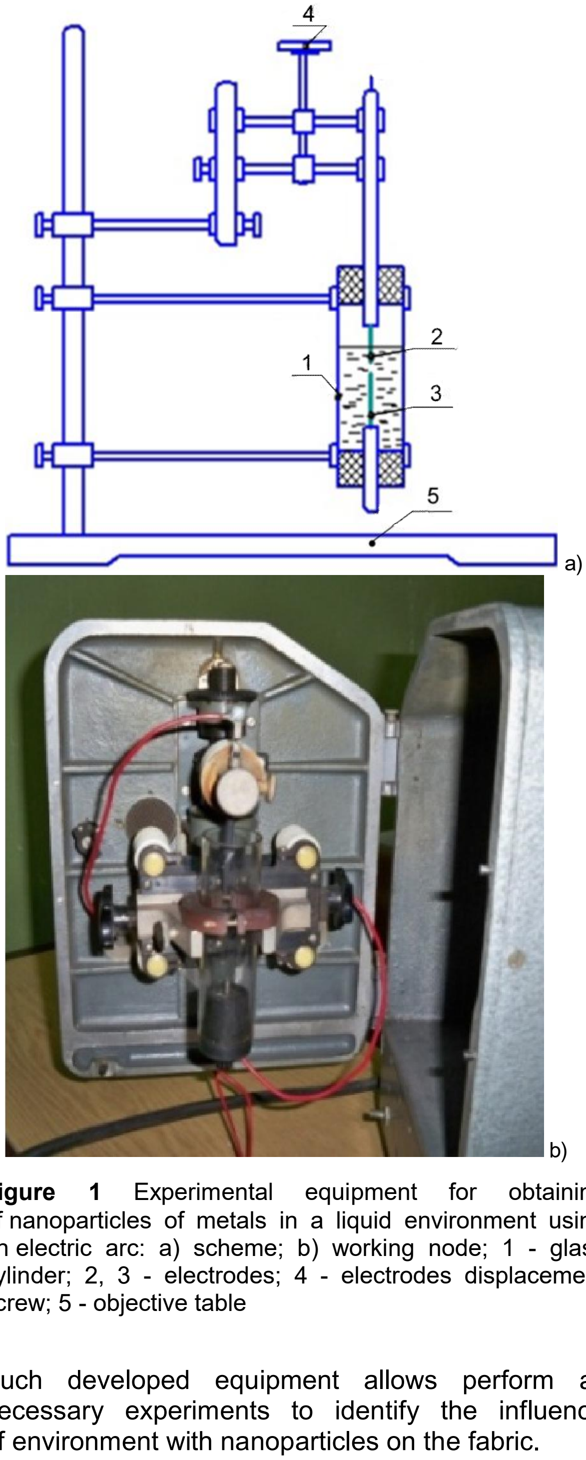


Figure 1 Experimental equipment for obtaining of nanoparticles of metals in a liquid environment using an electric arc: a) scheme; b) working node; 1 - glass cylinder; 2, 3 - electrodes; 4 - electrodes displacement screw; 5 - objective table

Such developed equipment allows perform all necessary experiments to identify the influence of environment with nanoparticles on the fabric.

2.2 Methodology

Nano systems were prepared by an electric arc method of dispersing metals in the form of lysols (dispersion environment – water, alcohol).

The peculiarity of lysols is that they can be stable only at fairly low concentrations (up to 1%). Increasing their concentration is accompanied by an intensive process of coagulation of particles.

The nanoparticles of metals were obtained by the method of erosive and explosive dispersion of metal granules by pulses of electric current in deionized water with pulse energies, which exceeds the sublimation energy of the dispersed metal. For this, the metal pellets were placed in a dielectric capacity with electrodes. Pulses of electric current with amplitude of current pulses in the range of 0.8-2 kA were passed through granules. Dispersion of granules took place in deionized water, which has a high specific resistance.

The concentration of nanoparticles in water environment is 10-100 mg/l. At the concentration of nanoparticles of metals less than 10 mg/l, the bactericidal activity of material is weakly expressed. At a concentration of more than 100 mg/l the stability of solution decreases and from it precipitate of nanoparticles of metals falls.

To conduct research from modifying materials and receiving packages, which can absorb the EMF, were used different textile materials, the characteristics of which are given in Table 1.

Table 1 Characteristics of textile materials used for modification and research

Textile material	Textile material characteristics		
	Textile material	Surface density [g/m^2]	Density [g/cm^3]
PET fabric with conductive thread	99% PET; 1.0% carbon thread	114	–
Bleached beard	100% cotton	140	–
Adhesive material "Sharnet"	100% copolymer of ethylene and vinyl acetate	14,0	–
Aerosil AM-300	99.3% silicon dioxide	–	2.36

Note: PET – polyethylene terephthalate

By method [19], were obtained Ag, Cu and Fe nanoparticles in water and alcohol dispersion environment. The main number of particles was small in size up to 200 nm. In the experiment, a water suspension of polyethylene glycol (PEG) and nanoparticles of metals was obtained. After removing a water environment received substance was added directly to the polymer. It is known that the addition of PEG to a fibrous polymer facilitates the formation. Therefore, it is advisable to introduce nanoparticles directly into the PEG. Subsequently, these colloidal solutions were added to the fiber forming polymer, stirred and dried. The technique for the introduction of nanoparticles directly into PEG was developed. The disperse system (PEG-water) was chosen. The metal was dispersed in a solution of PEG which, after removal of the dispersion environment, was added to the fiber forming polymer. PEG was placed in a porcelain device and heated to a temperature above 100°C, but not more than 130°C. Then, with a special device, in the received PEG substance was added water dispersion of metal, but in small portions.

3 RESULTS AND DISCUSSION

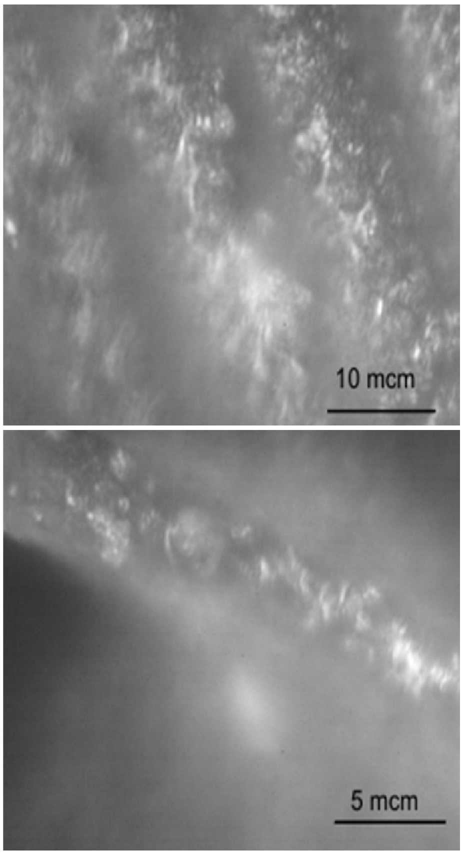
A series of studies on the modification of textile materials by copper nanoparticles was carried out to verify the effectiveness of proposed solutions. Copper sulphate was dissolved in glucose solution at a temperature of 30-50°C. The textile sample was soaked in this solution at constant stirring. To maintain pH 8-9, sodium hydroxide was added gradually (after 10, 20 and 30 minutes). As a result, copper nanoparticles were formed in the porous structure of the textile material and on its surface. Modification of the textile material was carried out directly in the reaction environment [20].

All operations of the process of copper sulphate reduction with glucose, with the formation of nano powder of copper, were carried out in air at atmospheric pressure.

Before making the modification of the textile material the apreat and surface-active substances were removed (washing at a temperature of 50-60°C, concentration of non-ionic detergent 2-3 g/l). Modification of textile materials by nano-dispersed copper particles was carried out in solution of pentavalent copper sulphate and glucose at a molar ratio of glucose to five-water copper sulphate (1.0-2.5)-1.0. Copper sulphate (17.0-42.5 g) was dissolved in a 10-40% solution of glucose at a temperature of 50-60°C. Into the prepared solution immerses dusted water samples of textile material (bath module 1:10). Gradually, the temperature of the reaction mixture was raised to 70°C. The samples were kept in isothermal conditions for 20-30 minutes. In the reaction mixture with samples of textile material 0.25-5.00 g of sodium hydroxide was added in several techniques. As a result of the reaction, the environment was heated to a temperature of 75-90°C and a monovalent copper oxide was formed. During the reaction, the pH of the environment was constantly decreasing, therefore, at some time intervals, several more portions of sodium hydroxide were added additionally to 0.25-5.00 g to maintain the pH of the solution, preferably 8-9.

Copper nanoparticles of 30-45 nm in size were obtained. The reaction ended after 60-70 minutes, depending on the concentration of reagents and pH of the environment. Copper nanoparticles were formed on surface and in the structure of textile material. Textile samples were dried in air.

The samples of unmodified and nanomodified fibrous materials: cotton fabric impregnated with silver iodide salt colloidal solution (Figure 2a) and polypropylene non-woven fabric modified by silver nanoparticles (Figure 2b), were selected for research



a)
b)

Figure 2 Optical image of fibrous materials bleached and modified by Cu: a) fabric; b) non-woven fiber

Modified research samples were obtained. 24.3 g of 5-water copper sulphate was dissolved in 100 ml of a 30% solution of glucose (in air at atmospheric pressure) at a temperature of 60°C (molar ratio of $C_6H_{12}O_6$:$CuSO_4 \cdot 5H_2O$ = 1.75). In this solution, specimens of textile material pre-moistened in distilled water were immersed and the temperature increased to 70±2°C. The samples were kept at this temperature for up to 30 minutes and then the first portion of 2.5 g of sodium hydroxide was injected.

As a result of the reaction, the mixture was heated to 90°C. In the process of reaction, the pH of reaction environment decreases, so every three 15-minute intervals, three servings of 2.5 g of sodium hydroxide were injected. The reaction time was 60-70 minutes.

As a result, monovalent copper oxide was formed, which with the addition of the next three portions of sodium hydroxide was reduced to copper. At the end of the reaction, samples of textile materials were washed and dried in air without spin in the strained state.

Optical microscopy shows that the impregnation of textile materials in the solution of metal salts with the subsequent restoration of metal ions ensures the formation of nanoparticles of metals in the structure of the textile material and on its surface. Thus, a new method for modifying the nanoparticle of metals by impregnation in a salt solution with the subsequent restoration of metal ions in the structure and on the surface of the textile material was proposed and investigated. The equipment of complex man protection from artificial non-ionizing EMR was developed. Such equipment is characterized by spraying nanoparticles of metal on the fabric, which ensures their further impregnation. As a disadvantage, it can be noted that such equipment is experimental nature. So, it is necessary to improve the construction of equipment in further research. This will ensure high-quality research with greater accuracy.

It should also be noted that the study was conducted only with copper particles, which limits the scope of research. Therefore, it is important to conduct further research on the developed equipment using the developed method for a significant number of nanoparticles of various metals. Application of nanoparticles of various metals will allow to establish the most effective material for complex man protection from ionizing radiation.

4 CONCLUSION

The analytical researches from the definition of influence of artificial non-ionizing EMR on the man were conducted. The main factors influencing on this process were determined.

The method of obtaining nanoparticles of metals directly in the structure of textile materials by impregnating them with solutions of metal salts was developed.

The experimental equipment for obtaining nanoparticles of metals by the method of their sputtering by means of an electric arc in a liquid environment was developed

Experimental researches with the modification of textile materials by nanoparticles of metals were carried out. The mechanism of influence of copper nanoparticles on the structure of fabric was determined.

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OPTIMIZING SEWING SPEED FOR BETTER SEAM QUALITY OF DENIM FABRIC

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Abstract: *Sewing process is the most common task in any garments manufacturing company. The worker usually gets paid according to number of items made, which causes the demand to run the sewing machines at highest speeds. In this research it is determined if this high speed effect the seam strength and what should be optimum speed considering denim fabric with commonly used polyester core spun thread. The results shows that the seam strength is significantly decreases with increase of sewing speed and the acceptable quality with better production can be achieved if the sewing speed is 40 Hz.*

Keywords: *Sewing, needle, temperature, clothing*

1 INTRODUCTION

A sewing machine is one of the most common machine of any clothing, automobile, footwear or home textile products. Saint in 1790 is considered as the inventor of first working sewing machine [1]. Lockstitch sewing machines due to strong stitch and easy use are the major sewing machines used in any clothing industry. Lockstitch is a stitch performed in most household and industrial sewing machines (single needle) [2]. The upper thread runs from a spool, through guides and finally passes through the needle eye. The lower thread in the bobbin assembly located under [3]. Ideally, the stitch is made in the middle of the fabric layers considering the tension of the upper and lower thread are adjusted properly [4].

1.1 Basic thermal mechanism of needle heating

The actual sewing needle heating is rather a complicated process. Needle temperature rises as the sewing starts and continues to rise till the steady state is attained. During the complete process, the needle temperature varies minor at the needle penetration and withdrawal from fabric [5-7].

The heat is generated from the following sources:

Heat flux is dependent on needle penetration force, withdrawing and frictional forces acting on needle by the fabric. Heat flow from the friction between sewing thread and needle eye. It is dependent on type of sewing thread and thermal conductivity of thread, needle and friction coefficient between yarn and needle can influence the needle temperature. The sewing needle heating thermal heating mechanism is shown in Figure 1.

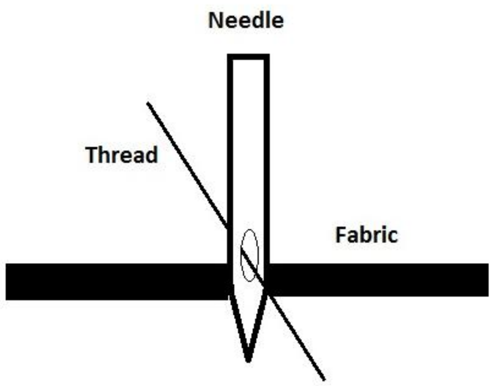

Figure 1 Illustrative image of sewing needle and thread

On the other hand, the heat leaves the needle by [1]:

- Convection of the outer surface of the needle to the environment. Heat loss by convection is considered as the major source in cooling the needle. The convective heat flow equation can be expressed by Newton's law of cooling
- The heat conduction in the needle from higher point to lower temperature points, also the heat loss to the needle holder. The conductive heat flow can be expressed by Fourier's law.
- The heat of conduction from the needle to sewing thread and fabric, the needle and textile materials have great difference of thermal conductivity but still at the time of machine stoppage the ultimate contact with needle-thread and needle–fabric causes local heating and damages the textile material.

Conductivity factor λ [W/(m.°C)] cab be expressed by following equation:

$$\lambda = Q.L/A.t.(T_1\text{-}T_2) \quad (1)$$

where Q is heat flow, L is textile material thickness, t is time interval and T_1-T_2 is temperature difference.

Radiation heat between the needle outer surface and the environment. According to the researchers [5] the radiation play minor role in needle cooling, due to thin size and very low emissivity [4]. The equation can be expressed by the Stefan-Boltzmann law as:

$$P = \varepsilon.\sigma.A.(T^4\text{-}T_s^4) \quad (2)$$

where P is radiated power, ε is emissivity of material, A is radiation area, σ=5.67*10^{-8} W/m^2·K^4, T is temperature of radiator [°C] and T_s is temperature of surrounding [°C].

1.2 *Experimental techniques of measurement*

There are multiple efforts in the past to experimentally observe the sewing needle heating. The experimental techniques to measure sewing needle temperature can be classifies as we can see in Figure 2.

2 METHODOLOGY

It is known from previous research [8-12] that the inserted thermocouple method gives precise and repeatable results; same method is used in this research work.

2.1 *Inserted thermocouple method*

In this method for measuring sewing needle temperature, a thermocouple by Omega (K type 5SC-TT-(K)-36-(36)) was inserted into the groove of the sewing needle and soldered. The thermocouple was located near the eye of the needle to measure the exact needle temperature and the temperature was measured at different sewing speeds. This method proved to be very efficient as it provided continuous changes in needle temperature every second and it had a low standard deviation. Figure 3 shows the placement of the thermocouple inside the needle groove. The thermocouple remained inside the needle groove during the sewing process and measurements were recorded wirelessly on a computer through a wireless end device (MWTC-D-K-868).

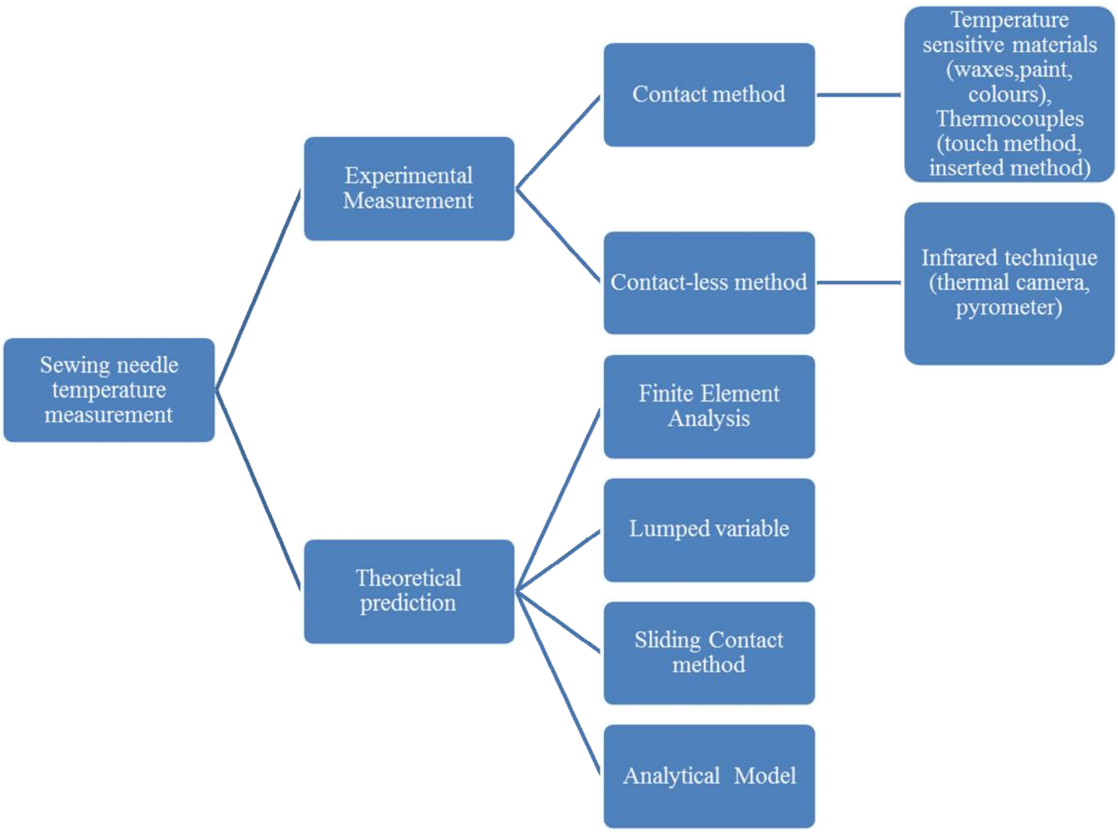

Figure 2 Experimental and theoretical methods to measure needle temperature

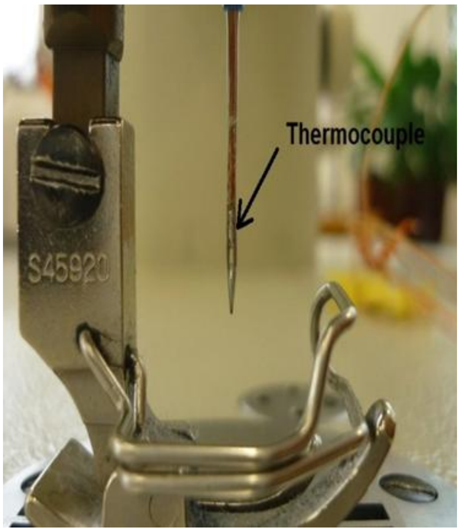

Figure 3 Thermocouple inserted inside needle groove

Conditions for all experiments were kept constant at 26°C and 65% RH. The devices used for the experiments are listed below:

- Lockstitch machine (Brother Company, DD7100-905).
- Thermocouple by Omega (K type 5SC-TT-(K)-36-(36)) for the inserted method.
- Thermocouple by Omega (TJ36-CAIN-010U-6) for the touch method.
- Needles (Groz-Becker 100/16) R- type.
- Relevant parameters of the sewing thread are shown in Table 1.
- Relevant parameters of the denim fabric are shown in Table 2.

Table 1 Sewing thread used for the experiments

Thread type	Company name	Fineness [tex]	Twist [t/m]	Twist direction (ply/single)	Coefficient of friction μ
Polyester–polyester core spun	AMANN-Saba C-80	20x2	660	Z/S	0.13

Table 2 Fabric used for the experiments

Fabric type	Weave	Weight	Ends/cm	Picks/cm	Fabric thickness
100%cotton denim	2/1 Twill	257 g/m^2	25	20	0.035 cm

3 RESULTS AND DISCUSSION

In our research the machine speed of 16-80 Hz is tested for polyester core spun thread and it is concluded that the needle temperature rises linearly with the increase of sewing speed. The higher the speed, the more heat goes to the needle during the unit time, hence resulting in an early high peak temperature. The more heat is taken by the needle within unit time, the faster it reaches it stability temperature because the heat absorption rate decreases when the machine speed is going higher. The important reason for this needle temperature rise is also due to the higher thermal conductivity of the needle as compared to the textile material and more friction heat goes in to the needle during each cycle with higher sewing speed.

It is seen in Figure 4 that the sewing speed has linear relation with the needle temperature and it is visible the breaking strength of the thread decreases linearly with higher sewing speeds.

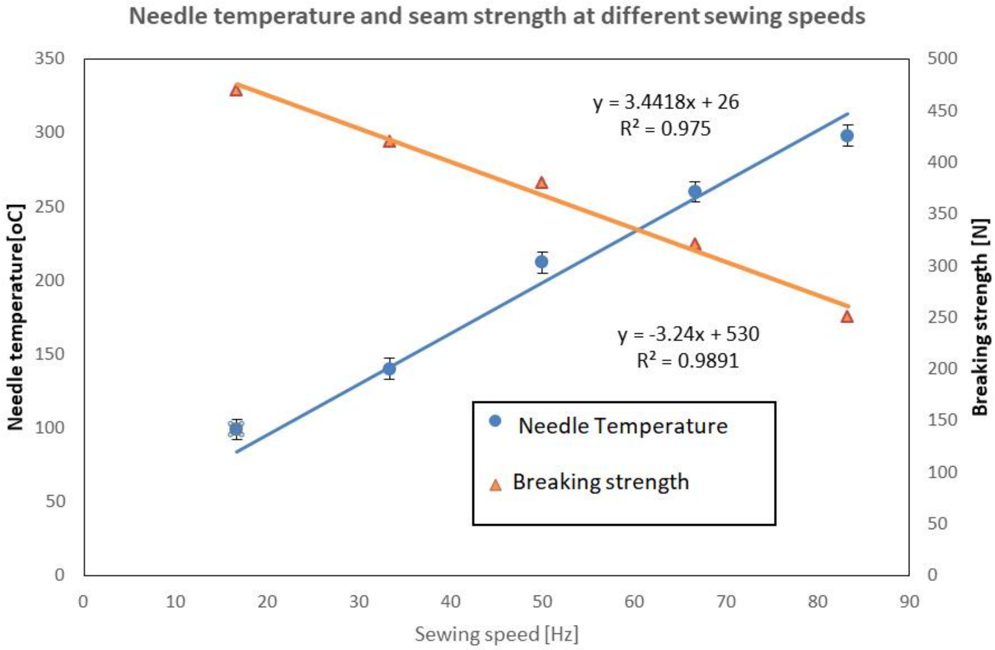

Figure 4 Effect of sewing speed on breaking strength

3.1 Effect of fabric thickness

In this research work, it is observed that the fabric thickness plays an important role in the needle heating, with the thinner fabrics or low number of layers the peak temperature is decreased greatly. With each new layer of fabric the temperature is increased by nearly 10°C. One reason is obvious that there will be low friction generated by thin fabrics. The other reasons are that the needle takes in much more friction heat in the same time period and makes bigger temperature difference for different fabric thickness. This allows the operator to do the sewing for longer time for thin or low number of layers of fabric as the peak temperature is less and temperature stability is reached much earlier as compared to heavy or multi-layered fabrics. The Figure 5 shows a marginal increase in temperature with addition of every extra layer at different speeds of sewing.

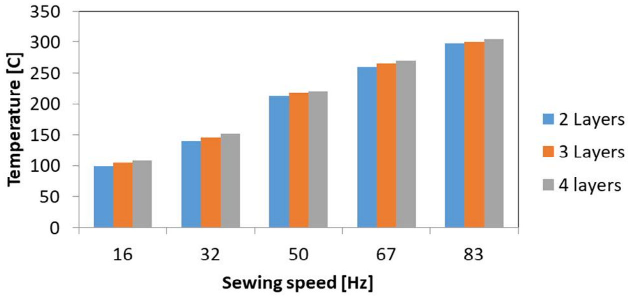

Figure 5 Effect of fabric layers on sewing needle temperature

4 CONCLUSION

This research shows that needle temperature has a dominant influence on the strength of sewing thread. Seam thread was considered as the thread with the weakest tensile properties as compared to the parent thread, the research shows that the hot needle mainly damages the thread. As thread moves from cone to the seam, it undergoes various stresses; there is a marginal decrease in tensile strength for thread at 16-15 Hz of machine, whereas loss of tensile strength of thread is much significant from 40 Hz of machine and higher. The seam loses 60% of its actual strength when sewing speed is low (nearly 16 Hz) as compared to high sewing speed (nearly 80 Hz). There are multiple solutions how to decrease the sewing needle temperature but the focus of this research is to show the impact of high speed sewing on the seam strength of the denim fabric. It is recommended to use the sewing machine at lower speed to have better sewing thread's strength.

Acknowledgement: *This project was funded by the Deanship of Scientific Research (DSR) at King Abdulaziz University, Jeddah, under grant no. G-400-253-39.The authors, therefore, acknowledge with thanks DSR for technical and financial support.*

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INNOVATIVE METHODOLOGY AND SOFTWARE FOR QUALITY CONTROL OF NEW BAST RAW MATERIAL WITH OILSEED FLAX

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Abstract: *The scientific novelty of this work is to create an innovative approach to the assessment of oilseed flax straw and retted straw, on the basis of which technical specifications are declared; nomenclatures of quality characteristics of straw and retted straw as industrial raw materials and their limit values are defined, the software to improve and accelerate the process of determining the quality of new raw materials was developed. This stems from the fact that nowadays oilseed flax is a technical agricultural crop that can play a strategically important role in the formation of the domestic market of bast raw material as well as of ready-made competitive ecological products. This is a very important issue for Ukraine, as most state enterprises operate on imported raw materials, a high price of which reduces the competitiveness of finished goods in the domestic and world markets.*

Keywords: *oilseed flax, straw, retted straw, quality, computer system, methodology, technical specifications.*

1 INTRODUCTION

So far, in today's conditions of the development of advanced technologies, the directions of application of bast raw materials have increased significantly and in its list, in practice, such unconventional crop as oilseed flax has been introduced. Economically developed countries such as Canada, the USA, Germany, Sweden, Italy and France have been using this flax group for over 11 years, not just for seeds. Fibers derived from stems of oilseed flax now occupy a niche of bast raw material of the "new generation" for the production of a wide range of products of various industrial uses [1].

Oilseed flax, provided it is in sufficient amount in our country [2], acts as the main source of natural raw materials for various industries in the conditions of their full raw material import dependence. Therefore, processing of oilseed flax stems at the enterprises of Ukraine and the production of innovative products on the basis of the use of natural raw materials of high quality is a step towards the future.

The scientists of Kherson National Technical University (further - KNTU) developed resource-saving technologies for complex processing of oilseed flax stems [3]. Under these technologies, in laboratory and production conditions, the samples of innovative products of various functional uses were created: filter paper [4], blended yarn [5], cellulose-containing semi-finished products, composite products and non-woven materials of such types as flax batting, upholstery cloth and nonwoven cloth [6]. These products have a great economic importance, but there are other obstacles in organizing the industrial complex for processing oilseed flax stems in Ukraine. This is due to the lack of targeted regulatory documents for the assessment of products from oilseed flax stems. After all, industrial processing of raw materials, the manufacture of innovative products, as well as their implementation in the domestic and world markets are impossible without the basics of standardization, certification and the use of its methods and means [7].

2 LITERATURE REVIEW

All over the world, the latest technologies and equipment for the complex processing of oilseed flax stems for the manufacture of innovative products are being developed and implemented. At the same time, the system for assessing the quality of straw, retted straw and oilseed flax stems has significant drawbacks. It stems from the fact that the enterprises of Canada, the USA, Germany, Sweden, Italy, France and Poland are assessing oilseed flax straw and retted straw by organoleptic methods, which are carried out by certified highly skilled specialists and the fibers are assessed according to the current regulatory documents for determining the quality of long-stalked flax, cotton and other textile fibers of natural or chemical origin [8-13]. In Russia, Belarus and Ukraine, the determination of some qualitative indicators of straw, retted straw and oilseed flax fiber is carried out according to the existing regulatory documents for long-stalked flax: GOST 28285-89, GOST 24383-89, DSTU 4149:2003, GOST 9394-76, DSTU 5015:2008, TU 17 U 00306710.079 – 2000, TU.U. 05495816.005 – 2000 [3, 5-7].

As a result of systematized experimental research carried out by the scientists of KNTU it is proved that straw, retted straw and oilseed flax fibers present fundamentally new bast raw material since they differ significantly by morphological, anatomical, chemical composition and technological properties from the features of long-stalked flax [3, 6]. Therefore, it is incorrect to use the aforementioned regulatory documents for assessing the quality of products from oilseed flax stems.

Thus, based on the foregoing, the topical issue of today is the creation of a targeted methodology for determining the quality level of new bast raw material from oilseed flax: straw, retted straw and fibers. The results of the scientific work should be declared in regulatory documents and approved at the state level.

3 RESEARCH METHODOLOGY

In the course of detailed analysis of the world and domestic experience of industrial use, scientific research, as well as the principles for assessing the products of oilseed flax stems, a nomenclature of all the quality characteristics of straw and retted straw has been determined and their range from a minimum to a maximum value has been generalized [8-14]. The summary of results is shown in Tables 1 and 2.

The obtained results of scientific research are an important theoretical basis when creating a new methodology for assessing the quality of straw, retted straw and oilseed flax fibers, taking into account all modern requirements of consumers.

Subsequently, it was necessary to determine which indicators (Tables 1 and 2) affect the quality level of raw materials and predict the feasibility of its primary processing. Therefore, in order to solve the tasks set, the existing methods of qualimetry are analyzed, which are now widely used to determine the general level of quality of a certain product [15, 16].

In our case, standardization objects - straw, retted straw and fiber from oilseed flax stems are ambiguous, because they can act as raw materials and products and also do not have basic (standardized) values. Thus, in order to determine the importance of the characteristics of the quality of oilseed flax straw and retted straw, it is expedient to use an expert method with the mathematical and statistical processing of the expert estimates obtained.

Table1 Quality characteristics of oilseed flax straw and their limit values

№ of position	Quality characteristics of straw	Limit values
1.	Moisture content [%]	technological 6.0-8.0
		standardized 19.0
		actual: in rolls - not < 20.0 in bales - not < 25.0
2.	Bast yield from stems [%]	11.0-40.0
3.	Impurity [%]	5.0-20.0
4.	Straw color group	I, II, III
5.	Technical part in total length [%]	60.0-90.0
6.	Technical length [cm]	15.0-78.0
7.	Total length [cm]	up to 90.0
8.	Diameter [mm]	1.0-4.1

Table 2 Quality characteristics of oilseed flax retted straw and their limit values

№ of position	Quality characteristics of retted straw	Limit values
1.	Moisture content [%]	technological 6.0-8.0
		standardized 19.0
		actual: in rolls - not < 20.0 in bales - not < 25.0
2.	Fiber yield [%]	11.0-40.0
3.	Degree of retted straw maturation (separation, unit/intensity of reflected light flux, lux)	- mature (4.1 and more/less than 23) - immature (from 3.1 to 4.0/23-27) - straw (3.0 and less/more than 27)
4.	Fiber color index (retted straw color group)	1.0-4.0 (I, II, III, IV)
5.	Impurity of retted straw [%]	5.0-20.0
6.	Technical part in total length [%]	60.0-90.0
7.	Technical length [cm]	15.0-78.0
8.	Total length [cm]	up to 90.0
9.	Diameter [mm]	1.0-4.1

The procedure for straw and retted straw assessment was carried out by experts using the elements of the mixed method [15, 17]. For the processing of expert estimates, the method of ranking was used, after that the sum of ranks *Ri* was calculated. The results of the experiment are shown in Tables 3 and 4.

Table 3 Matrix ranking of technological characteristics of oilseed flax straw

№ of position	Quality characteristics of straw	Ranked estimate of quality indicator								R_i
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
1.	Bast yield from stems	8	8	8	8	8	8	8	8	64
2.	Impurity	4	5	5	3	5	6	6	5	39
3.	Straw color group	6	7	7	5	7	7	7	7	53
4.	Moisture content	5	6	6	4	6	5	5	6	43
5.	Technical part in total length	1	4	3	6	2	2	4	2	24
6.	Technical length	3	2	4	7	3	3	2	3	27
7.	Total length	2	3	2	1	4	4	3	4	23
8.	Diameter	7	1	1	2	1	1	1	1	15
Sum of ranked estimate of each j-expert Σm_{ij}		36	36	36	36	36	36	36	36	-
Total sum of ranks ΣR_i		-								288
Average sum of ranks T		36								
Control sum of ranks Σx_{ij}		36								

Table 4 Matrix ranking of technological characteristics of oilseed flax retted straw

№ of position	Quality characteristics of retted straw	Ranked estimate of quality indicator								R_i
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
1.	Fiber yield	7	9	8	9	8	8	9	9	67
2.	Impurity	4	6	5	3	5	6	7	5	41
3.	Fiber color group	8	5	7	5	7	5	6	7	50
4.	Separability	9	8	9	8	9	9	8	8	68
5.	Moisture content	5	7	4	4	6	7	5	6	44
6.	Technical part in total length	6	4	3	7	4	4	3	2	33
7.	Technical length	3	3	6	6	2	3	4	3	30
8.	Total length	1	2	2	1	3	2	1	4	16
9.	Diameter	2	1	1	2	1	1	2	1	11
Sum of ranked estimate of each j-expert Σm_{ij}		45	45	45	45	45	45	45	45	-
Total sum of ranks ΣR_i		-								360
Average sum of ranks T		40								
Control sum of ranks Σx_{ij}		45								

The sum of ranks of each quality indicator R_i was calculated by the following formula:

$$R_i = \sum_{j=1}^{n} m_{ij} \quad (1)$$

where: m_{ij} - rank of i-quality indicator, set by j-expert; n - number of experts.

The verification of the correctness of the matrix compilation was performed on the basis of the calculation of the control sum $\sum x_{ij}$ (2) and the average sum of ranks T (3):

$$\sum x_{ij} = \frac{(1+m)\cdot m}{2} \quad (2)$$

where: m - number of expert assessment objects (indicators).

$$T = \frac{\sum R_i}{m} \quad (3)$$

The sums in the columns of the matrix are equal to each other and the control sum of ranks, and therefore, the matrix is composed correctly [15].

The high relevance and reliability of the received expert estimates (ranks) is confirmed by the mathematical and statistical method (Tables 5 and 6) according to which the degree of coincidence of experts' estimates, expressed by the coefficient of concordance K_u (4), the total sum of the squares of deviations S (5) and the square of deviations for each parameter Δ_i^2 (6) were determined:

$$K_u = \frac{12\cdot S}{n^2(m^3-m)} \quad (4)$$

$$S = \sum_{i=1}^{m} \Delta_i^2 \quad (5)$$

$$\Delta_i = R_i - T \quad (6)$$

where: S is the sum of the squares of deviations of the sum of the ranks of each object of examination from the average sum of the ranks.

Further work with expert estimates is only feasible if the coefficient of concordation is greater than or equal to 0.4 [15]. In our case, the coefficient of concordation K_u of the characteristics of the quality of oilseed flax straw is 0.731 and that of retted straw is 0.832, which indicates the presence of a high degree of consistency of expert opinions and allows assessing the agreement of experts' decisions as “satisfactory". Subsequently, on the basis of the expert estimates obtained, according to the scale of relative significance, the weight coefficients q_i were determined for each characteristic of the quality of straw and retted straw, according to the following formula:

$$q_i = \frac{R_i}{\sum R_i} \quad (7)$$

Table 5 Mathematical and statistical processing of the results of the ranking of technological characteristics of the oilseed flax straw

№ of position	Quality characteristics of straw	Mathematical processing of data		
		Ri	Δ_i	Δ_i^2
1.	Bast yield from stems	64	28	784
2.	Impurity	39	3	9
3.	Straw color group	53	17	289
4.	Moisture content	43	7	49
5.	Technical part in total length	24	-12	144
6.	Technical length	27	-9	81
7.	Total length	23	-13	196
8.	Diameter	15	-21	441
Total		288	-	-
Total sum of the squares of deviations *S*		-	-	1966
Coefficient of concordance K_u		0.731		

Table 6 Mathematical and statistical processing of the results of the ranking of technological characteristics of the oilseed flax retted straw

№ of position	Quality characteristics of retted straw	Mathematical processing of data		
		Ri	Δ_i	Δ_i^2
1.	Fiber yield	67	27	729
2.	Impurity	41	1	1
3.	Fiber color group	50	10	100
4.	Separability	68	28	784
5.	Moisture content	44	4	16
6.	Technical part in total length	33	-7	49
7.	Technical length	30	-10	100
8.	Total length	16	-24	576
9.	Diameter	11	-29	841
Total		360	-	-
Total sum of the squares of deviations *S*		-	-	3196
Coefficient of concordance K_u		0.832		

Then, to the ordinal scale conduct a direct measurement of the weight coefficients, the sum of which must be equal to one. This will allow to distinguish from all *m* indicators the most significant indicators for which the condition $q_i > 1/m$ is fulfilled. Since $\Sigma\ qi = 1$, then the weight coefficients of meaningful indicators must be calculated according to the formula:

$$q_{i0} = q_i^* / \sum_{i=1}^{m} q_i^* \quad (8)$$

Determination of weight coefficients makes it possible to select significant qualitative characteristics of oilseed flax straw and retted straw stems, which in aggregate testify to the expediency of their primary processing. According to the research results, scales of relative importance of the characteristics of oilseed flax straw and retted straw were created, which are presented in Figures 1 and 2 in accordance.

Experts estimated the weight of each indicator according to the scale of relative significance. The total of all properties was taken as 1. Therefore, the most weighting coefficients will be those that are as close as possible to one.

Analyzing all the calculations obtained by the expert method, it can be claimed that the most important quality characteristics are those with the highest weight coefficients. That is, for straw they are bast yield stems, impurity, the group of straw color and moisture content, and for retted straw they include fiber content, the degree of retted straw maturity, fiber color indicator and its impurity. It is these characteristics that indicate the general level of quality of straw and retted straw as industrial raw materials.

A summary quality assessment is proposed to name "the number of oilseed flax straw" and "the number of oilseed flax retted straw". Since the quality level, that is the number of straw and retted straw, depends on the values of certain characteristics of quality, they were distributed to different degrees. As a result, for the first time, it is proposed to determine the number of oilseed flax straw and retted straw by five levels of quality: 5, 4, 3, 2, 1. For example, straw (retted straw) No. 5 is characterized by the best values of quality indicators, and straw (retted straw) No. 1 by the worst ones. A detailed analysis of the world and domestic works of scientific and practical nature (Tables 1 and 2) shows that the bast yield from stems and the fiber yield from the retted straw of this group of flax can vary in the range from 11 to 40%, the impurity of straw and retted straw from 5 to 20% and the color indicator of the retted straw fiber from 1.0 to 4.0. Therefore, for a more accurate evaluation of the quality of straw and retted straw, it was suggested to calculate the relative values W_i, of the above-mentioned characteristics in scores by differential method [7]. Relative values were calculated by the following formulas:

$$W_i = \frac{P_i}{P_{iv}} \cdot 100 \quad (9)$$

$$W_i = \frac{P_{iv}}{P_i} \cdot 100 \quad (10)$$

where: P_i - the value of the single quality indicator being evaluated; P_{iv} – the value of the best quality indicator from the available single indicators being evaluated; *i = 1, 2,...,* *n* - number of single quality indicators.

The formula (9) is used to assess the performance, an increase in the numerical value of which indicates an improvement in quality.

The formula (10) is used for comparison of indicators, reducing the numerical value which ensures the improvement of product quality. The differential evaluation reflects the linear relationship between the analyzed properties.

To determine the number of oilseed flax straw and retted straw for the first time, tables with fixed ranges of score values have been developed that correspond to a certain level of quality of raw materials, that is, the number.

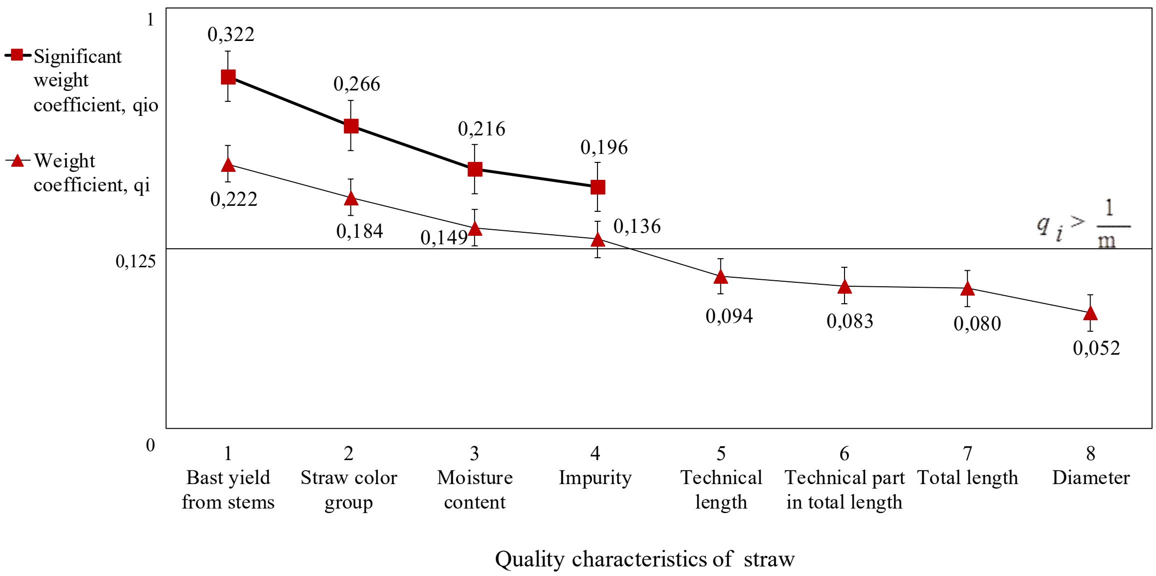

Figure 1 Scales of the ordinal for determining the significant of weight coefficients of the quality of oilseed flax straw

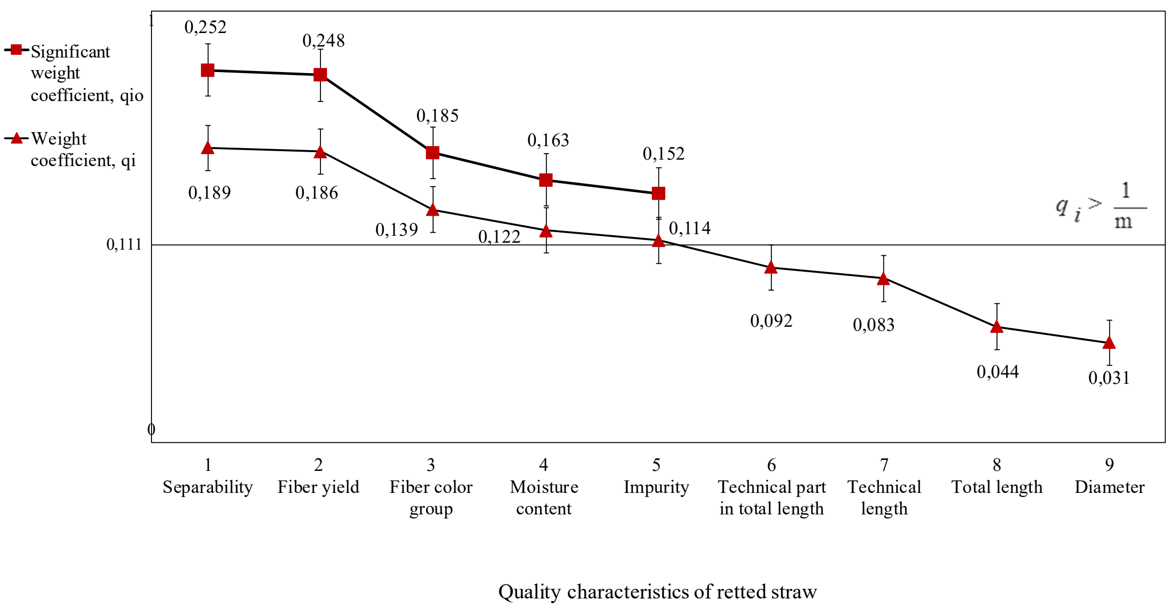

Figure 2 Scales of the ordinal for determining the significant of weight coefficients of the quality of oilseed flax retted straw

The result of the theoretical and experimental research was the development and approval of the technical specifications of TU U 01.1-2303511525 - 001: 2016 "Oilseed flax straw" at the State Enterprise "Kherson standart matrologia. Technical specifications" (Figure 3A) and TU U 01.1-05480298-001: 2017 "Oilseed flax retted straw, Technical specifications" (Figure 3C). In this case, the technical specifications are accompanied by the software “CQ Soilseed Flax” (Figure 3B) and “CQ Roilseed Flax” (Figure 3D) for straw and retted straw respectively.

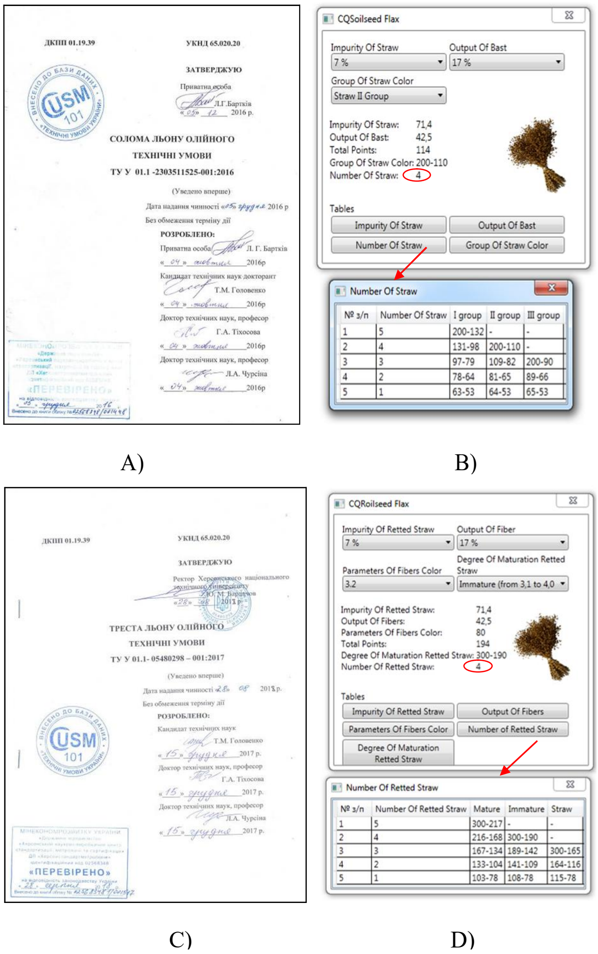

Figure 3 Technical specifications and the interface of the software for determining the quality of straw (A, B) and retted straw (C, D) of oilseed flax

These normative documents regulate the quality of oilseed flax straw and retted straw I and the expediency of their primary processing and industrial application. The use of automated systems can facilitate and accelerate the process of assessing raw materials at its entry to industrial production.

Software developed by KNTU scientists in a convenient standard interactive graphical interface that facilitates its mastering and can be used by consumers of any level of computer literacy.

The program is designed for one user and does not involve simultaneous operation of many users.

The software operation requires a personal computer running MS Windows XP SP3 and above. Computer systems are written in a high-level C# programming language using the Microsoft Visual Studio 2010 development environment.

This software calculates the number of oilseed flax straw and retted straw. For all input data there are tables that correspond to the indispensable characteristics of quality and their values obtained by the instrumental calculation. Input data are set through the drop down list, which makes it easier to work with the program.

Thus, when receiving oilseed flax straw or retted straw at an industrial plant, the moisture content and the number of raw materials will be taken into account. To determine the number of oilseed flax straw, the relative values of straw impurity and bast yield from stems are summarized. By the resulting score, which is rounded to an integer, taking into account the color group, according to the table given on the interface B in Figure 3, the number of oilseed flax straw is determined. To determine the number of oilseed flax retted straw, the relative values of retted straw impurity, fiber content and fiber color indicator are summarized. Based on the score rounded to an integer, taking into account the level of the maturity of retted straw, according to the table given on the interface D of Figure 3, the number of oilseed flax retted straw is determined.

4 RESULTS

A necessary condition for the effective functioning of the mechanism of self-regulation of a market economy is competition. It is an important driving force for the development and success of any enterprise. Increasing the competitiveness of products is possible only under the condition of increasing its quality in comparison with an analogue. To date, flax oil is the only cheap, compared to imported analogues, bast-fiber raw material in Ukraine, the volumes of which can meet the needs of domestic enterprises for the production of cellulose-paper, technical, textile products and composite goods.

In order to organize the processing complex of oilseed flax stems and with the aim of the certification of products obtained on their basis, a methodology for assessing the straw and retted straw of this group of flax was developed. This methodology became the basis for the technical specifications, which are approved at the state level. These normative documents regulate the quality of oilseed flax straw and retted straw and their general level of quality is a number indicating the expediency of industrial processing and the functional purpose of the obtained products;

give an opportunity to create new markets of cheap certified raw materials in Ukraine; they allow agricultural producers correctly determine the cost of straw and retted straw when it is sold to industrial facilities, increasing profits from growing this crop as a whole; rationally and economically consume raw materials of a certain quality and determine the functional purpose of potential products.

In order to automate the quality assessment of the new bast raw material, software was developed that improves and accelerates the processing of data obtained by instrumental methods.

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TANNIN TREATMENT OF SHEEP WOOL

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Abstract: *The aim of this study was to test the possibility of treating raw sheep wool with tannic acid. This treatment improves the odor of sweat wool and gives the wool antibacterial properties. The tests also suggest the possibility of anti-felt treatment. To achieve these aims, tannic acid was used as strong antioxidant. The sensory evaluation of raw wet sheep wool smell before and after tannin treatment was provided by a group of 30 assessors. This subjective assessment was supplemented by an indicative measurement of volatiles using gas chromatography. Antibacterial properties of tannic acid were evaluated by the method when eluates of treated and untreated wool were cultivated on the agar medium. The antibacterial effect of tannin has been manifested in growth of different number of bacterial colonies. Finally, electron microscope images showing some damage to wool fiber surface indicated the possibility of anti-felt treatment by using tannic acid. All results suggest that tannic acid could be an effective and ecological means of raw sheep wool treatment for use in the building or automotive industry.*

Keywords: *wool, tannic acid, odor, volatiles, antibacterial*

1 INTRODUCTION

Historically, sheep farming in Czech Republic was a widespread agricultural activity, especially in the mountain and foothills of Bohemia and Moravia. However, the socialist past of the country and its centralized economy and planning have meant that sheep farming has almost disappeared [1]. At present, many private breeders are returning to sheep breeding. The reason is mostly the desire to return to nature and to rediscover old traditions. Modern farmers use sheep mainly for milk and meat, but due to the overall reduction of the textile industry in the Czech Republic, there is no interest in sheep wool. The wool industry has been almost completely liquidated and private sheep farmers rarely process this raw material for textile purposes [2].

Central European sheep wool is not as fine and good as fine Merino wool from New Zealand, for example. However, it is a raw material that can be used very well in building and automotive industry, for applications such as sound and heat insulation. Wool fibers absorb moisture well. It can absorb almost one-third of its own weight in water [3, 4]. Wool ignites at a higher temperature than cotton and some synthetic fibers. It has a lower rate of flame spread, a lower rate of heat release, a lower heat of combustion and does not melt. It forms a char which is insulating and self-extinguishing and it contributes less to toxic gases and smoke than other flooring products when used in carpets.

Wool has a high specific heat coefficient, so it impedes heat transfer in general [5]. In addition, wool also absorbs sound like many other textile fibers [6].

However, the basic problem that limits the use of wool as an insulating material is its odor. The odor of wool is caused by both the fatty matter covering the raw wool fiber and the fiber composition itself. The building material of the wool is the fibrous protein keratin which is the source of sulfur-containing amino acids and numerous disulphide bridges. Fats and sulphur-containing compounds are the main source of volatile organic compounds that contribute to the raw wool odor in heat and moisture [7].

1.1 Tannins

Plant tannins are water-soluble polymeric polyphenolic compounds found in a variety of plant parts such as wood, tree bark, fruit peels, pods, leaves, roots and plant balls. Through their phenolic and carboxyl groups they form complexes with various substances - mainly proteins (protein coagulation on which the skin tanning process is based), amino acids and alkaloids. Tannins also form complexes with metal ions, polysaccharides and fats. Their typical representative is tannic acid (Figure 1), which is used, for example, in textile dyeing as a staining agent for the dyeing of cellulosic and other fibers. Phenolic groups of tannins can form effective bonds with different types of fibers and dyes to help fix dyes. In these reactions, the tannin is first drawn into the fiber or adhered to the surface of the fiber and the subsequent application of metal salts (Fe, Cr, Cu, Al, Pb or Sn ions) leads to the formation of complexes which fix the tannin to the dyed material. Subsequently, the applied dye is tied to the fiber more firmly and with higher affinity [8].

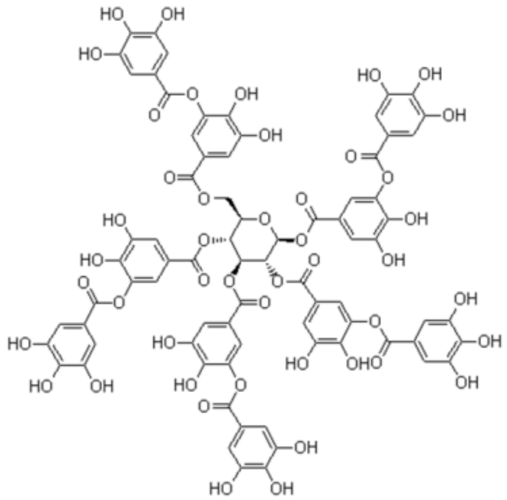

Figure 1 Acid gallic (gallotannin)

Tannins - gallotannins and condensed tannins (so-called proanthocyanidins and catechins, Figure 2) can bind to the fiber substrate by several mechanisms:

1. the ionic bond between the deprotonated phenol group and the protonated amino groups of the protein fibers (wool, silk) and polyamide,
2. the numerous hydrogen bridges that occur between pseudovacant hydrogen orbits of phenol groups (if not dissociated) with free electron pairs of oxygen or nitrogen in the fiber structure,
3. the covalent bonds that may arise between quinone and semichinone groups present in tannin and suitable reactive groups of fibers.

When tannins react with proteins (or amino acids), the crosslinking effect is also applied. E.g. when collagen is crosslinked with plant polyphenols (catechin or tannic acid), the hydroxyl group of amino acids hydroxyproline and serine, the aspartic acid carboxyl group, the amino group of lysine and the asparagine amide group are the potential site of interaction of polyphenols with collagen. The literature describes well-known tannin reactions not only with collagen but also with albumin and other proteins. E.g. the amino acid proline is also present in the sheep's wool, where it accounts for about 6.5% of all amino acids in keratin, so tannins with wool and other protein fibers can be expected to interact [9-11].

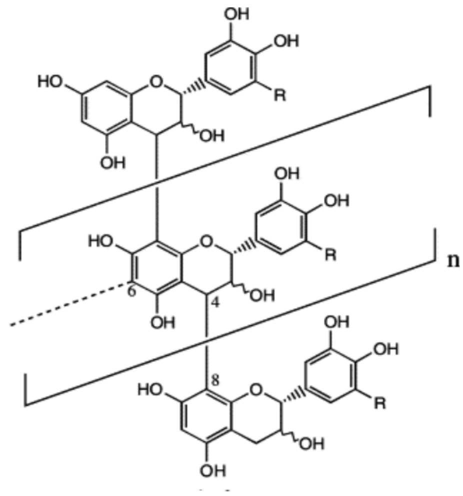

Figure 2 Condensed tannin (catechin)

Generally, plant tannins, catechins, proanthocyanidins and polyphenols have a strong affinity for proteins (and thus also for animal fibers made up of keratin - wool, rabbit hair, etc.). Protein coagulation, amino acid crosslinking, polyphenol binding to protein, change in protein configuration and thus change in functionality until inactivation or destruction (in general: protein denaturation) are the consequences of these reactions. All this is just a question of choosing the appropriate type, concentration and method of applying tannin or other polyphenol [12].

1.2 Antioxidant effect of tannins

Tannins, like polyphenols, are powerful antioxidants (reductants) having the ability to reduce other substances and oxidize themselves. They also can eliminate free radicals and ROS (reactive oxygen species). According to the antioxidant mechanism, antioxidants are divided into primary ones that reduce the activity of ROS by reacting the free electron and themselves to become a less dangerous and more stable radical and to secondary (reductants) that oxidize themselves and reduce the other substance. They are often oxidized by a dehydrogenation mechanism to form a carbonyl group. The antioxidant activity of polyphenols is a complex process that combines different mechanisms. The complexity of this process is evidenced by the fact that since 1955 about 700 articles have been published suggesting different in vivo and in vitro anti-oxidation mechanisms of polyphenols! The ability of polyphenols (PPh) to eliminate free radicals proceeds simplistically according to the equation (1) where the phenol group of polyphenols reacts with a strongly reactive radical which is “quenched” and polyphenol itself changes into a radical.

$$PPhOH + R\bullet \rightarrow PPhO\bullet + R \qquad (1)$$

Figure 3 shows a double mechanism (dehydrogenation and radical) of a flavonoid or polyphenol reaction with hydroxyl groups at ortho positions. In fact, the result of these interactions is the oxidation of polyphenols to various complex quinoid and semiquinoid structures, depending on the pH and redox potential of these compounds [13, 14].

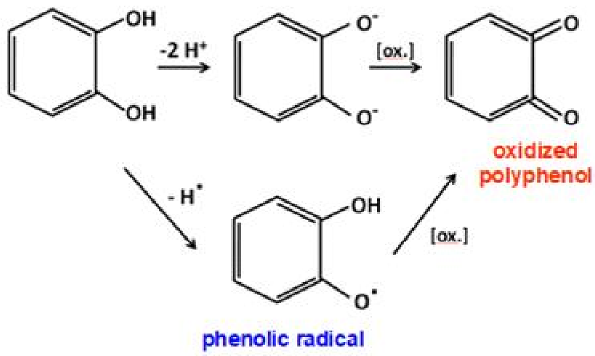

Figure 3 Double mechanism of polyphenol oxidation

1.3 Antibacterial effect of tannins

Tannic acid and gallic acid are very strongly bound to proteins and enzymes by hydrogen bonds, which is also one of the possible mechanisms of their action against microorganisms. This effect was observed when testing tannic acid, gallic acid and catechins for highly resistant MRSA (methicillin-resistant *Staphylococcus aureus*). One of the virulent factors of gold staphylococci, distinguishing it from other staphylococci, is the formation of so-called free or bacterial wall-bound plasma coagulase, which makes *S. aureus* capable of producing fibrin from plasma fibrinogen. The result is a protective sleeve (fibrin biofilm) around the bacteria itself or an infection deposit that severely impedes both the penetration of antibiotics and the penetration of macrophages [15].

S. aureus most often causes skin furuncles, skin and tissue abscesses and localized soft tissue infections, as well as osteomyelitis, mastitis, necrotizing pneumonia, endocarditis, toxic shock syndrome and sepsis. It turns out that the ability of tannins to form complexes with proteins is used here, because the tannic acid inactivates this protective shell of the bacterium, making it accessible to the bacterium to contact the antibiotic [16].

Iron and other trace elements are essential for the metabolism of aerobic microbes and therefore another mechanism of antibacterial action of polyphenols is explained by chelation of iron from the environment (in vivo from blood plasma), which makes this important micronutrient rendered inaccessible to bacteria.

The antibacterial effect of polyphenols is a complex of several mechanisms - protein binding and inactivation, chelation of metal ions, direct biochemical pathways affecting in cells including the inhibition of some enzymes and the induction of apoptotic effects in bacteria. Thus, chelating, antioxidant and sometimes pro-oxidative effects with antibiotic effects are combined as with synthetic and polysynthetic antibiotics. Their effectiveness is also conditioned by a lot of other factors such as the resistance of a bacterial strain, the concentration and availability of the antibiotic at the site of action, etc. [17, 18].

1.4 Evaluation of odor

Several methods can be used to evaluate the odor. Volatile substances can be separated, identified and quantified by means of a separating column and inert gaseous media (gas chromatography) using a suitable detector (a flame ionization detector - FID), an analyzer identifier unit (mass spectrometer - MS) and calibration standards. At the research workplaces, the so-called electronic nose is also developed, which is a complex of sensors that identify individual chemical volatile substances. The most important evaluator, however, remains the human nose, because even if an exact analysis of the volatile content of the sample is carried out, nothing or very little tells about how that scent is perceived by humans, because the odor is a very subjective perception.

Human olfactory cells function as chemoreceptors responsive to the volatile substances contained in the flowing air passing through them, respectively, around the olfactory epithelium in the nasal cavity, where numerous protuberances of these olfactory cells are present in the mucosa. The excitement generated by their chemical irritation is led to the olfactory center of the frontal lobes and to other parts of the brain (thalamus, hypothalamus). Then there will be a resulting impression influenced by past experiences and experiences associated with certain odors. For example, human smell is not sensible in comparison to some animals. However, an untrained person is able to recognize about 4 to 10 thousand odors, trained professional up to 10 times more.

Women also generally have a better sense of smell, which is related to their maternal role. However, it is shown that the sensitivity of human smell changes considerably throughout life. The biggest olfactory perception has children around the 6^{th} year of life and then it still falls olfactory sensitivity.

The 20-year-old human has 82% olfactory receptors with which he was born, at the age of 60 he drops to 38% and at age 80 to 28% of the original amount. The young people around 20-23 years of age have the best sense of smell, because they still have a high olfactory sensitivity, which is supplemented by a sufficient amount of information and experience. [19]

2 EXPERIMENTAL PART

2.1 Material and chemicals

Raw unwashed wool sheared from sheep, tannic acid (Lach-Ner, Czech), trypto-casein soya agar (TSA) (Biovendor, Czech) and natural spring water (without chlorine treatments) sterilized for 10 minutes by boiling, were used in this work.

2.2 Methods and devices

Solution of tannic acid at the concentration of 10 g/l was prepared. The raw sheep wool (4 g each sample) was dosed into hermetically sealed glasses marked A, B, C. 100 ml of tannic acid solution was added to glass A, 100 ml of spring water was added to B and C glasses. The glasses were hermetically sealed. Samples A and B were boiled for 5 minutes in a water bath. Subsequently, the samples were allowed to cool for 1 hour in this water bath. Throughout this time, cold water was left in vessel C. Samples B and C served as comparative samples. Sample B was prepared to distinguish the influence of boiling water from the tannin effect to odor decomposition. Sample C, which was left without boiling, was a comparative sample in which only cold water influenced the wool. All three glasses were shaken regularly throughout the period of wool contact with the fluid. After the samples A and B were cooled, the liquid from all three glasses was removed and the wobble wool was wrung out. The glasses with wet wool were hermetically sealed again. Thus, samples of the treated and untreated wool for olfactory (sensory) test, for quantitative bacterial test, for gas chromatography and electron microscope images (SEM) were prepared.

The sensory evaluation of the wool odor was done in the form of an olfactory test of randomly selected respondents who had the task of subjectively assessing the odor of the A, B and C samples and sorting them according to the intensity of odor from at least to the most odorous sample. Considering that women have a more sensitive sense of smell and because the sense of smell is getting worse in human life, 15 women and 15 men aged between 16 and 65 were interviewed to cover the widest possible age group. Samples A and C were also prepared for gas chromatography analysis. The vials were preheated to 45°C and a small volume of wet air from each vial was sampled directly through the rubber septum from the sample vessels into a gas chromatograph column with a mass spectrometer (GC-MS).

For the quantitative evaluation of the bacteria content in the samples, 1 g of material was removed from each wet wool fibers, 40 ml of sterilized natural water of 20°C was added and the samples were shaken vigorously for 2 minutes. The resulting eluates were each 1 ml dosed on the agar surface of the Petri dishes. Cultivation at 37°C took 24 hours. This procedure was performed on samples which were treated the same day and repeated after 5 days when still wet samples were left in hermetically sealed glasses at room temperature. After 24 hours of cultivation, colonies (CFUs) were counted in each Petri dish.

3 RESULTS AND DISCUSSION

3.1 Sensory evaluation of wool odor

Three samples in glass sealed containers (A, B. C) were presented to the respondents for snooze and to sort by intensity of odor from the least smelly to the most odorous. Sample A = wool treated with tannic acid at boiling, sample B = wool treated only with boiling water, sample C = untreated wool, washed only with cold water. Fifteen women aged 16 to 65 and fifteen men aged 17 to 62 were interviewed (Figure 4). The interviewees were selected randomly, but there were also 4 people (1 man and 3 women) who had or recently have had a valid certificate for sensory analysis and can be considered the professional assessors.

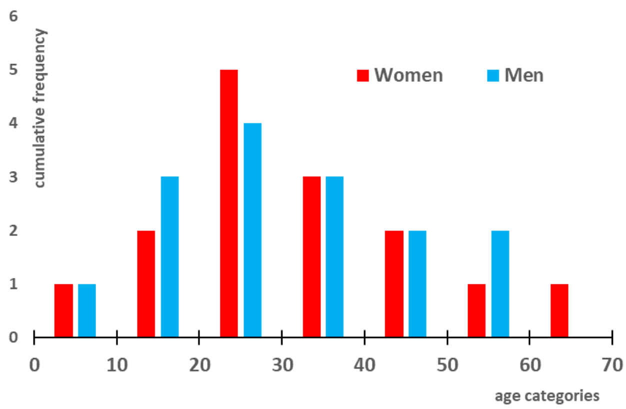

Figure 4 Age representation of evaluators

Twelve women and fourteen men (including four professional sensory evaluators) ranked samples in the same order A, B, C. One man and one woman evaluated the order of samples B, A, C, two other evaluators with different results ranked as A, C, B. In the sensory analysis, 87% of respondents (93% of women and 93% of men) identified a tannin-treated sample as the sample with the smallest odor intensity and the same percentage of women and men identified the sample of wet untreated wool as the worst smell. Subsequent questioning revealed that both respondents who placed a tannin-treated sample on the second or even third place in the order did so because the smell of the tannin-treated sample was not pleasant for them, not because they compared the samples with the increasing intensity of the odor. While the wet tannin-treated wool aroma resembled most of the respondents "the smell of wool after washing in washing machine", these two differently evaluating respondents described this odor as a "resembling varnish" or "lemon-like". The majority, however, said the odor of the wool had the lowest intensity and its aroma was not unpleasant.

3.2 Quantitative bacterial evaluation of wool samples

The number of bacterial colonies that grew on agar from 1 ml of eluate of one- and five-days old samples A, B and C after 24 hours is shown in Figure 5 and Table 1. It is evident that most of the bacteria contained an untreated raw wool eluate in both measurements, where the number of colonies was so high that they were uncountable. A sample of wool that had undergone heat treatment (5 minutes boiling in water) contained a noticeably lower number of bacteria. The eluate contained 825 CFU/ml, but after 5 days in wet and at room temperature, the bacteria on this fiber substrate significantly increased and 1 ml of the eluate contained almost two orders more of bacteria, which was at the limit of CFU counting on the agar surface. The tannin heat treated sample was initially almost sterile (4 CFU in 1 ml of eluate), after 5 days in a sealed container in wet and at room temperature, 212 CFU from 1 ml of eluate grew on the agar plate. The difference in the number of bacteria also corresponded to the odor of the samples: while sample A did not change the odor, sample B in the closed glass subjectively smelled more than the first day just after the heat treatment.

Table 1 Number of CFU in 1 ml of aqueous extract of wool

	sample A	sample B	sample C
1 day	4	825	uncountable
5 days	212	cca 10^4	uncountable

3.3 Gas chromatography

Analysis of gaseous substances in the samples A and C was performed using gas chromatography. The analysis was only indicative without the use of calibration standards. Identification of some volatiles was performed by a mass spectrometer using a software library to identify chemical substances. The presence of, for example, acetone, 3-methylpentane, heptanaldehyde, 2-ethylhexanol, methylheptyl acetate and others has been observed from sulfur and nitrogen-free volatile substances (Figure 6).

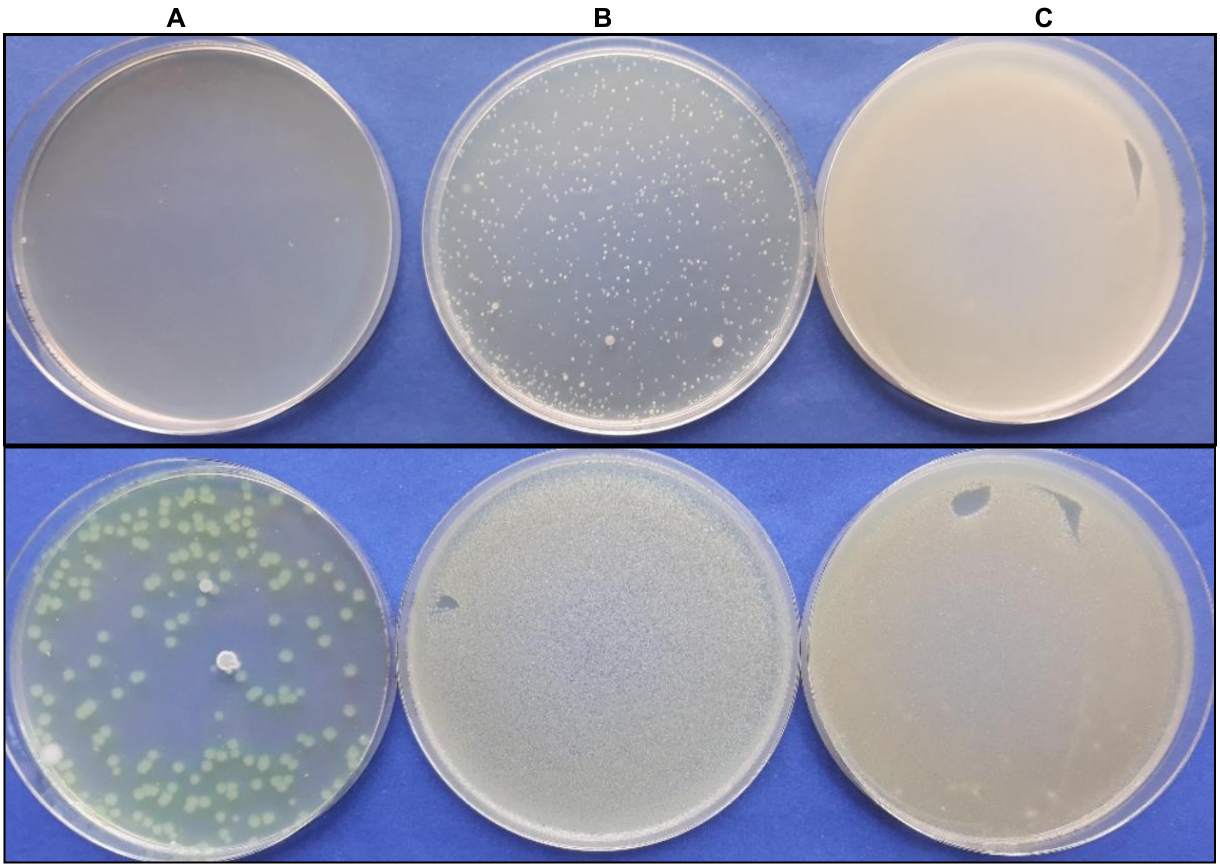

Figure 5 CFUs grown from wool eluates after 24 hours of cultivation from samples 1 day (top) and 5 days old (below)

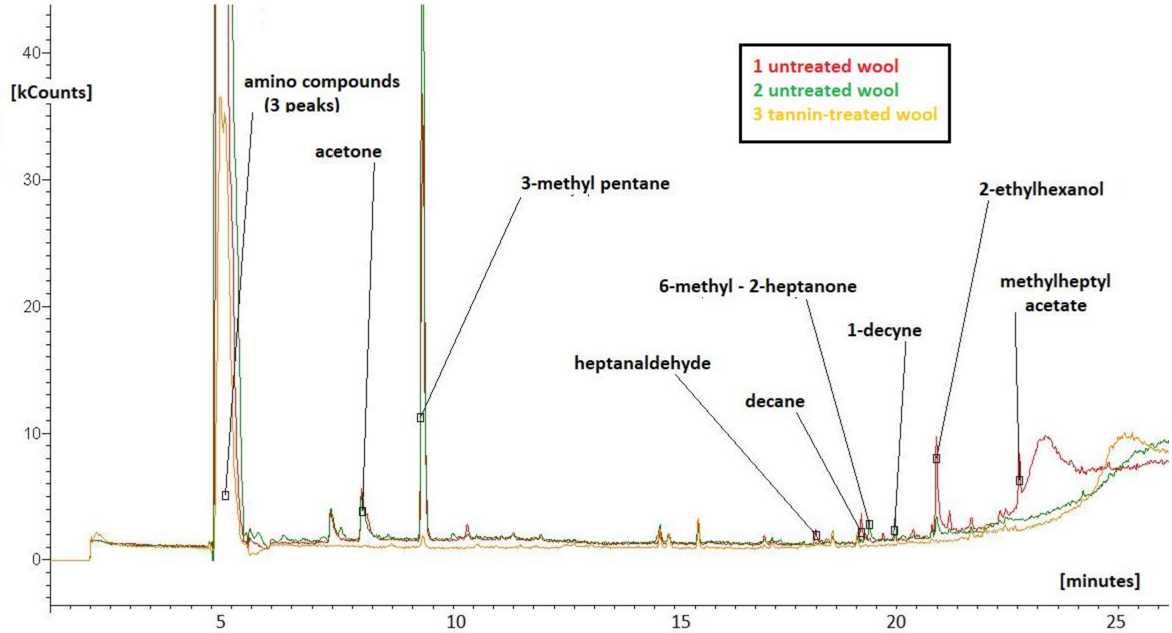

Figure 6 Some volatiles released from tannin-treated and untreated sheep wool (GC-MS)

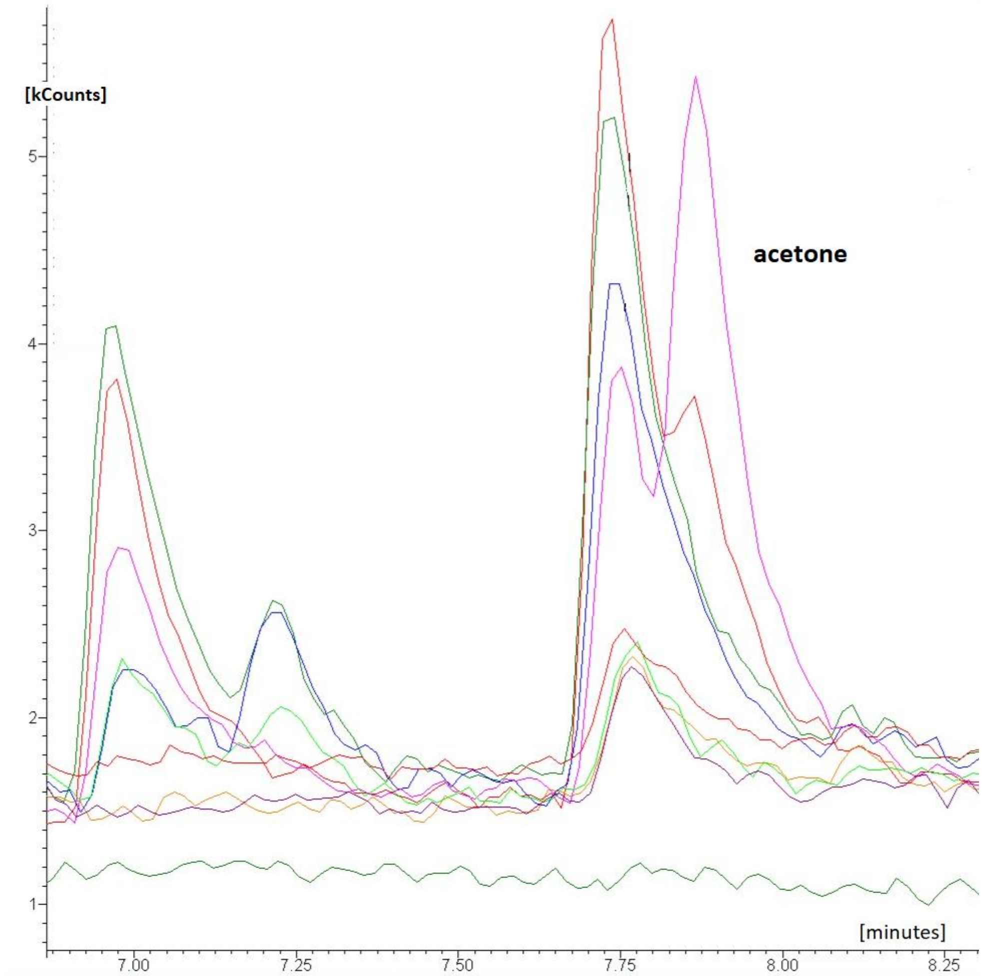

Figure 7 Zoomed peaks corresponding to acetone (GC-MS)

The chromatogram contains several peaks. The highest being identified as indeterminate volatiles containing amino groups, and 3-methyl pentane and 2-ethyl hexanol. Unfortunately, volatiles in the first half of the chromatogram were not reliably identified. The record shows that the most volatile small molecules with shorter retention times such as hydrogen sulphide (H_2S), carbon disulphide (CS_2), ethanol, sulphur dioxide (SO_2) or carbonyl sulphide (COS) are beyond the sensitivity of this chromatographic column, which is primarily determined and calibrated to analyze soil contaminated by higher hydrocarbons. However, it is clear from the record that the air sample from the tannin-treated wool follows the untreated wool peaks with noticeably lower values. Figure 7 shows an increased peak from a retention time of 7.7 minutes, identified as acetone. It is a composite record of 4 tannin-treated and 4 untreated wool samples, and it is clear to see the difference in the values of these two groups of samples because all four tannin-treated samples are near the baseline.

3.4 SEM images

The cause of the felting of animal fibers is their structure. Animal fiber has tiny scales on the surface that make the fibers captured, intertwined and interconnected. Fully reinforced fabric (felt) is produced by moisture, heat and chemicals that open the scales. The motion leads to fibers interconnections.

Figure 8 SEM image of untreated wool fibers

However, locally and spontaneously, this phenomenon occurs, for example, by mechanical action, resulting in fuzziness (pilling) that degrades the appearance of the fabric. This can be prevented by a non-felt treatment, which means preventing the scales on the surface of the fibers from catching each other. The scales can be removed from the fiber or masked (polymeric coatings) so that they are firmly glued to the fiber. All or part of them can be removed chemically, physically (singe, cutting) or enzymatically.

Figure 9 shows the wool fiber after heat treatment with a tannin solution having damaged and partially chipped scales. Since tannins denature proteins, i.e. interact with amino acids using the mechanisms described in section 1.1., which leads to the loss of the original function of the protein, the change of its structure and eventually its destruction. We will continue to study this effect.

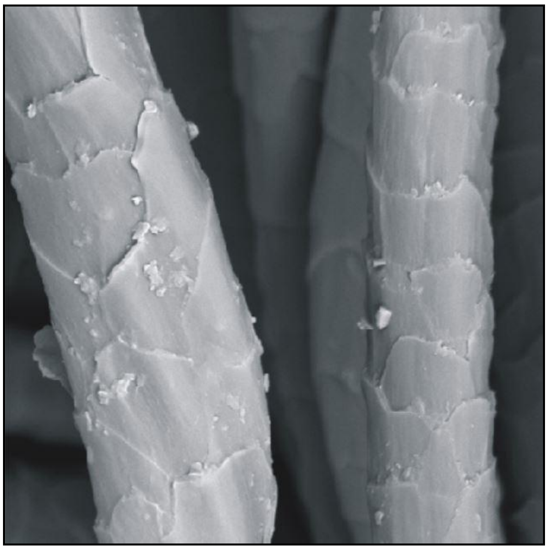

Figure 9 SEM image of tannin-treated wool fibers

4 CONCLUSION

In this work the antioxidant and antimicrobial properties of tannic acid were used in the treatment of raw sheep wool. The heat treatment of fibers using tannin solution not only significantly reduced the unpleasant odor of the raw wool, but also reduced the bacterial growth on fibers surface very significantly. It is evident that the main cause of the unpleasant wool odor are bacteria on the surface of wool fibers that decompose fat, keratin and other organic substances to form volatile substances that are the source of odor. Through a panel of evaluators who carried out a sensory analysis of raw wool odor, we have shown that heat treatment by the tannin solution (tannic acid respective) significantly reduces the intensity of the raw wool odor. At the same time, the treated wool, due to tannin, acquires some antimicrobial resistance, although this treatment did not imply a perfect sterility of the fibrous surface. Since the number of bacteria on the surface of the wool was very low even after 5 days of wet fibers in a sealed container at room temperature, the tannin-treated wool did not have an unpleasant smell unlike wool without heat treatment or wool that was cooked only in water. The lower content of some volatile substances in the tannin-treated wool was recorded even in gas chromatography. Moreover, the electron microscope image of wool fibers treated with tannin at the boiling point suggests that the tannin wool treatment led to some fibers to morphological changes. Surface structure has been disturbed, damaging and breaking the flakes on the surface of the fibers has been observed. This can be used, for example, for an anti-felt treatment of wool.

We have demonstrated that plant tannins can be used as an inexpensive, ecological and effective means of treating raw wool that is not suitable for garment processing but could be used very well, for example, in buildings or automobiles as an insulating material.

***Acknowledgement**: This study is a result of the research funded by the project No. LO1201 with a financial support from the MEYS (Czech Rep.) under the NPU I program. Special thanks to Dr. Pavel Hrabák and all willing respondents from Technical University of Liberec.*

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ABSORBENCY AND WICKING OF WATER ON TERRY WOVEN FABRICS

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Abstract: *This paper reports the concept of absorbency and wicking of water as well as water transfer management for terry woven fabrics. Evaluated terry woven fabrics with the different material composition and structural parameters were used for the manufacturing of towels. The terry woven fabric is designed to take moisture away from the skin and it should be performed in the shortest time. Therefore, the sorption and suction properties were evaluated by measuring the absorbency and wicking. It has been proved that the material composition and basic parameters influence these properties and the high initial absorbency capacity is accompanied by a low starting suction height of the terry woven fabrics.*

Keywords: *absorbency, wicking, terry woven fabrics, permeability, water transfer management*

1 INTRODUCTION

Transferred from the skin to the textile material and further into the surrounding environment, water determines the level of comfort for one woven fabric component. The transfer of water from the skin through the porous woven fabric to the environment is performed in the following ways: convection, conduction (diffusion through a system of pores and capillary), sorption (absorption, diffusion and desorption) and migration (adsorption by surface fibers) [1]. There are various factors determining the permeability of the water by the woven fabric [2].

In order to analyze these properties in terry woven fabrics, it is necessary to evaluate the transfer and sorption properties of this assortment [3]. The transfer properties are determined by capillary wicking. It is influenced by capillary action, pore distribution and surface tension. Absorbency process is a continuation for evaluation and specification of properties which were determined by measuring of the absorption of water by the woven fabric. The measurements were repeated after every washing (max. number of washing procedures = 5 times).

The aim of this experiment was to evaluate the dependence between absorbency and wicking on a selected range of terry woven fabrics which are intended for the production of towels. Changes in these properties can be influenced by the material composition and woven fabric structure. Based on the mentioned fact, the effect of these parameters on the sorption properties was also evaluated in the paper.

2 EXPERIMENTAL PART

2.1 Materials

A terry towels are textile products which have a loop piles on one or both sides. Research process was based on the selection of 9 terry fabrics with the different material composition (Figure 2). Before the measurement process of mentioned properties, it was necessary to make an analysis of the structure of terry fabrics. The area density, mass per unit area, thickness of fabrics and linear density of all sort thread was evaluated [5-7].

The characteristics and parameters of selected investigated terry fabrics are shown in the Table 1.

Measurements of thickness were performed before washing and after the final fifth washing.

Besides one type of weft threads, two systems of warp threads are required for production of terry woven - basic warp and loop warp [4]. Therefore, Figure 1 shows a different fineness of warp, weft and loop weft threads in the terry woven fabrics [7].

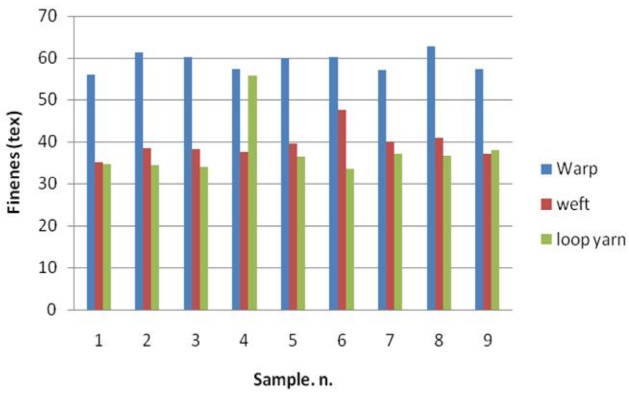

Figure 1 Fineness of thread in the terry woven fabrics

Figure 2 Terry woven fabrics

Table 1 Parameters of terry woven fabrics

Sample No.	Material composition of terry woven fabrics	Mass per unit area ρ_s [g.m^{-2}]	Area density ρ_v [kg.m^{-3}]	Thickness *h* [mm]		Thickness difference *h* [%]
				before washing	after 5 washing	
1	100% cotton	400	180	2.22	2.39	7.65
2	100% cotton	450	202	2.23	2.64	18.39
3	100% cotton	500	209	2.39	2.84	18.33
4	100% cotton	600	187	3.21	3.43	6.85
5	100% microcotton	400	152	2.63	2.86	8.75
6	70% cotton 30% tencel	450	219	2.05	2.57	25.37
7	60% cotton 40% regenerated cellulose	450	219	2.05	2.53	23.41
8	55% cotton 45% regenerated cellulose	450	208	2.16	2.68	24.07
9	50% cotton 50% regenerated celulose	450	175	2.56	3.09	20.70

2.2 Methods

The research process involved the measurements of absorbency and wicking in relation the terry woven fabrics. These properties were measured before washing and after the 1st, 2nd, 3rd, 4th, 5th terry washing of fabrics.

2.2.1 Measurement of absorbency

Standard method is based on the weighing of sample before and after water absorbency.

The testing procedure was used for a determination of water absorbency under the specified conditions. Air conditioned samples (number 10) with dimensions of 100×100 mm were weighed with an accuracy of 0.1 g.

The samples are fixed on the cradle holder and placed into a container with distilled water at 20±1°C and the water level in container was 50 mm above the top part of the sample (Figure 3). After 60±1 minutes, holder with samples was removed from the water and it was left in a vertical position for 120±3 seconds to drip the excess water [8, 9]. Then, samples were weighed in an accuracy of 0.1%. The result of weight loss for tested samples was calculated with the following formula:

$$N = \frac{m_1 - m_0}{m_0}.100 \qquad (1)$$

where *N* [%] is an absorbency of water, m_1 [g] is weight samples after a water absorbency and m_0 [g] is weight of before samples a water absorbency.

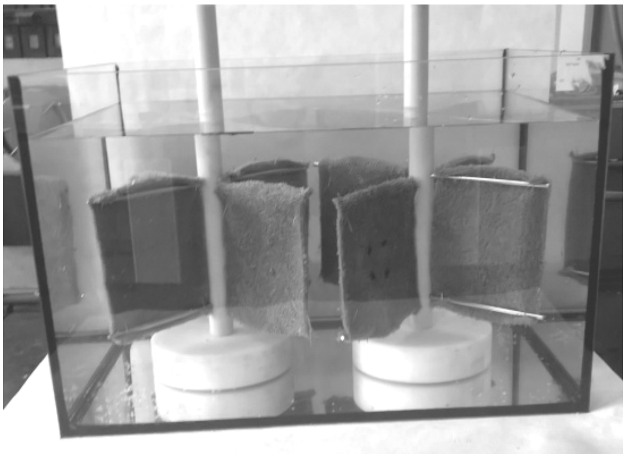

Figure 3 Measurement of absorbency of terry woven fabrics

2.2.2 Measurement of wicking

Wicking is caused by capillary forces inside the terry woven fabrics. The capillary action was measured in such a way that the terry woven fabric strip (6 samples) with predefined dimensions was immersed into the water (Figure 4). The depth of the immersed end of the sample was 2 mm. A suction height was measured by vertical meter at predetermined time intervals. The total testing time was 30 minutes because after that time, there was the occurrence of the steady state. The testing was performed in the direction of the warp and weft [10].

Figure 4 Measurement of wicking of terry woven fabrics

3 RESULTS AND DISCUSSION

3.1 Absorbency of terry woven fabrics

The absorbency of all terry woven fabrics was considerably high. She was calculated from the weight of the samples before and after the test according to formula (1). Figure 5 shows a comparison of the results of measurement of absorbency of the tested materials. The results of measurements were based on the following facts:

- the highest absorbency capacity was observed for samples before washing,
- the absorbency capacity of the samples was stabilized due to repeated washing,
- the highest water absorbency was measured for the sample 5 because of the higher fineness of used fibres (designated as micro cotton) and the lower mass per unit area,
- made of 100% cotton, terry fabrics had better absorbency properties than those which contained any other component together with cotton.

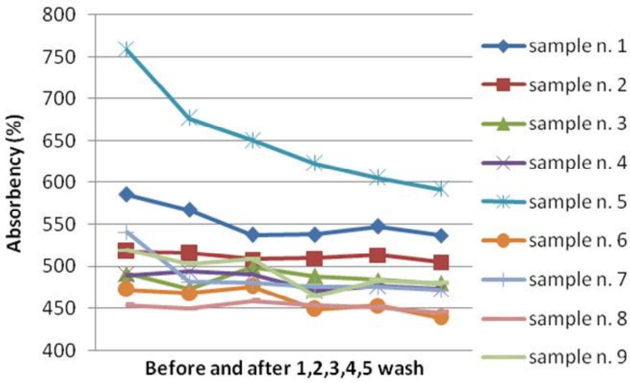

Figure 5 Measurement of terry woven fabrics absorbency

3.2 Wicking of terry woven fabrics

Figures 6 and 7 show a comparison of the results for wicking measurement in the direction of warp and weft [10]. The results of measurements were:

- the similar wicking in the warp direction than in the weft direction was measured,
- the wicking value has been stabilized after a repeated washing,
- the highest wicking was measured for samples designated as 1 and 2, which were manufactured of 100% cotton.
- a different behaviour during wicking was observed only sample designated as 3.

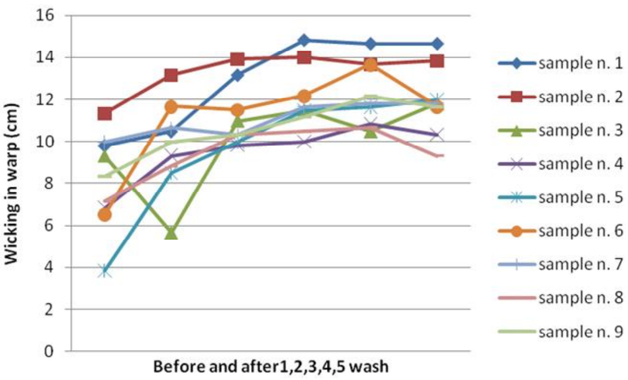

Figure 6 Wicking of terry woven fabrics in direction of warp

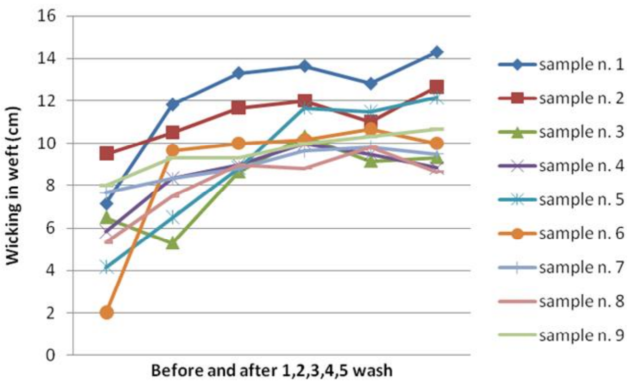

Figure 7 Wicking of terry woven fabrics in direction of weft

The results of wicking and absorbency after the last washing procedure were compared by correlation analysis. In relation to the monitoring of the properties, the rate of correlation dependence is negligible. However, in Figures 5-7 it can be seen that by repeated washing the absorption decreases and the wicking increased (up to the level equalized after the fifth wash).

4 CONCLUSION

The paper presents the results of comparative tests which were performed for terry woven fabrics (terry towels). The reason for performance of these measurements was to specify the most suitable terry towel in relation to the sorption of water in the shortest possible time. Mentioned measurements were made before and after five individual washing procedures. On the basis of the analysis and obtained results for terry fabrics assortments, it can be concluded that:

- the absorbency capacity of terry fabrics was the highest before washing. It subsequent decreased after repeated washing;
- it was confirmed that the best absorbency capacity was exhibited by woven fabric which was made of 100% cotton (sample designated as 1 and 5);
- it was also proven that the fineness of cotton fibres increases the absorbency capacity (sample designated as 5);
- the absorbency of the towel was decreasing and increasing wicking due to repeated washing;
- as the water absorbency is the highest and wicking is lower during all washing processes, it is possible to conclude that:
    - due to absorbency, physical as well as chemical processes occurred in the fibres, causing a change absorbency
    - wicking was increased due to changes in shape (narrowing) of the capillaries during repeated washing.

Generally, it can be assessed that the high initial absorbency capacity of the terry fabric is accompanied by a low starting suction height of the fabric. During a repeated washing, both properties were stabilized. There is a negligible ratio of correlation dependence between absorbency and wicking. Thickness of the terry fabrics was increased due to a repeated washing. In comparison to the terry fabrics containing cotton, this increase in thickness was higher for terry fabrics which contained any other component together with cotton (Table 1). Measurements of selected properties proved that the material composition can affect the evaluated properties. Based on the performed measurement procedures, it can be stated that cotton can be considered as the best material for the production of this assortment. It was repeatedly proven that the assessed properties of textile woven fabrics are influential parameters for moisture [11].

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This paper is a continuation of the sorption properties evaluation of fabrics published in the journal Fibers and Textiles 23(2), 2018, pp. 59-63.

PATTERN DESIGN AND MOTIF PLACEMENT OF BATIK *SANGGIT* IN SHORT-SLEEVE SHIRT STYLE

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Abstract: *The current trend of Indonesian fashion mode indicates a massive process of batik industrialization that drives batik transformation to any modern outfit. Along with this process, the challenge had occurred regarding to how the batik is applied in any modern outfits without sacrificing its aesthetical motif. It means the modern batik outfit requires the harmonious motif junction in every linked bloc of outfit pattern, which is archetypally called as sanggit. This research proposed a model of pattern design and motif placement of batik sanggit in short-sleeve shirt mode. The authors outline the combination between pattern design and motif placement as the essential factor to generate batik sanggit in short-sleeve shirt mode. The key is to place the motif into the blocs of the pattern designs by precisely flipping and mirroring the motif until it reach the harmonious motif junction. The harmonious motif junction could be attained by extending the motif over the measurement of pattern design that provides a space to harmonizing the motif. Thus, the motif would match each other even it is located in different bloc of pattern.*

Keywords: *batik sanggit, short-sleeve shirt, pattern design, motif placement.*

1 INTRODUCTION

Traditionally, batik is produced in form of a long cloth corresponding with its function as the material for a long-dress outfit [1]. The regular measurement of a batik cloth is about 115 cm wide and 250 cm long [2, 3]. Batik cloth is decorated by motifs and ornaments, which those are mostly inspired from cosmological interpretation, such as *pagi-sore*, one-headed, two-headed, oblique, *ceplok*, upright symmetrical and random motif [4]. As a traditional handicraft, the beauty of batik depends on the tacit knowledge of craftsman [5]. Fundamentally, the craftsman must have three basic skills of batik production: dyeing, waxing and coloring [6].

Industrialization has driven batik transformation from traditional to modern outfits. Modern batik outfits require harmonious motif junction in every linked bloc of pattern, which is archetypally called *sanggit*. Consequently, it brought a fundamental change in the practice of batik production. The production of modern batik outfits employs the process of cutting and sewing. This process could cause several problems of motif harmonization [7], such as the fractals problem [8] or the Irregular Strip Packing Problem [9]. These problems become the main challenge for the batik craftsman, especially in the production of batik *sanggit*.

Following Haake's [10] and Lawrence's [11] argumentations, the authors argue that an efforts to generate appropriate formula of motif harmonization should be grounded by a conceptual foundation of pattern design and motif placement. Most of the researches take a computer vision technique to harmonize the batik motifs [12], such as the utilization of computational generative pattern [13], the Interactive Evolutionary Algorithm [14], the Scale Invariant Feature Transform [15], and the Dotted-Board Model and Extended Local Search [16]. Unfortunately, those researches are neglecting the importance of the theoretical and conceptual foundation in motif harmonization. It means the rapid technological utilizations are less followed by a fundamental research on pattern design and motif placement.

In order to filling this gap, this research aims to formulate a model of pattern design and strategy of motif placement as a conceptual foundation to produce batik *sanggit* in short-sleeves shirt style. The designed pattern and motif placement could become a ground for further development of batik production in modern outfits. Thus, this development would give benefits for batik craftsman, especially for small batik industries by giving empowerment to elevate the aesthetic dimension of modern batik as well as satisfying the demand of the consumer.

2 METHODS

Qualitative descriptive [17] and participatory action [18] were used as the research methods. As a research participants were: three motif designers, four batik makers, two batik dyers and one tailor. They work at Dewi Ratih batik industry, Jalidin batik industry and Royal Tailor, which are categorized as the small batik industry in Sragen and Sukoharjo, Central Java, Indonesia. Data resources were determined based on two sampling techniques: purposive and snowball. The data were collected through observation, interviews, focus group discussion and literature review. The flow model was used to analyze the data. Qualitative descriptive was employed to obtain the data about the existing pattern design and motif placement. The authors reviewed the literature and interviewed the batik craftsman regarding the practical aspect of batik production, including the design process, cutting pattern and blocs seaming. The participatory action was applied to develop the draft and acquire the standard measurement of pattern design and motif placement. The motifs were then placed on the designed pattern, screened into a piece of cloth and being processed in a short-sleeve shirt pattern in middle and extra-large size. The draft was analyzed, revised and retested to reach the harmonious motif junction. If the harmonious junction was attained, the draft was then standardized

3 ANALYSIS

3.1 The existing batik pattern and motif placement

From the observations, it could be concluded that the craftsman is using regular measurement of batik cloth and measurement for producing batik in short-sleeve shirt style [19]. The craftsman employs two sets of button pattern for short-sleeve shirt batik: the edge button and the middle button. The edge button provides a space to matching the motif on the edge of the cloth. Moreover, the woven yarn on the edge of the cloth is stronger than in the middle. This button pattern is easy to be applied in the batik writing production. However, the edge button pattern has a weakness if it is applied into screening process in the batik printing production. It is because the edge button pattern only employs 110-centimeter of wide from the batik regular measurement. Thus, 5 cm would be wasted and, consequently, the pattern will cut off in the same width on the left edge of cloth.

Different with the edge button, the middle button has an advantage if it is applied to the 115 cm screen. The cloth is applied based on the right edge line so that the left edge cut off 5 cm. Therefore, the motif could be matched in the middle of the front bloc. However, the middle button has a weakness if it is applied on the dyed technique, particularly to make a straight-line motif.

The common technique to harmonizing motif junction is simply folding the cloth until the motif match precisely. The technique emphasizes the efficiency of cloth usage, but would be hard to be applied in others batik patterns, particularly in symmetrical and random patterns. If the symmetrically patterned clothes are made into blouses or shirts, then the motifs may never become fully *sanggit*. Meanwhile, in the cases of random motif, the motifs will cut off and cannot be *sanggit*.

In sum, the craftsman could only employ in limited motif to make batik in *sanggit* style. It is because the existing motif, which is the regular motif, is not designed in certain purposes of short-sleeve mode. Thus, the pattern design and special motif placement adjusted the short-sleeve pattern should be developed. The motifs should be placed in a particular pattern so that the aesthetic value of batik can be fully obtained.

3.2 The developed pattern design

Based on those existing pattern and motif, the authors then developed a pattern design of short-sleeve shirt in extra-large (XL) and middle (M) size. The developed pattern design consists of 7 blocs which covers the section of half rear body circumference, the length of the shirt, quarter front body circumference, arm circumference, short-sleeve length, collar and pocket. The calculation of the developed pattern design of short-sleeve shirt mode for extra-extra-large (XL) size is explained in the Table 1.

Table 1 The calculation of the developed pattern design in XL size

Blocs	Code-Pattern	Hem	XL Short-sleeve		
			Body	Total	Remains
1	*2*	*3*	*4*	*5=3+4*	*6=2-5*
Half rear body circumference	A-70	4	60	64	6
Length of shirt	A-90	6	82	88	2
Quarter front body circumference	BC-39	2	36	38	1
Arm circumference	DE-70	3	54	57	13
Short-sleeve length	DE-45	6	31	37	8
Collar	F-20x85	6	41	47	38
Pocket	H-20x30	2	12x14	14x16	6x14

The Table 1 shows that in the code-pattern A, the calculated size of half rear body circumference is 70 cm. Meanwhile, the tailor only needs 64 cm so it will remain 6 cm. The length of short-sleeve shirt on in the developed pattern is 90 cm. It is only needed 88 cm so it remains 2 cm. In the Code-Pattern B and C, the size of quarter front body is 39 cm; meanwhile it is only needed 38 cm. Thus, the pattern would remain 1 cm. In the Code-Pattern D and E, the size for arms is 70 cm and it is only need 57 cm for the shirt. Therefore, it will remain 13 cm. The length of short-sleeves is 45 cm, whereas the tailor only needs 37 cm, so it will remain 8 cm. In the Code-Pattern F, the size of collar is 20 cm width and 85 cm long; meanwhile it is only need 47 cm. In the Code-Pattern G, the size of pocket is 20 cm width and 30 cm long; however, it is only needed 14 cm width and 16 cm long, so it will remain 6 cm and 14 cm. The rest of the cloth is used to place the pocket to become *sanggit* with the motifs.

The Figure 1 depicts the illustration of the developed pattern design of short-sleeves shirt mode.

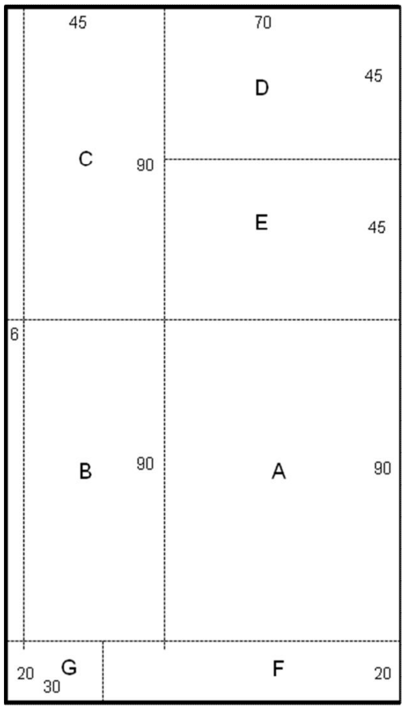

Figure 1 The illustration of developed pattern of short sleeve shirt

Meanwhile, the calculation of the developed pattern in middle (M) size, in some sections of the pattern, is different with the XXL size. The calculation could be seen on the Table 2.

Table 2 The calculation of the developed pattern in M size

Sections	Code-Pattern	Hem	M Short-sleeve		
			Body	Total	Remains
1	*2*	*3*	*4*	*5=3+4*	*6=2-5*
Half rear body circumference	A-70	4	54	58	12
Length of shirt	A-90	6	77	83	7
Quarter front body circumference	BC-39	2	29	31	8
Arm circumference	DE-70	3	48	52	18
Short-sleeve length	DE-45	6	26	32	13
Collar	F-20x85	6	38	44	41
Pocket	H-20x30	2	12x14	14x16	6x14

Table 2 shows that in the Code-Pattern A, the measurement of half rear body circumference is 70 cm. To make a short-sleeve shirt, the tailor only needs 58 cm, so it will remain 12 cm. The length of short-sleeve shirt on the developed pattern is 90 cm; however, it is only needed 83 cm so it remains 7 cm. In the Code-Pattern B and C, the measurement of quarter front body is 39 cm. Meanwhile, it is only needed 31 cm; thus, the pattern would remain 8 cm. In the Code-Pattern D and E, the measurement for arms is 70 cm and it is only need 52 cm. Therefore, it remains 18 cm. The length of short-sleeves is 32 cm from 45 cm of developed pattern, so it remains 13 cm.

3.3 The developed motif placement

The motif is placed based on the developed pattern design by emphasizing on the harmonious motif junction in the blocs. The backside bloc in Code-Pattern A that is 70 cm and 90 cm is created as the main section of motif placements. The main motif is then divided into two equal sections: left side and right side. The life side section is extended 6 cm lengthen of the main motif. This section is then applied on the left chest bloc in the Code-Pattern B (see Figure 2c). The right side section is also extended 6 cm and then reversed and applied on the right chest bloc in Code-Pattern C (see Figure 2d). The short-sleeves bloc, with 70 cm wide and 45 cm long, is taken from a particular part of the main motif, such as from the below part. This section is applied on the right side of short-sleeve sections in Code-Pattern E. Meanwhile the left side section in Code-Pattern D is applied by the reflection on the right side (see Figure 2e). The motif of pocket in Code-Pattern G is taken from the motif of the left chest bloc, which is same with the pocket's positions. The motif of collar in Code-Pattern F is captured from the desired motif, such as from the above section of the main motif (see Figure 2f). The illustration of the developed motif placement can be seen in the Figure 2.

The developed motif placement could generate a batik *sanggit* in short-sleeves shirt mode in any regular size. The motifs in the junction parts, such as in the buttons, the left section, right section, pockets, and collar, can be fully harmonized with each other. The harmonious motif junction could be seen from any angle of the front side, the left side, the right side, and the pocket of the shirt. The motif of the front section can be made similarly or the reversely from the backside motif. If the motif of the backside is different from the front motif, then the motif can be posited upside down from the axis. Meanwhile, the motif in collar section can be made a differently with the main motifs. The result of the developed motif placement could be seen in the Figures 3-6:

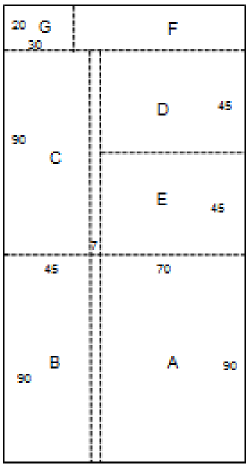

Figure 2a Short sleeve shirt pattern

Figure 2b Examples of batik motif (master) that will be developed in pattern (2a), motifs are placed in part A

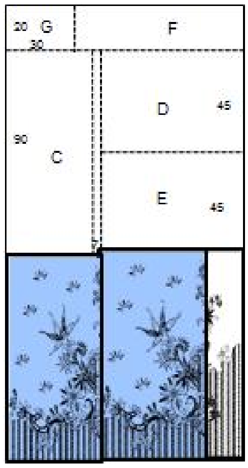

Figure 2c Half of the left master motif is applied on the left chest bloc in the Code-Pattern B

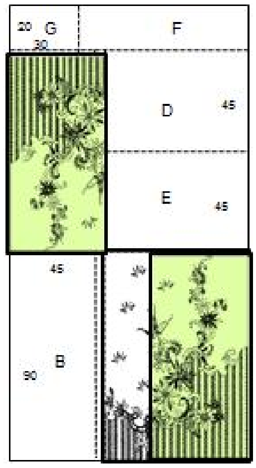

Figure 2d Half of the right master motif is applied on the right chest bloc in the Code-Pattern C

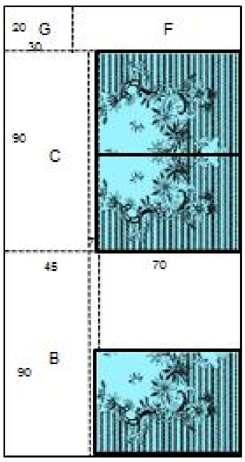

Figure 2e Half of the lower master motif is applied on the right side of short-sleeve sections in Code-Pattern E. Meanwhile the left side section in Code-Pattern D is applied by the reflection on the right side

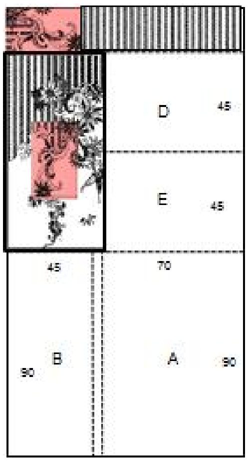

Figure 2f Pocket motif is applied to the pattern of the G section in a horizontal position, and parts F are made with arbitrary motifs (lines)

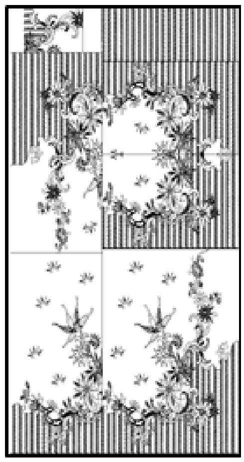

Figure 2g The results of applying the motif to all parts of the pattern of short sleeve shirts

Figure 2h Examples of batik motif patterns of short sleeve shirts

Figure 3 Front side view

Figure 4 Backside view

Figure 5 Right side view

Figure 6 Left side view

4 DISCUSSION AND CONCLUSION

This research has proposed a model of pattern design and motif placement for batik *sanggit* in short-sleeves shirt style. Theoretically, the proposed model could solve the aesthetic problem in the modern batik production, particularly to make batik in *sanggit* style. The authors outline the combination between pattern design and motif placement as the theoretical foundation to generate batik *sanggit* in short-sleeves shirt style. This is supporting argumentation about the importance of the conceptual foundation of pattern design and motif placement to harmonizing the motifs [10].

Along with Almond's finding [20], this research shows that the pattern cutting and design determines the production of modern outfit. Thus, the efforts to develop the innovative cutting pattern and design should be evolved. In the cases of batik production, the innovative cutting pattern should be followed by a precise motif placement.

The appropriate design pattern and motif placement potentially could solve the problem of fractal problems and the problem of Irregular Strip Packing Problem (Irregular SPP).

The important key is to place the motif into the blocs of the pattern designs by precisely flipping and mirroring the motif until it reach the harmonious motif junction. The harmonious motif junction could be attained by extending the motif over the measurement of pattern design that provides a space to harmonizing the motif. Thus, the motif would match each other even it is located in different bloc of pattern. The archetype of the sequential process [21], also become a decisive element to match the batik motifs as a whole part of the short-sleeve shirt, particularly in the collar and pocket blocs that takes from the waste of main patterns. The precise motif placement, especially on the collar and pocket section, is considered to the zero-waste pattern particularly for the developed motif placement in the collar and pocket section.

However, the ease problem in the pattern design and motif placement of batik *sanggit* is unresolved. The ease problem in batik production could not be resolved only just comparing the common and original body dimension [22]. In the cases of pattern construction of batik *sanggit*, these problems become more complex because it also relates to the detail ornaments in every bloc. The developed pattern and motif placement only can be used in regular measurement of short-sleeve shirt, which means that it probably disregard the fitness of pattern and body dimension.

In the further research and development, the proposed model could be used as the foundation for technologizing the modern batik production based on the traditional tacit knowledge. Following Page's suggestion [23], the develop pattern design and motif placement should be more integrated into creative pattern technology to evolve the quantity of batik *sanggit* production. Thus, the usage of computer-aided designed [24] and 3D printing technology [25] are important to be considered by the batik technology developer. As highlight [26], this process would be likely the era of transmission when the old knowledge of batik production, that underlines the handcraft skill, meets with the new knowledge of modern batik production, with its technology and computational usage, in which, in the cases of batik production, this transmission required revolution in the pattern design and motifs placement.

Acknowledgement: *The author thanks the Directorate of Research and Community Service, Directorate General for Research and Development, Ministry of Higher Technology Research and Education of Republic of Indonesia, who has funded this research under the contract number: 353 /UN27.21/PN/2016 dated February 22, 2016.*

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ELECTRICAL, RHEOLOGICAL AND MECHANICAL PROPERTIES OF POLYVINYL CHLORIDE/COPPER PLATED GRAPHITE COMPOSITES

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Abstract: *The issue of the creation of electroconductive polyvinylchloride/copper plated graphite (PVC/COGR) composite materials is devoted to the work. There have been presented electrical (specific electrical volume resistivity), mechanical (tensile strength and elongation at break) and rheological (melt flow index) features of PVC/COGR composites in this work. An increase in the volume content of copper plated graphite in the PVC matrix results in monotonically falling curves with a well-defined percolation threshold. The decrease in tensile strength by ~1.4 times and elongation at break by ~6 times has been observed in the PVC/COGR composite films obtained by extrusion and pressing methods. The melt flow index decreases with the increase of copper plated graphite concentration by exponential law over ~3 times. The main factors that affect the electrical, mechanical and rheological properties of compositions have been reviewed.*

Keywords: *polyvinyl chloride, copper plated graphite, extrusion, pressing, specific electrical volume resistivity.*

1 INTRODUCTION

Due to the complex of its properties, polymer materials are very important in industry and in everyday life. Expansion of plastics scope put the task for the creation of electroconductive polymer materials that combine the properties of polymers and metals.

There are two types of plastics. One is called thermosetting resin which does not soften again and hardened; and the other is called thermoplastic resin which becomes soft or hard when its temperature rises or falls. Thermosetting resin has an older history. Polyvinyl chloride is commonly referred to as PVC or vinyl and is second only to polyethylene in volume use. Normally, PVC has a low degree of crystalline and good transparency. The high chlorine content of the polymer produces advantages in flame resistance, fair heat deflection temperature, good electrical properties and good chemical resistance. However, the chlorine also makes PVC difficult to process. The chlorine atoms have a tendency to split out under the influence of heat during processing and heat and light during end use in finished products, producing discoloration and embrittlement. Therefore, special stabilizer systems are often used with PVC to retard degradation [1].

Due to the high specific electrical resistance, the polymers are mainly used in electrical engineering as insulators. In some cases, it is necessary that the polymers have current conducting properties. Polymeric electroconductive composite materials are widely used for the manufacture of low-power electrically-conductive elements, shielding and antistatic coatings, conductive adhesives, paints, pastes, air filter elements, in medicine to stimulate bone tissue growth, as anthropogenic implants [2].

Increasing the conductivity can be achieved by injection of the electroconductive fillers into composite materials, for example, metal powders or fibers, various types of carbon materials. Phenol-formaldehydes, epoxides, furans and other resins, which as a result of solidification form three-dimensional structures, as well as thermoplastics and rubbers, are often used as the binder [3].

PVC composites filled by carbon black or graphite composites is one of the most extensively studied systems because of its widespread used antistatic, electrostatic dissipative and semi conductive materials. Carbon black with high surface area can lead to electrical current percolation at lower concentrations and to form a conductive carbon network; however, the porous structure of carbon black can decrease mechanical properties of composites, hence, carbon black filler loading within a polymer matrix is limited, Graphite based composite bipolar plates are made on a combination of graphite and a polymer resin with conventional polymer processing methods like compression molding or injection molding.

As one of the commonly used conductive carbon fillers, graphite not only has good conductivity but is also helpful for improving process ability due to its lubricating effect in the melt. Usually, carbon fibers are used for mixing with polymer for reinforcement to improve mechanical properties. However, most of these studies were mainly focused on the mechanical aspects of the composites [1, 4, 5].

Copper filled polymer composites are widely used for electromagnetic interference shielding. They have a lighter weight than metals and are less costly. These composites exhibit several interesting features due to their resistivity variation with thermal, mechanical or chemical treatments. It was found that morphology and structure of conductive pathways within the composite were key parameters determining most of its electrical properties [6].

However, methods for obtaining such materials don't always ensure homogeneity of the filling and the actual results did not correspond to the expected results. The electrical insulation material is considered to be better, the higher its electro-physical properties. The latter is characterized by the values of the specific electrical resistance, electrical resistance to breakdown and dielectric losses. The value of these characteristics depends on the aggressive factors (in particular on moisture absorption), temperature and frequency of the electric field. Prospective materials for the above-mentioned purposes may be PVC/COGR composite systems. They are relatively new composites that combine properties of copper and graphite in the PVC matrix [7-10].

2 MATERIALS AND METHODS

Polyvinyl chloride (PVC) brand PVC-C-63M was used as a polymer matrix for the production of electroconductive composite materials. Its characteristics are shown in Table 1.

Table 1 Properties of PVC brand PVC-C-63M

Indicators	The standard for the brand
Appearance	Homogeneous powder of white color
Amount of extraneous substances and dirt [pcs], not more than	6
Amount of transparent dots in 0.1 sm^3 [pcs], not more than	2
Bulk density [kg/m^3]	450-550
Flow rate [s], not more than	16
The weight of absorption plasticizer [grams per 100 grams resin PVC], not less than	18
Temperature stability of the film at 160°C [min], not less than	10
Mass fraction of volatile substances and moisture [%], not more than	0.3
Mass fraction of vinyl chloride [$million^{-1}$], not more than	10

Copper plated graphite, represented as graphite (brand GK-1) covered by copper (brands M-5, M-7 and M-8) were used as conductive filler. It has been established that metallized graphite significantly increases the viscosity of compositions and, due to this, the cooling process of compositions proceeds under conditions of strong adsorption interaction of the binding agent to the filler surface. The use of copper plated graphite makes it possible to create electroconductive polymers with high adhesive strength [7, 8].

The characteristics of copper plated graphite which was used in this paper are given in Table 2.

Table 2 Properties of copper plated graphite

Indicator	The standard for the brand
Copper content [%]	Not more 90
Density [kg/m^3]	Not more 150
Current density [A/sm^2]	3.7-4.5
Limit of flexural [MPa]	1.5
Hardness in Rockwell B	0.05
Average particle size [nm]	104

As a result of the research, the following electroconductive PVC compositions were selected (Table 3). It is difficult to obtain high level of homogeneity with mixture components for electroconductive PVC/COGR compositions. This has been achieved by using overhead mixer. After mixing the composition mixture has been placed in a heated mold. Mold with compositional mixture have been placed in heat chamber for ~10 min at ~160°C [8].

Table 3 Recipes of electroconductive PVC compositions

Components	The content of components in the composition [% vol.]			
PVC-C-63M	55	53	47	42
Dioctyl phtalate	31	29	25	21
Zinc stabilizers	6	5	5	4
Titanium ceruse	1	1	1	1
Calcium stearate	2	2	2	2
Distilled graphite	5	10	20	30

The obtained compositions were studied in laboratory conditions. The value of the specific electrical volume resistivity, tensile strength, elongation at break and melt flow index was determined according to standard methods [2, 3].

3 RESULTS AND DISCUSSION

The results of the research of the dependence of specific electrical volume resistivity to direct current on the volumetric content of copper plated graphite for the PVC composite system are presented in Figure 1.

It is a monotonically falling curve with a well-defined percolation threshold. Sharp reduction of specific volumetric resistance (increase in conductivity) with an increase in the content of the filler up to 10% vol. occurs at the percolation threshold (5% vol.) for compositions made by extrusion (■) and pressing (●). The value of the percolation threshold was found as the point of intersection of straight lines, approximating the low-level branch and the incident site of the characteristic. According to Figure 1, the value of percolation threshold for compositions obtained by extrusion and pressing methods ~5.2% vol., corresponding to the percolation theory of electrical conductivity.

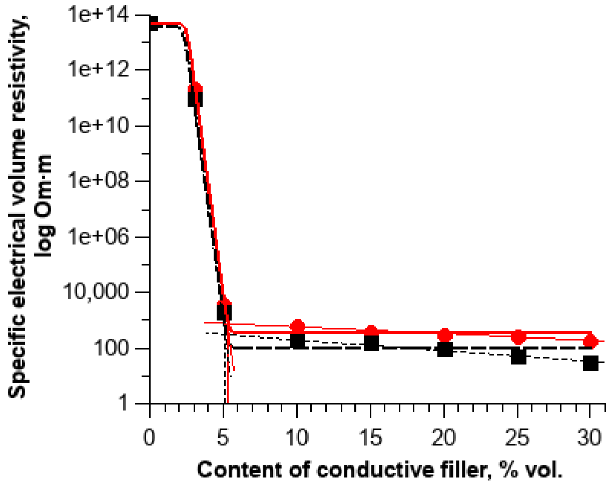

Figure 1 Dependence of specific electrical volume resistivity of conductive PVC compositions on the content of copper plated graphite (obtained by extrusion ■ and pressing ● methods)

The Figure 1 consists of three sections: a high-altitude section (section I: 0-3% vol.) where the resistance is determined by the resistivity of the polymer matrix. The area of maximum change (section II: 3-5% vol.), where the resistance of the composite is no longer determined by the resistivity of the matrix, but also not determined by the resistivity of the conductor and the section (section III: 5-30% vol.) of the minimum resistance, where the dependence is weak, since the specific electrical volume resistivity is determined by the resistance of the conductor.

The effect of the dispersed filler on the strength of the filled compositions depends on the nature of the distribution of the particles of the filler, their size and interaction at the boundary of the phase separation [6, 7]. When the film is stretched, the polymer matrix is deformed by the destruction of adhesive bonds with the filler, which reduces the strength and elongation at the tensile strength for highly filled by dispersed particles compositions.

With the increase of the dispersed filler content in the PVC composition, the material becomes more fragile and the strength and elongation at break decrease. It should be noted that the destruction of the sample compositions was without formation of a neck. This is due to a decrease in deformation in the midgesferolite areas in which the filler is mainly concentrated, as a result of a decrease in the mobility of macromolecules under the influence of a solid surface. The deformation of the spherulites themselves is complicated because they are surrounded by fragile non-deformable, high-content filler substrates and therefore a fragile break occurs along the midgesferolite boundaries before the stress for the stepwise destruction of the structured sites is achieved. The dependence of the strength and elongation at break of composite material on the content of copper plated graphite is shown in Figures 2 and 3.

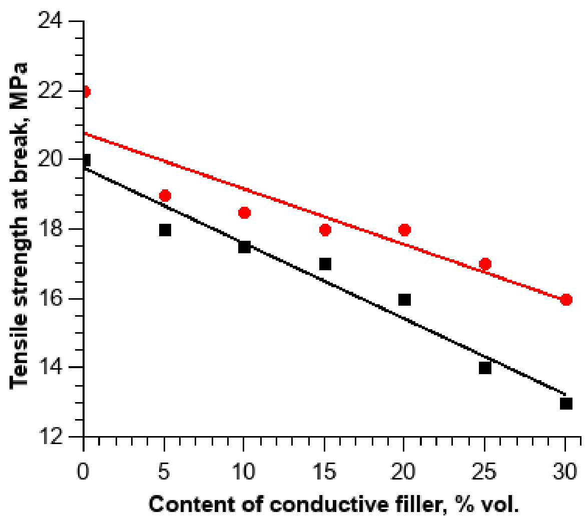

Figure 2 Dependence of tensile strength for conductive PVC compositions on the content of copper plated graphite (obtained by extrusion ■ and pressing ● methods)

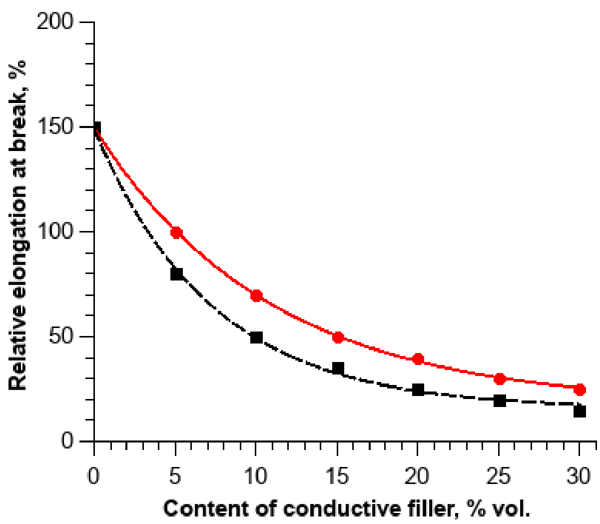

Figure 3 Dependence of relative elongation at break for conductive PVC compositions on the content of copper plated graphite (obtained by extrusion ■ and pressing ● methods)

From the above-mentioned dependencies it is clearly visible that the strength and elongation at break decreases by the increase of the filler concentration for the compositions obtained by extrusion and pressing methods. This can be explained by an increase of the filler content which is localized during crystallization in the disordered parts of the polymer. If these particles are large in comparison with the unordered regions, then they affect these parts with their entire surface, touching several such regions and also the crystalline regions which they affect less. Depending on the strength of this interaction between polymer matrix and filler, there is a different reduction of the flexibility of the macromolecules that interact with the surface of the particles of the filler, which can reach values less than critical. The phenomenon is accompanied by a deterioration of strength and elongation at break. In this filling interval, the tendency to aggregate filler particles may increase, which can cause negative effects on the properties of the compositions.

At even higher concentrations of the filler, the growth of defective spherulites and other supramolecular formations increases, the size of their distribution diminishes, the degree of crystallinity decreases, the crystallite's size and degree of perfection diminishes, overstrain and defects occur. They are present at low concentrations, but their negative effects are often overlapped by the positive effects of the fillers on the supramolecular structure and the flexibility of the structural units (relaxation behavior) of the polymer.

Qualitatively, the effect of the filler on the viscosity of composite materials can be estimated depending on the melt flow index (MFI) from the filler content. As can be seen on Figure 4, with the increase in the content of the MFI filler decreases by exponential law for extruded (■) and pressed (●) specimens. The decrease in MFI indicates an increase of the composition viscosity.

The melt flow index of the filled polymers depends on the nature of the filler, on its concentration and the nature of the interaction with the polymer. The study of these dependencies allows us to select the filler, establish its optimal concentration and also determine the energy load on the equipment and conditions of processing, in which qualitative products can be obtained.

Changing the melt flow index of the filled system is explained by hydrodynamic effects and mechanical forces on the polymer matrix. Hydrodynamic effects are due to the fact that the conditions of flow for one particle affect the nature of the flow for the dispersion medium near other particles, more precisely with no rigidity or sphericity of the particles formed by macromolecules and their associates. The change in the properties of the polymer medium in the composition is due to the adsorption interaction of the particles with the polymer and the limitation of the molecular mobility of the chains in the adsorption layer.

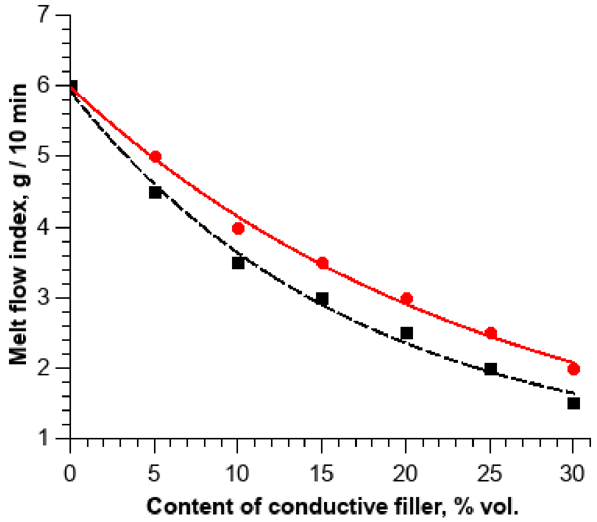

Figure 4 Dependence of the melt flow index for conductive PVC compositions on the content of impregnated graphite (obtained by extrusion ■ and pressing ● methods)

4 CONCLUSIONS

The dependencies of electro-physical, mechanical and rheological properties of compositions based on PVC on the content of copper plated graphite were determined.

It was established that a sharp decrease of the specific electrical volume resistivity with an increase of the filler content up to 10% vol. occurs at the percolation threshold (5% vol.) and the value of the percolation threshold for the compositions obtained by extrusion and pressing methods is ~5.2% vol., corresponding to the percolation theory of electrical conductivity.

It has been established that an increase of the filler content up to 30% vol. leads to a monotonous decrease in the tensile strength, elongation at break and index of melt flow for the extruded and pressed compositions.

The obtained results of experimental research can be applied at a choice for rational structure of conductive PVC with the given electro-physical, mechanical and rheological properties.

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STUDY OF INFLUENCE OF THE PREPARATION METHOD ON THE LIGHT FASTNESS OF COTTON KNITTED FABRIC

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Abstract: *The main goal of this research is to study the effect of preparation methods (boiling, bleaching, combined boiling and bleaching principle, developed preparation principle) on the quality of cotton knitted fabric, sorption capacity in relation to reactive dyes and light fastness of colour. The quality of the preparation was evaluated in terms of capillarity, degree of removal of waxy substances, whiteness, breaking load and sorption of reactive dyes using traditional methods. The light fastness of the obtained colours was evaluated after exposure of Light Fastness Tester (Mercury-Tungsten Lamp) RF 1201 BS («REFOND») with a PCE-TCR 200 colorimeter. It has been established that high indices of light fastness of colours obtained on cotton knitted fabric with reactive dyes are ensured by the developed preparation principle.*

Keywords: *light fastness, cotton knitted fabric, reactive dyes, preparation, dyeing.*

1 INTRODUCTION

Light fastness of colour is an important indicator of quality for textile materials intended for sportswear, T-shirts and clothes for children. Preparation of textile materials is an important stage, since the efficiency of dyeing processes and final finishing, and hence the quality of the textile material as a whole, depends on its implementation [1, 2].

Since the range of fabrics for summer clothing is widely represented by cotton knitwear, the study of the effect of its preparation on the light fastness of colors is an actual task.

The process of cotton knitwear preparation is the most technologically complex, energy-consuming and labor-intensive stage of finishing works. Therefore, technologically and scientifically-based exclusion of some operations is relevant when producing high quality cotton knitted fabrics with low cost.

It is known [3, 4] that the preparation includes a set of processes that ensure the removal of natural impurities (mainly waxy substances) and substances deposited on the fabric during their manufacture (oiling agents) from grey knitted fabric in order to give high capillarity and whiteness. In the course of preparation, the following aggressive factors influence on textile materials:

1) alkaline boiling solution at high temperature, which is the cause of the destruction of cellulosic material under the influence of atmospheric oxygen;
2) peroxide compounds used in bleaching and leading to a decrease in the strength and degree of polymerization of cellulose.

The milder conditions will be during the preparation of textile materials, the more will be preserved strength and natural properties of cellulose, and clothing will have a higher quality [5-7]. There is no direct relationship between high indices of light fastness and other indicators of the resistance of colors to physical and chemical effects (washing, dry and wet crocking). However, it can be argued that, in general, the quality of color depends on the rate of diffusion and sorption of the dye, which are determined by the physicochemical properties of the fiber [8].

It is known [6, 7] that on a fabric that has been maximally cleared of natural and technological contaminations, it is possible to get pure and bright colors that are resistant to washing, dry and wet crocking. But it should be noted that the effect of the degree of preparation on resistance of obtained colours to the action of light was not investigated on cotton knitted fabric with different degrees.

2 THE GOAL OF THE STUDY

The goal of present work was to study the influence of the preparation method of cotton knitted fabric on its quality, sorption ability in relation to reactive dyes and on the stability of colours to the action of light.

3 MATERIALS AND METHODS

Study of influence of the preparation method on the light fastness of colors was carried out on grey cotton rib knitted fabric 1×1 with surface weight 150 g/sm^2. Preparation of grey knitted fabric was carried out under the conditions given in Table 1.

The textile auxiliaries used are Ultravalon TC, Albafluid CD, Albaflow FFC-01, Clarite by Huntsman NMG and Oxipav A1214C.50 by LLC Research and Production Association NII PAV.

The combined preparation principle of knitted fabric and composition of surfactants were developed in previous works [9, 10]. The surfactant composition contains in a certain ratio Ultravon TC as a wetting agent, Albafluid CD as an anticrease agent, Albaflow FFC-01 as a defoamer and Oxipav A1214.50 as a detergent.

The capillarity of fabric was determined by the height of potassium dichromate solution (5 g/l) on a 30 cm long strip of fabric after 30 and 60 min.

Whiteness was evaluated using a PCE-TCR 200 colorimeter.

The degree of wax removal was measured using a gravimetric method by determining the samples mass before and after extraction of knitted fabric with petroleum ether for 6 h.

The breaking strength was determined using the tearing machine RT-250K by breaking small strips.

Dyeing cotton knitted fabric was carried out using reactive bifunctional dyes Bezaktiv Cosmos S-C: Rot, Blue and Gold (Bezema) by exhaust dyeing method with the 1/50 solution rate. The dye solution contained 1% dye and dyeing auxiliaries (30 g/l NaCl + 15 g/l Na_2CO_3). The dyeing was done for 60 min in 60°C, and afterwards overflow cold, hot washing, boiling soaping and cold rinsing procedures are applied.

The light fastness of samples was evaluated after exposure of Light Fastness Tester (Mercury-Tungsten Lamp) RF 1201 BS (REFOND) with a PCE-TCR 200 colorimeter.

Colour measurements were averaged for each sample. Total colour difference (*dE*) was measured on the dyed cotton knitted fabrics samples after light exposure. Colour difference was calculated according to CIE 1976 L*a*b* equation (1):

$$dE = [(dL)^2 + (da)^2 + (db)^2]^{½} \quad (1)$$

where *dL* – difference in lightness-darkness,

da – difference in redness-greeness

db – difference in yellowness-blueness.

Table 1 Cotton fabric preparation conditions

Preparation method	Preparation conditions
Boiling	TF-129B (washing agent) – 2 g/l Albafluid CD (anticrease agent) – 0.8 g/l Soda ash – 1.5 g/l Treatment at 80°C for 20 min. Washing in hot water, drying
Bleaching	Ultravalon TC (wetting agent) – 1.1 g/l Albafluid CD (anticrease agent) – 0.8 g/l Albaflow FFC-01 (defoamer) – 0.5 g/l Clarite (hydrogen peroxide stabilizer) – 0.4 g/l Hydrogen peroxide 60% w/w – 1.5 g/l Sodium hydroxide – 1.5 g/l Treatment at 98°C for 20 min Washing in hot water, neutralization, washing in hot water, drying
Base principle	***Boiling:*** TF-129B (washing agent) – 2 g/l Albafluid CD (anticrease agent) – 0.8 g/l Soda ash – 1.5 g/l Treatment at 80°C for 20 min Washing in hot water. ***Bleaching:*** Ultravalon TC (wetting agent) – 1.1 g/l Albafluid CD (anticrease agent) – 0.8 g/l Albaflow FFC-01 (defoamer) – 0.5 g/l Clarite (hydrogen peroxide stabilizer) – 0.4 g/l Hydrogen peroxide 60% w/w – 1.5 g/l Sodium hydroxide – 1.5 g/l Treatment at 98°C for 20 min Washing in hot water, neutralization, washing in hot water, drying
Developed principle	Treatment in solution: Surfactant composition – 1.5 g/l Hydrogen peroxide 60% w/w – 1.5 g/l Sodium hydroxide – 1.5 g/l Treatment at 80°C for 20 min Washing in hot water, neutralization, washing in hot water, drying

4 RESULTS AND DISCUSSION

The degree of preparation was evaluated by the value of capillarity (Figure 1), whiteness (Figure 2), degree of waxes removal (Figure 3) and strength (Figure 4) of the prepared textile material.

Grey cotton knitted fabric has no capillarity. The minimum capillarity that a textile material must have after preparation is 100 mm; well-prepared fabrics are characterized by capillarity in the range of 150-170 mm. The results of determining the effect of preparation method on capillarity are shown in Figure 1.

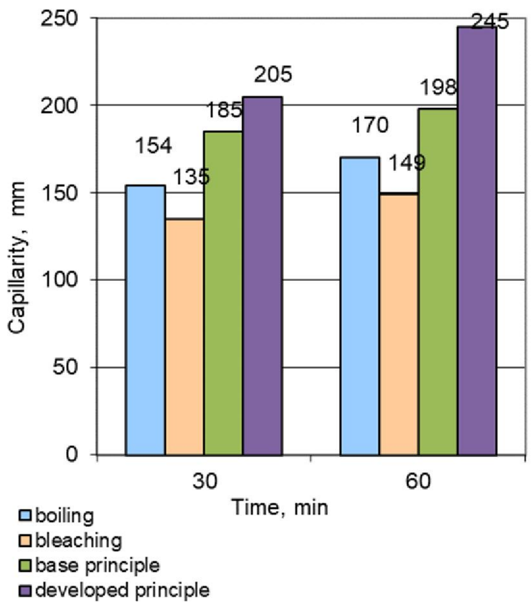


Figure 1 The influence of preparation method of cotton knitted fabric on the capillarity index value

The results show that the studied preparation methods provide indexes of the capillarity of cotton knitted fabric at the level of 135-205 mm in 30 min and 149-245 mm in 60 min. It should be noted that the lowest capillarity is characteristic of the sample after bleaching and the highest capillarity is characteristic of the sample prepared according to the developed principle.

The obtained results (Figure 2) showed that individually alkaline boiling and bleaching provide a slight increase in whiteness compared with the preparation by combined methods according to the base and developed principles.

The diagram in Figure 3 illustrates the obtained data on the degree of wax removal from knit samples depending on the preparation method. The data indicate that a grey sample contains most waxes. After preparation according to the studied methods the content of wax-like substances decreases. Moreover, when preparing according to the base principle, there is less wax on the knitted fabric than after alkaline boiling. The least amount of waxes contains a sample prepared according to the developed principle.

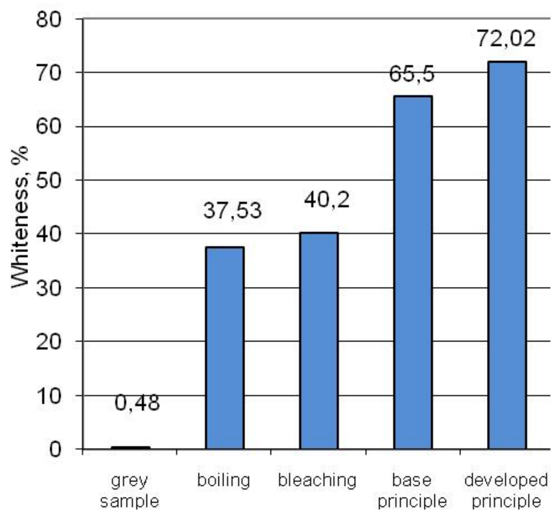


Figure 2 The influence of the preparation method of cotton knitted fabric on the value of whiteness index

The data presented in Figure 3 correlate with the results of the determination of capillarity and show that no more than ≈58% of initial waxes are removed during knitted fabric preparation according to individual principles and to the combined base principle. This fact explains the low indexes of knitted fabric capillarity according to these methods of preparation.

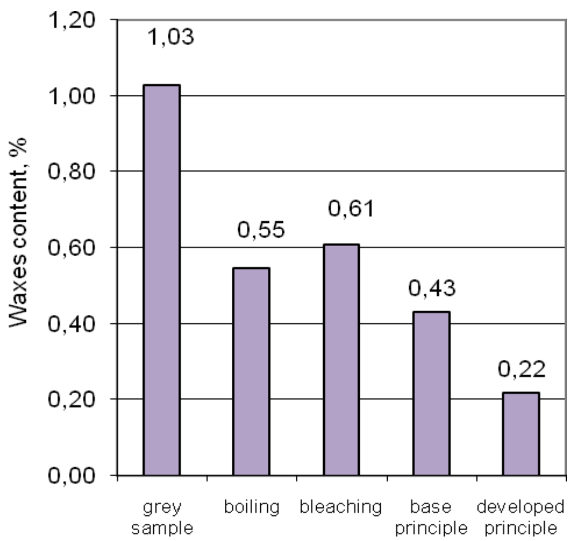


Figure 3 The influence of the preparation method of cotton knitted fabric on the waxes content

It is established (Figure 4) that the bleached sample and the sample prepared according to the base principle have the lowest strength. The knitted fabric prepared according to the developed principle is the least damaged.

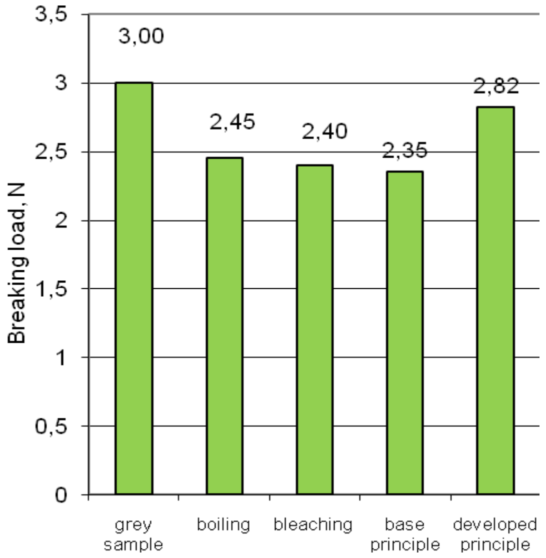


Figure 4 The influence of the preparation method of cotton knitted fabric on the index of breaking load

Grey cotton knitted fabric does not have capillarity due to the presence of natural fatty and waxy substances and knitting oil. Available waxy substances are arranged on the fiber in such a way that their hydrophobic groups are directed away from the surface of the fiber, as a result of which textile materials are not wetted with water, becoming hydrophobic.

Removal of cotton waxes and oils applied to the threads prior to the knitting process and some amount of water-soluble cellulose impurities during the boiling process increases the capillarity of the knitted material. However, during the boiling, cotton colouring matters are not removed, which leads to a slight increase in the whiteness of the knitted material and, as a result, to obtain less bright colors.

The bleaching solution is not able to penetrate deep into the fibers during bleaching due to the presence of hydrophobic substances on the surface of the textile material. The conditions of the bleaching process (pH of the medium, temperature) are such that in the first stage waxes and oils are removed. At this time, hydrogen peroxide, intended for the oxidation of coloured cotton impurities, decomposes unproductively. Thus, neither high capillarity nor whiteness can be achieved during whitening. In addition, the high temperature of the bleaching process at 98°C and the presence of hydrogen peroxide cause significant damage to the textile material.

The combined preparation method by the base principle includes sequential operations of boiling and bleaching, as a result of which the knitted fabric acquires high indexes of capillarity and whiteness. However, the preparation by the base principle occurs at elevated temperatures, which leads to a decrease in the strength of the textile material.

The developed preparation principle of cotton knitted fabric through the use of highly effective surfactant composition allows combining operations of boiling and bleaching as well as carry out the process at a reduced temperature of 80°C [9, 10]. The result is a textile material with a high degree of removal of waxy substances, high indexes of capillarity, whiteness and a low loss of strength. In addition, this technology of preparation due to the use of low temperatures is energy saving, more economical and environmentally friendly.

Next, we studied the effect of the preparation method on the degree of fixation of reactive dyes on the knitted fabric (Figure 5), on the fading kinetics of colours on cotton knitted fabric (Figure 6) and the light fastness of the colours obtained (Table 2).

The results (Figure 5) show that among the studied preparation methods, only the developed principle provides high fixation indexes of reactive dyes. Obviously, this is due to a more complete removal of wax-like substances and oil from knitted fabric during its preparation, and, therefore, high capillarity and high sorption properties of the textile material. The sorption surface of the fiber is determined by systems of submicroscopic pores and capillaries as well as existing cavities and cracks. In the process of preparation, the structure of the fibrous material changes, the surface is freed from impurities, pores open and microcracks appear. The internal stress decreases, causing unevenness of properties, ensuring the penetration of chemical reagents into the fiber. As a result, the dyes penetrate deeper into the fiber and the degree of fixation of the reactive dyes on cotton knitted fabric is increased.

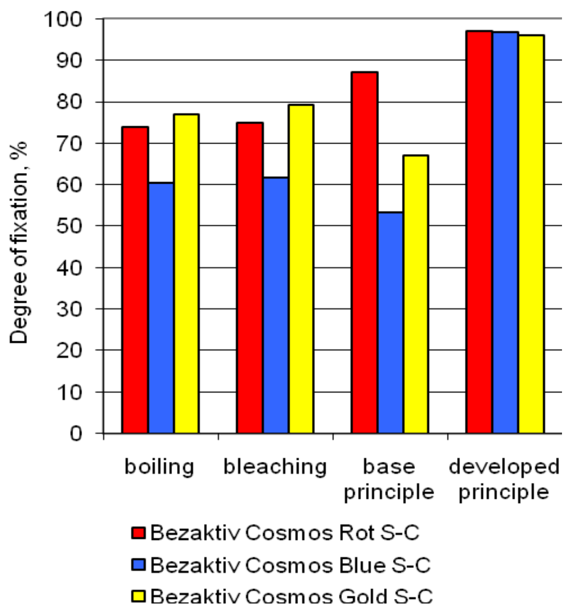
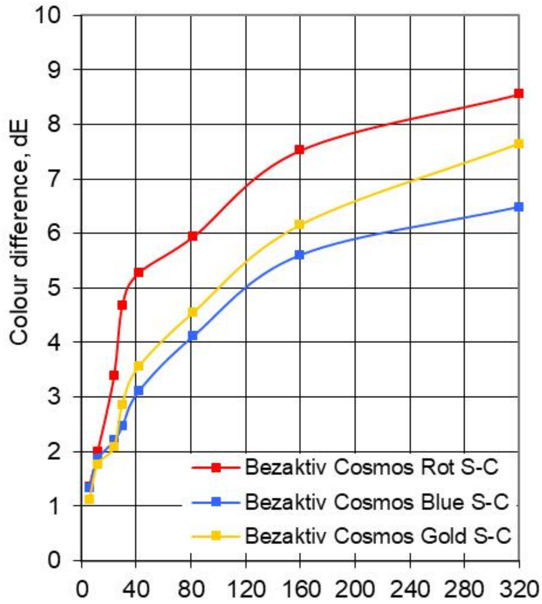


Figure 5 The influence of the preparation method of cotton knitted fabric on the degree of fixation of reactive dyes

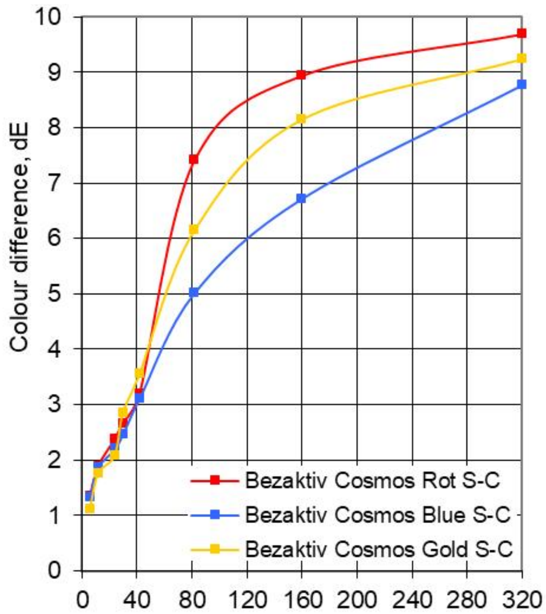
Table 2 The influence of the preparation method of cotton knitted fabric on the light fastness of colours of reactive dyes

Dye	Light fastness			
	Boiling	***Bleaching***	***Base principle***	***Developed principle***
Bezaktiv Cosmos Rot S-C	2	2	3	4-5
Bezaktiv Cosmos Blue S-C	2-3	2	4	5-6
Bezaktiv Cosmos Gold S-C	2	3	4	5

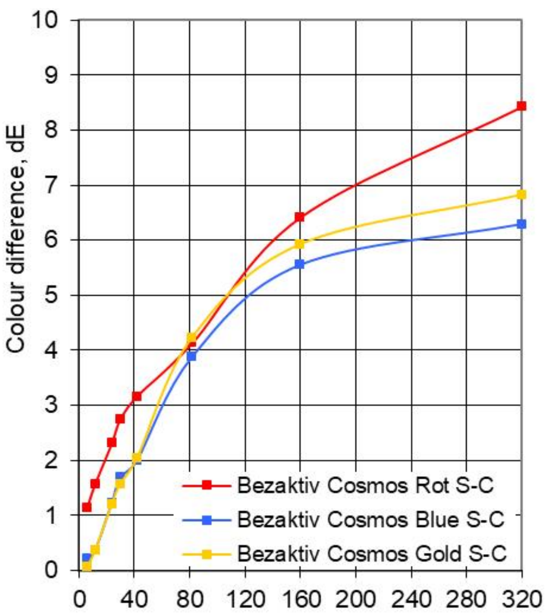
The obtained data testify to low indices of light resistance of the colors of the samples prepared by the methods of boiling and bleaching and according to the base principle. The light fastness of the colors of knitted fabric, prepared according to the base mode, is somewhat higher than that of samples subjected to alkaline boiling and bleaching. The reason for this may be the incomplete removal of waxes and, as a result, low capillarity indexes, which leads to non-dyeing of the textile material and a decrease in the resistance indexes of the obtained colours to the action of light. The colours of knitted fabric, prepared according to the developed principle, are characterized by high index of light fastness.



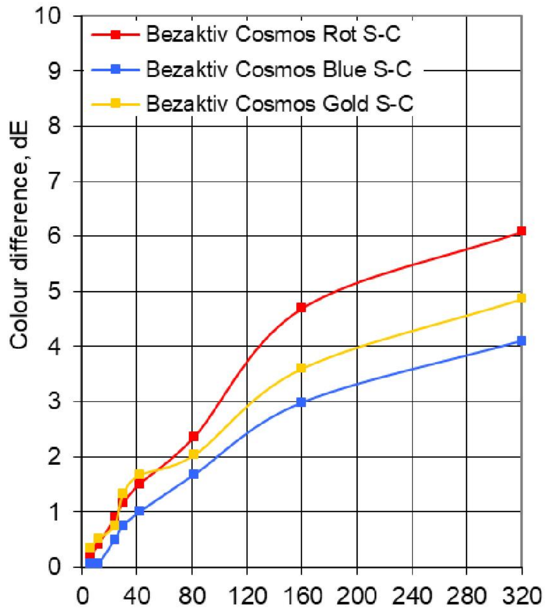
a) boiling;



b) bleaching;



c) base principle;



d) developed principle.

Figure 6 The influence of the preparation method of cotton knitted fabric on the fading kinetics of colours of reactive dyes

5 CONCLUSIONS

It has been established that the developed preparation principle of cotton knitted fabric contributes to the maximum removal of wax-like and colouring matters from a textile material, and as a result, increased capillarity and whiteness. In this case the strength of knitted fabric is reduced slightly. This is facilitated by the application of the previously developed highly effective surfactant composition, which allows to combine the operations of boiling and bleaching and to carry out the preparation process at a reduced temperature of 80°C.

As a result of preparation according to the developed principle the knitted fabric obtains high sorption properties in relation to reactive dyes and the resulting colours are characterized by high resistance to the action of light.

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IMPROVEMENT OF STRUCTURE AND TECHNOLOGY OF MANUFACTURE OF MULTILAYER TECHNICAL FABRIC

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Abstract: *At present during construction and operational commissioning of main oil and gas lines pipes with external factory polyethylene coating are used. Comparing to field coating of pipelines with insulation material introduction of factory insulation of pipes technology allowed for both getting a boost of pipes construction and significantly improve efficiency of its anticorrosive protection. In both, the first and the second, cases for backing up and laying pipes with external factory insulation coating the chains and cords cannot be used. Extreme pressure in the contact area leads to damage of insulation coating, inducing metal corrosion where sections with damaged insulation contact with water and soil.*

Woven power grips are used for laying pipes with factory insulation coating. These grips are manufactured of multilayer technical fabrics. Structure of multilayer technical fabrics and conditions of its formation on a loom determine effectiveness of the woven power grips manufacturing process.

In this work the improvement of multilayer technical fabric was conducted and experimental researches of its formation on the loom were carried out. The influence was determined of warp yarn input tension, value of different tension of shed and value of spade on value of beat-up force, main technological parameter determining intensity of fabric formation process.

The researches that were carried out allowed to improve the structure of the multilayer technical fabric. Comparative analysis of conditions of prototype formation and formation of proposed multilayer technical fabric on the loom was carried out. Resulting from the experiment beat-up force value regression dependences on value of input tension of warp yarns, different tension of shed and value of spade were obtained. Analysis of regression dependences allowed to determine optimal parameters of loom threading.

Keywords: *woven power grips, multilayer technical fabric, beat-up force, warp yarns tension, fabric tension, fabric breaking force.*

1 INTRODUCTION

At present during construction and operational commissioning of main oil and gas lines pipes with external factory polyethylene coating are used (Figure 1a). Factory insulation of pipes is the reliable protection against corrosion. Polymer coating prevents from rust formation and early wear of steel utilities. Corrosion protection is applied to steel pipelines, which are laid under ground or in high humidity. Constant contact with wet ground, air and water may lead to rapid damage of metalware. Polymeric factory insulation protects metal against contact with aggressive external environments and by several times extends the service life of pipelines. Comparing to field coating of pipelines with insulation material introduction of factory insulation of pipes technology allowed for both getting a boost of pipes construction and significantly improve efficiency of its anticorrosive protection. In both, the first and the second, cases for backing up and laying pipes with external factory insulation coating the chains and cords cannot be used [1]. Extreme pressure in the contact area leads to damage of insulation coating, inducing metal corrosion where sections when damaged insulation contacts with water and soil.

Woven power grips (Figure 1b) are used for laying pipes with factory insulation coating. These grips are manufactured of multilayer technical fabrics [1-3]. Structure of multilayer technical fabrics and conditions of its formation on a loom determine effectiveness of the woven power grips manufacturing process [1-4].

Design of woven power grips is presented on the Figure 2. Woven power grip represents locked loop from 20 cm multilayer technical fabric, ends of which are joined in the H area. Surface of grip A is in contact with ground surface. Surface of grip B is in contact with insulation coating of the pipe. In the areas C and D the grip is in contact with rollers of the lifting machine. These four areas provide for maximum wear of the surface of multilayer technical fabric. Process of friction between the surface of the woven power grip and indicated areas is of great importance [5-7]. Should gravitation force of the pipe G increase, width of the grip may be extended by means of adding another strip of 20 cm multilayer technical fabric (Figure 1b).

a) b)

Figure 1 Components and way of laying oil and gas pipelines: a) pipes with external factory insulation coating; b) woven power grips

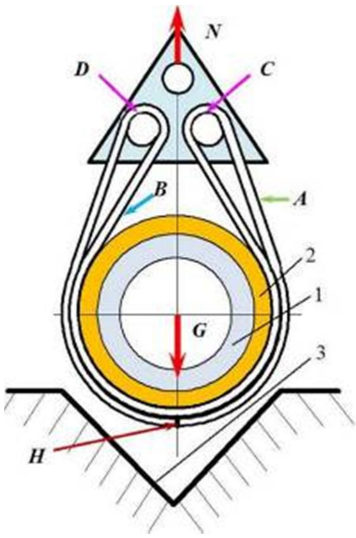
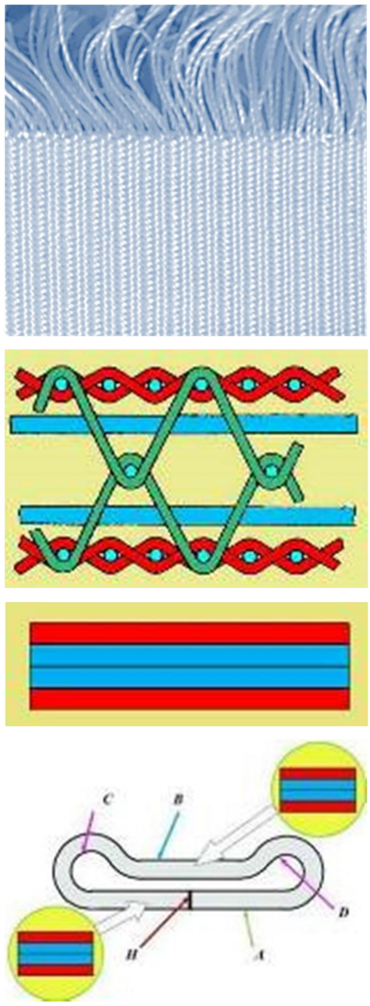


Figure 2 Design of woven power grip: 1 - pipe; 2 - insulation coating; 3 - ground surface; A - surface of the woven power grip, which is in contact with ground; B - surface of the woven power grip, which is in contact with insulation coating; C, D - surface of the woven power grip, which is in contact with rollers of the lifting machine; H - area of edge-joint of multilayer technical fabric; G - gravitation force of the pipe; N - lifting force

2 MATERIALS

Multilayer technical fabric MTF-1 (Figure 3a) was used for woven power grip. This fabric consists of 5 layers. Figure 3b shows cross-section of fabric along warp yarns. Warp yarns of external protective layers (PL) are shown in red colour, warp yarns of force layers (FL) are shown in blue colour. Warp yarns for binding external protective layers and force layers (BIN) are shown in green colour. Main element of woven power grip is warp yarns of the force layers.



a) b) c) d)

Figure 3 Multilayer technical fabric MTF-1: a) general view; b) cross-section of fabric along warp yarns; c) conventional design of cross-section of fabric along warp yarns represented as layers; d) woven power grip represented as locked loop from multilayer technical fabric MTF-1

External protective layers are meant for protection of the force layers (Figure 3c). For fabric MTF-1 (width 20 cm) 816 hard-twisted caprone multifilaments 29 tex S110x2 S300 Z 180 were used as warp yarns of external protective layers (PL) [8]. 544 caprone multifilaments 93.5 tex S 30 Z 60 were used as warp yarns of force layers (FL).

136 caprone multifilaments 29 tex S110x2 S300 Z 180 were used as warp yarns for binding of external protective layers and force layers (BIN).

Analysis of woven power grip as locked loop from multilayer technical fabric MTF-1 (Figure 3d) shows that top protective layer is inside the loop and does not protect force layers. It is formed of hard-twisted caprone multifilaments, which are significantly more expensive in manufacturing comparing to manufacture of warp yarns of the force layers. This layer is virtually extra one in the structure of the multilayer technical fabric. This condition should be considered while improving the structure of the multilayer technical fabric.

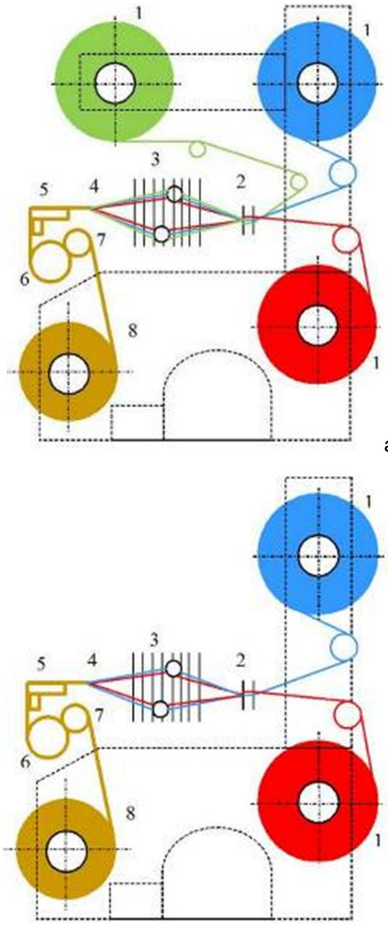


Figure 4 Elastic system of threading for warp yarns on looms:
a) during manufacture of multilayer technical fabric MTF-1;
b) during manufacture of multilayer technical fabric MTF-9;
1 - weaver beam; 2 - warp yarn break detector; 3 - heddle frames of shed development mechanism; 4 - area of multilayer technical fabric formation; 5 - breast beam; 6 - roller; 7 - roller for fabric pressing; 8 - shaft for winding of fabric; ■ - warp yarns for binding external protective layers and force layers (BIN); ■ - warp yarns of force layers (FL); ■ - warp yarns of protective layers (PL); ■ - multilayer technical fabric

Figure 4a shows elastic system of warp yarns threading while manufacturing of multilayer technical fabric MTF-1. Automatic loom with center-shed dobby for 8 heddle frame was used to manufacture the fabric. Warp yarns are arranged on three beams. It significantly aggravates servicing of the loom [2, 3]. Different contraction of warp yarns (Figure 3b) involves creation of different input tension for each type of warp yarns [4, 8-10].

Figure 4b shows elastic system of warp yarns threading while manufacturing of multilayer technical fabric MTF-9. Warp yarns are located on two beams. It makes servicing of the loom much easier while manufacturing of fabric comparing to multilayer technical fabric MTF-1.

In result of researches carried out for woven power grip the multilayer technical fabric MTF-9 (Figure 5a) was offered. This fabric includes 6 layers. Figure 5b shows cross-section of fabric along warp yarns. Warp yarns of external protective layers (PL) are shown in red colour, warp yarns of force layers (FL) are shown in blue colour. Main element of the woven power grip is warp yarns of the force layers (FL).

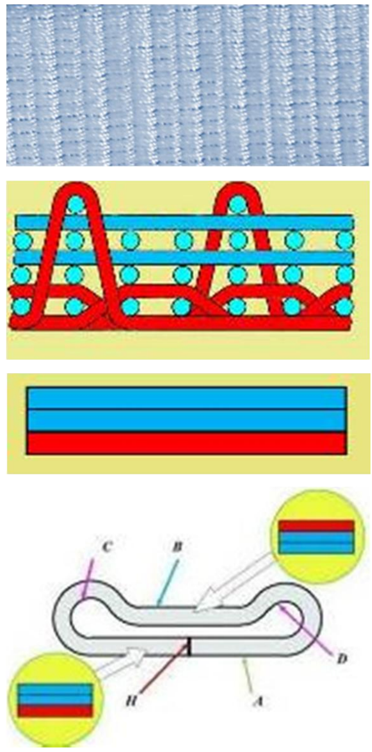


Figure 5 Multilayer technical fabric MTF-9:
a) general appearance; b) cross-section of fabric along warp yarns; c) conventional representation of cross-section of fabric along warp yarns in the form of layers; d) woven power grip in the form of locked loop made of multilayer technical fabric MTF-9

External protective layers are intended for protection of the force layers (Figure 5c). For fabric MTF-9 (width 20 cm) 488 caprone multifilaments 29 tex S110x2 S300 Z 180 were used as warp yarns of the external protective layers (PL). 952 caprone multifilaments 93.5 tex S 30 Z 60 were used as warp yarns of force layers (FL). In this structure connection between the layers is due to warp yarns of the external protective layers (PL). Hard-twisted caprone multifilaments 29 tex S110x2 S300 Z 180 were used as weft yarns.

Analysis of the woven power grip in the form of locked loop made of multilayer technical fiber MTF-9 (Figure 5d) shows that warp yarns of the two force layers (FL) will be placed inside the woven power grip. While using the woven power grip, force layers will not contact with ground surface, pipe surface, and rollers of the lifting device (Figure 2). It will allow to avoid damage to the force layers. Exclusion of upper protective layer allowed to increase number of warp yarns in the two force layers (FL).

3 EXPERIMENT

Four plans of experimental researches were implemented to determine the influence of the structure of the multilayer technical fabric for power grips on conditions of its formation on the loom [5-7, 9-14]. Two multilayer technical fabrics MTF-1 and MTF-9 were chosen for experiment. Tables 1 and 3 represent matrixes of the experimental researches that were carried out to determine influence of the input tension of warp yarns of the protective layers on beat-up force value for multilayer technical fabric MTF-1 and MTF-9. Position of the backrest over the middle level and value of spade corresponded to the center of the experiment that was carried out to determine joint influence of the spade and different tension of shed on the beat-up force value. For multilayer technical fabric MTF-1 the input tension of warp yarns of the protective layers changed within the limits from 164.7 to 223.4 cN. For multilayer technical fabric MTF-9 the input tension of warp yarns of the protective layers changed within the limits from 125.8 to 175.4 cN.

Table 1 Matrix of the plan that determines influence of the input tension of the warp yarns of the protective layers on the beat-up force value for multilayer technical fabric MTF-1

№.	Position of the backrest over the middle level		Value of spade		Input tension of the warp yarns of the protective layers
	x_1	h [mm]	x_2	φ_Z [°]	P_S [cN]
I-1	0	0	0	45	192.2
I-2	0	0	0	45	164.7
I-3	0	0	0	45	178.3
I-4	0	0	0	45	208.3
I-5	0	0	0	45	223.4

In Table 1 x_1 coded representation h - values of vertical shift of backrest. When backrest is higher than average level then value h = 10 mm (Table 2 for fabric MTF-1) in coded representation it appears as +1, when backrest is lower than average level then value h = -10 mm (Table 2 for fabric MTF-1) in coded representation it appears as -1. When backrest is at the average level then value h = 0 mm (Table 2 for fabric MTF-1) in coded representation it appears as 0. Value φ_Z shows the value of spade - angle, created by the warp yarns during beat-up. In coded representation it appears as x_2. For multilayer fabric MTF-1 if x_2=0 φ_Z=45°, if x_2=1 φ_Z=55°, x_2=-1 φ_Z=35°. All abovementioned is true for fabric MTF-9. Numeric values shall be taken from Tables 2 and 4.

Tables 2 and 4 show matrixes of orthogonal design of the second order for two factors that determine joint influence of spade and different tension of shed on the beat-up force value for multilayer technical fabric MTF-1 and MTF-9.

Table 2 Matrix of orthogonal design of the second order for two factors that determine joint influence of spade and different tension of shed on beat-up force value for multilayer technical fabric MTF-1

№.	Position of the backrest over the middle level		Value of spade	
	x_1	h [mm]	x_2	φ_Z [°]
I-6	-1	-10	-1	35
I-7	-1	-10	+1	55
I-8	+1	10	-1	35
I-9	+1	10	+1	55
I-10	0	0	-1	35
I-11	0	0	+1	55
I-12	-1	-10	0	45
I-13	+1	10	0	45
I-14	0	0	0	45

Tension of shed is influenced by the value h. If value h = -10 mm branches of the upper part of shed will be more tight. If value h = 10 mm branches of the lower part of shed will be more tight. Increase or decrease of the said parameters lead to change of contact angles between warp yarns and guides and conditions of relative movement of the weft yarn towards warp yarns in the multilayer fabric formation area [9, 11, 15, 16]. For multilayer technical fabric MTF-1 the value of spade changed within limits from 35 to 55°. This value of spade is explained by the formation of external protective layers of this fabric with plain weave (Figure 3b). Different tension of shed was created by means of vertical displacement of the top point of backrest in reference to middle position. This value was changing within limits from 10 to -10 mm. Minus indicates that backrest descended below middle position. For multilayer technical fabric MTF-9 the value of spade changed within limits from 6 to 22°. This value of spade allows to realize normal formation of external protective layer. Different tension of shed was changing within limits from 10 to -10 mm.

Connection between denominated and coded values for multilayer technical fabric MTF-1 shall be as follows:

$$x1 = \frac{h}{10}, \quad x2 = \frac{\varphi_Z - 45}{10}, \tag{1}$$

for multilayer technical fabric MTF-9 shall be as follows:

$$x1 = \frac{h}{10}, \quad x2 = \frac{\varphi_Z - 14}{8}. \tag{2}$$

Table 3 Matrix of the plan that determines the influence of the input tension of warp yarns of protective layers on the beat-up force value for multilayer technical fabric MTF-9

№.	Position of the backrest over the middle level		Value of spade		Input tension of the warp yarns of the protective layers
	x_1	*h* [mm]	x_2	φ_Z [°]	P_S [cN]
II-1	0	0	0	14	150.6
II-2	0	0	0	14	125.8
II-3	0	0	0	14	143.2
II-4	0	0	0	14	162.0
II-5	0	0	0	14	175.4

Table 4 Matrix of orthogonal design of the second order for two factors that determine joint influence of spade and different tension of shed on beat-up force value for multilayer technical fabric MTF-1

№.	Position of the backrest over the middle level		Value of spade	
	x_1	*h* [mm]	x_2	φ_Z [°]
II-6	-1	-10	-1	6
II-7	-1	-10	+1	22
II-8	+1	10	-1	6
II-9	+1	10	+1	22
II-10	0	0	-1	6
II-11	0	0	+1	22
II-12	-1	-10	0	14
II-13	+1	10	0	14
II-14	0	0	0	14

Experimental setup for determining technological efforts during formation of multilayer technical fabrics is described in the work in reasonable details [2-4, 11]. It included eight-channel amplifier 8АНЧ-7М, oscillograph H-700, power modules for them. Separate measuring tensometric units were intended to determine tension of warp yarns, beat-up force, and tension of fabric. Time records after 0.2 seconds were recorded by the oscillograph H-700 itself. Figure 6 shows an example of oscillogram. Three repetitive oscillograms were done for each series. Calibration charts were obtained for each measuring tensometric unit for determining tension of warp yarns, beat-up force and tension of fabric. These charts were used for interpretation of oscillograms.

The work contains a series of experimental researches that determines influence of the structure of the multilayer technical fabric and conditions of its manufacturing on the loom on the breaking load value of 20 cm strip. This series of experiments was carried out in the Institute of strength problems of the Academy of Sciences of Ukraine. Experiments were carried out using INSTRON 8802 tensile-testing machine (breaking force up to 250 kN). Ten replicated experiments were carried out for each series.

To fasten 20 cm strip of the multilayer technical fabric shaped clamps with movable axles (70 mm in diameter) were inserted into the upper and lower grips of INSTRON 8802 tensile-testing machines [17]. Loose ends of fabric wrapping around these axles and were joined. To fix the joint the area of joining was clamped on both sides with metal plates, fixed by 5 screws with nuts on each end of the sample. Such a fastening scheme made it possible to exclude slippage of the loaded branch of the fabric against the unloaded end of the fabric during tensile tests.

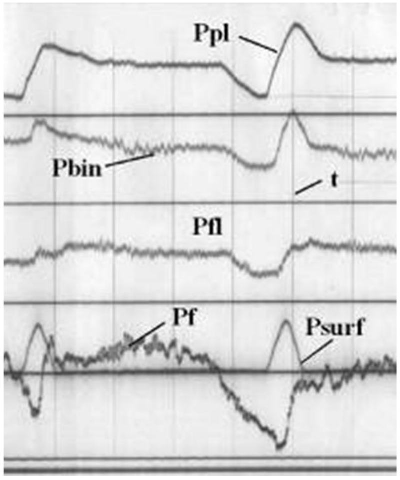


Figure 6 Example of oscillography record of technological efforts during formation of multilayer technical fabrics: PSURF - beat-up force; PPL - tension of the warp yarns of the external protective layers (PL); PBIN - tension of warp yarns for binding of external protective and force layers (BIN); PFL - tension of warp yarns of the force layers (FL); PF - tension of fabric; t - time

4 RESULTS AND DISCUSSION

Figure 7 shows results of tensile test for 20 cm strips of multilayer technical fabrics MTF-1 and MTF-9.

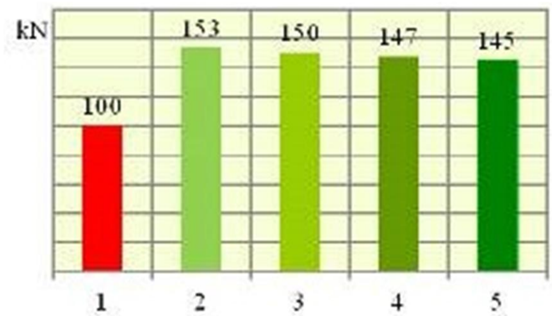


Figure 7 Breaking force values of the multilayer technical fabrics: 1) MTF-1 (density of weft yarns 100 yarns/dm); 2) MTF-9 (density of weft yarns 100 yarns/dm); 3) MTF-9 (density of weft yarns 120 yarns/dm); 4) MTF-9 (density of weft yarns 130 yarns/dm); 5) MTF-9 (density of weft yarns 140 yarns/dm)

Where the same density of fabric along the weft yarns breaking strength of the multilayer technical fabric MTF-9 is higher by 53% comparing to its prototype. The influence of density along the weft yarns of the multilayer technical fabric MTF-9 on the breaking force value was determined separately. It was established that the higher the density along the weft yarns the lower breaking force value. It is explained by more strained conditions of fabric formation on the machine.

Figure 7 represents results of experimental researches determining breaking load processed in terms of math statistics methods. They reflect the process with the 95% confidence probability.

According to experiment plans the data were obtained that determined the influence of threading tension of the warp yarns on the conditions of multilayer technical fabric formation MTF-1 (Table 5) and MTF-9 (Table 6).

For multilayer technical fabrics MTF-1 if threading tension of the ground/back warp yarns increases from 164.7 cN (variant I-2) to 223.4 cN (variant I-5) the beat-up force increases from 139.3 to 152.5 cN by one yarn. At the same time the value of the beat strip decreases from 22.3 to 12.6 mm. Where threading tension increases, warp tension at the fell of the fabric in the moment of beat increases as follows: ground/back warp yarns from 239.0 cN (variant I-2) to 289.6 cN (variant I-5) and weft warp yarns from 168.7 cN (variant I-2) to 244.2 cN (variant I-5).

For multilayer technical fabrics MTF-9 if threading tension of the ground/back warp yarns increases from 125.8 cN (variant II-2) to 175.4 cN (variant II-5) the beat-up force increases from 72.5 to 118.7 cN by one yarn. At the same time the value of the beat strip decreases from 18.2 to 7.2 mm. Where threading tension increases, warp tension at the fell of the fabric in the moment of beat increases as follows: ground/back warp yarns from 217.7 cN (variant II-2) to 261.4 cN (variant II-5) and weft warp yarns from 124.1 cN (variant II-2) to 206.3 cN (variant II-5).

Tables 5 and 6 represent data determining influence of the feeding tension of warp yarns for conditions of formation of multilayer technical fabrics MTF-1(Table 5) and MTF-9 (Table 6). They represent results of measurings: P_S - feeding tension of warp yarn; P_{SURF} - beat-up force per one warp yarn being fed, being static and being dynamic; P_{FZ} - tension of warp yarn before the area of multilayer fabric formation; P_{RZ} - tension of warp yarn before shedding motion; t_P - time of beat-up; l_P - length of the beat strip; P_F - tension of fabric per one warp yarn.

Table 5 Results that determines influence of the input tension of warp yarns of the protective layers on the beat-up force value for multilayer technical fabric MTF-1

№.	Warp yarns	Branch of shed	P_S [cN]	P_{SURF} [cN]		P_{FZ} [cN]	P_{RZ} [cN]	$t_P \cdot 10^{-2}$ [s]	l_P [mm]	P_F [cN]
				Statics	Dynamics					
I-1	PL	1	192.2	61.2	142.8	264.0	249.6	2.5	15.9	73.4
		2	192.2			251.5	240.3			
		3	192.2			228.6	221.0			
	BIN	1	47.8			137.6	130.1			
		2	47.8			136.2				
	FL	3	102.1			213.7	199.1			
I-2	PL	1	164.7	42.8	139.3	239.0	226.7	3.08	22.3	56.3
		2	164.7			229.9	219.6			
		3	164.7			212.5	203.4			
	BIN	1	47.8			132.8	125.6			
		2	47.8			131.5				
	FL	3	42.2			168.7	97.2			
I-3	PL	1	178.3	52.9	140.0	253.7	239.8	2.53	16.7	71.1
		2	178.3			242.0	231.2			
		3	178.3			230.3	222.6			
	BIN	1	47.8			140.5	132.8			
		2	47.8			139.0				
	FL	3	69.5			203.1	149.2			
I-4	PL	1	208.3	67.8	147.8	277.9	262.7	2.35	15.0	93.0
		2	208.3			267.1	255.1			
		3	208.3			257.4	248.8			
	BIN	1	47.8			142.1	134.8			
		2	47.8			140.7				
	FL	3	125.4			231.1	245.3			
I-5	PL	1	223.4	72.3	152.5	289.6	273.8	2.09	12.6	94.2
		2	223.4			280.0	267.5			
		3	223.4			273.6	264.4			
	BIN	1	47.8			139.1	131.5			
		2	47.8			137.6				
	FL	3	150.3			244.2	287.5			

Table 6 Results that determines influence of the input tension of warp yarns of the protective layers on the beat-up force value for multilayer technical fabric MTF-9

№.	Warp yarns	Branch of shed	P_S [cN]	P_{SURF} [cN]		P_{FZ} [cN]	P_{RZ} [cN]	$t_P \cdot 10^{-2}$ [s]	l_P [mm]	P_F [cN]
				Statics	Dynamics					
II-1	PL	1	150.6	51.9	101.6	246.6	235.5	2.01	11.9	70.8
		2	150.6			256.7	241.0			
		3	150.6			172.8	169.5			
	FL	1	56.1			181.7	169.0			
		3	56.1			96.3	93.1			
II-2	PL	1	125.8	29.1	72.5	217.7	208.8	2.68	18.2	74.7
		2	125.8			225.7	211.9			
		3	125.8			145.8	143.1			
	FL	1	26.8			124.1	115.5			
		3	26.8			65.1	63.0			
II-3	PL	1	143.2	34.2	80.3	229.6	220.1	2.26	14.5	76.6
		2	143.2			239.7	225.0			
		3	143.2			157.9	154.9			
	FL	1	38.3			134.6	125.2			
		3	38.3			81.0	78.3			
II-4	PL	1	162.0	52.1	197.4	255.8	245.3	1.96	11.7	82.5
		2	162.0			272.3	255.7			
		3	162.0			176.4	173.1			
	FL	1	61.6			194.0	180.5			
		3	61.6			102.5	99.1			
II-5	PL	1	175.4	59.8	118.7	261.4	250.5	1.39	7.2	86.6
		2	175.4			275.1	258.3			
		3	175.4			188.5	185.0			
	FL	1	72.2			206.3	191.9			
		3	72.2			152.6	147.6			

Two plans of active carrying out of experiment (Tables 7, 8) were realized to determine joint influence of spade value φ_Z and different tension of shed h. For multilayer technical fabric MTF-1 the value of different tension of shed changed within limits from -10 to 10 mm with a step of 10 mm; the value of spade changed within limits from 350 to 550 with a step of 100. For multilayer technical fabric MTF-9 the value of different tension of shed changed within limits from -10 to 10 mm with a step of 10 mm; the value of spade changed within limits from 60 to 220 with a step of 80. Such decrease in value of spade comparing to multilayer technical fabric MTF-1 induces decrease in dynamic and static components of the warp yarns tension in the 3rd branch of the shed. The backrest shall be installed 10 mm lower with respect to neutral line; and that what corresponds to its optimal position.

Using data from Tables 7 and 8 for multilayer technical fabric MTF-1 and MTF-9, using well-known method of coefficient determination in the regression equation for orthogonal design of the 2nd order the following regression dependencies were obtained: for MTF-1

$$P = 2488.2 + 46.3h - 14.8\varphi_Z - 0.68h\varphi_Z - 1.4h^2, \quad (3)$$

for MTF-9

$$P = 1511.2 + 16.7h - 31.4\varphi_Z - 0.7h\varphi_Z - 0.4h^2 + 0.7\varphi_Z^2. \quad (4)$$

Efficacy of obtained regression dependences were checked using SPSS program for statistical processing of experimental data [4-7, 10, 12-16]. Analysis of coefficient significance of regression dependences (3) and (4) allowed to drop insignificant [6, 11-14, 17]. In regression dependences (3) and (4) value of spade φ_Z shall be inserted in degrees [°], and h value that characterizes different tension of shed shall be inserted in mm.

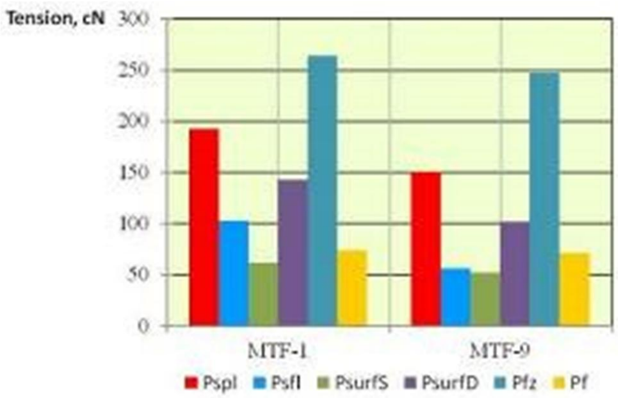


Figure 8 Comparative analysis of the manufacturing conditions for multilayer technical fabrics MTF-1 and MTF-9: ■ - tension of warp yarns of the external protective layers(PL) in static conditions P_{SPL}; ■ - tension of warp yarns of the force layers(FL) in static conditions P_{SFL}; ■ - beat-up force equivalent to one warp yarn in statics $P_{SURF}S$; ■ - beat-up force equivalent to one warp yarn in dynamics $P_{SURF}D$; ■ - tension of warp yarns of the external protective layers(PL) before the area of fabric formation P_{FZ}; ■ - tension of fabric equivalent to one warp yarn P_F

Table 7 Results that determines joint influence of spade and different tension of shed on beat-up force value for multilayer technical fabric MTF-1

№.	Warp yarns	Branch of shed	P_{SURF} [cN] Statics	P_{SURF} [cN] Dynamics	P_{FZ} [cN]	P_{RZ} [cN]	P_F [cN]
I-9	PL	1	39.1	117.7	229.6	217.3	67.2
		2			219.5	209.6	
		3			200.0	193.2	
	BIN	1			153.8	145.4	
		2			152.2		
	FL	3			145.9	135.9	
I-7	PL	1	33.7	98.5	226.1	213.7	76.9
		2			215.3	205.6	
		3			194.8	188.3	
	BIN	1			148.5	140.4	
		2			146.9		
	FL	3			139.3	129.7	
I-8	PL	1	49.1	139.7	243.9	230.5	64.3
		2			232.6	222.2	
		3			209.6	202.5	
	BIN	1			166.4	157.3	
		2			164.6		
	FL	3			186.8	174.0	
I-6	PL	1	38.6	108.4	229.5	216.9	75.1
		2			219.0	209.2	
		3			198.2	191.4	
	BIN	1			153.5	145.1	
		2			151.9		
	FL	3			145.7	135.7	
I-12	PL	1	36.4	102.1	226.6	214.1	69.8
		2			216.1	206.4	
		3			192.5	186.0	
	BIN	1			150.5	142.3	
		2			148.9		
	FL	3			140.5	130.9	
I-13	PL	1	42.2	120.9	236.2	223.3	73.1
		2			225.2	215.1	
		3			204.3	197.4	
	BIN	1			164.1	155.1	
		2			162.3		
	FL	3			165.5	154.1	
I-10	PL	1	48.1	133.0	239.8	226.7	67.0
		2			230.7	220.4	
		3			205.6	198.7	
	BIN	1			164.3	155.3	
		2			162.5		
	FL	3			174.8	162.8	
I-11	PL	1	40.8	111.6	234.3	221.4	71.8
		2			223.1	213.1	
		3			208.1	201.1	
	BIN	1			159.3	150.6	
		2			157.6		
	FL	3			146.2	136.2	
I-14	PL	1	42.8	119.6	236.0	223.1	66.9
		2			224.3	214.3	
		3			203.4	196.6	
	BIN	1			163.7	154.8	
		2			162.0		
	FL	3			164.4	153.1	

Figure 8 shows comparative analysis of the manufacturing conditions for multilayer technical fabrics MTF-1 and MTF-9. Threading tension of the warp yarns of the external protective layers (PL) decreased by 22% (from 192.2 to 150.6 cN), threading tension of the warp yarns of the force layers (FL) decreased by 45% (from 102.1 to 56.1 cN), beat-up force, equivalent to one yarn, in static conditions decreased by 15% (from 61.2 to 51.9 cN), beat-up force, equivalent to one yarn, in dynamic conditions decreased by 29% (from 142.8 to 101.6 cN), tension of the warp yarns of the external protective layers (PL) decreased by 7% (from 264.0 to 246.6 cN), tension of fabric at the moment of beat, equivalent to one yarn, decreased by 4%(from 73.4 to 70.8 cN). Value of beating strip decreased from 15.9 to 11.9 mm.

Table 8 Results that determines joint influence of spade and different tension of shed on beat-up force value for multilayer technical fabric MTF-9

№.	Warp yarns	Branch of shed	P_{SURF} [cN]		P_{FZ} [cN]	P_{RZ} [cN]	P_F [cN]
			Statics	Dynamics			
II-9	PL	1	26.2	76.6	153.5	147.2	58.9
		2			161.3	151.4	
		3			135.9	132.9	
	FL	1			124.1	115.5	
		3			107.5	103.4	
II-7	PL	1	22.3	72.5	145.0	131.0	48.3
		2			152.2	143.5	
		3			128.7	125.8	
	FL	1			117.6	109/4	
		3			94.2	90.6	
II-8	PL	1	39.2	97.6	196.2	188.1	68.1
		2			205.5	192.9	
		3			169.0	166.7	
	FL	1			158.2	147.1	
		2			138.5	135.2	
II-6	PL	1	28.2	79.2	158.4	151.9	51.9
		2			166.8	155.6	
		3			137.9	136.0	
	FL	1			128.4	119.4	
		3			102.3	99.9	
II-12	PL	1	24.1	73.2	145.1	139.1	45.4
		2			154.2	144.8	
		3			126.6	124.2	
	FL	1			107.9	100.4	
		3			89.1	86.1	
II-13	PL	1	30.1	79.9	160.6	154.0	54.4
		2			168.3	158.0	
		3			141.1	138.5	
	FL	1			129.5	120.5	
		3			112.8	109.1	
II-10	PL	1	35.6	88.3	177.0	169.7	63.1
		2			186.0	174.6	
		3			154.1	152.0	
	FL	1			143.1	133.1	
		3			125.6	122.5	
II-11	PL	1	24.5	75.6	150.8	144.6	50.9
		2			159.2	149.4	
		3			135.7	132.6	
	FL	1			122.5	114.0	
		3			105.2	101.1	
II-14	PL	1	28.7	79.6	159.1	152.6	60.2
		2			167.6	157.4	
		3			140.8	138.1	
	FL	1			129.1	120.1	
		3			112.1	108.4	

Obtained results allow to state that multilayer technical fabric MTF-9 manufactured on the machine at smaller technological loads. It allows significantly cut yarn breakages, preserve their strength properties, and increase machine capacity.

5 CONCLUSIONS

Resulting from multi-method experimental researches in improvement of structure and technology of multilayer technical fabric manufacturing the new structure was obtained. Its use leads to 50% increase in strength of power grip for laying pipes with factory insulation coating of oil and gas pipelines. Realization of active planning of the experiment allowed to determine optimal parameters of threading for loom, at which beat-up force of the weft yarn will have minimum necessary value for obtaining multilayer technical fabric of the defined structure. At the same time threading tension of the warp yarns of the external protective layers (PL) decreased by 22%, threading tension of the warp yarns of the force layers (FL) decreased by 45%, beat-up force, equivalent to one yarn, in static conditions decreased by 15%, beat-up force, equivalent to one yarn, in dynamic conditions decreased by 29%, tension of the warp yarns of the external protective layers (PL) before the fabric formation area decreased by 7%, tension of fabric at the moment of beat, equivalent to one yarn, decreased by 4%.

Beat-up force value regression dependences on spade value and different tension of shed were obtained.

Obtained results may be used to improve the structure and technology of multilayer technical fabric manufacturing.

***Acknowledgement:** We express our gratitude to the Institute of Strength Problems of the Academy of Science of Ukraine for the provided opportunity to carry out tests with multilayer technical fabric samples on the INSTRON 8802 tensile-testing machine (breaking force up to 250 kN). We are really grateful to Private Joint Stock Company "Technical Textiles Factory "TEKHNOFILTR" for provided raw materials and machines to carry out experiments and for opportunity to test results of the research under factory conditions.*

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ANALYSIS OF THERMAL PROPERTIES AFFECTED BY DIFFERENT EXTENSION LEVELS OF COMPRESSION SOCKS

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Abstract: *The aim of this research is to analyze the effect of various extension levels on thermal properties including thermal conductivity and thermal effusivity of compression socks. Compression socks are recommended as tool for compression therapy but discouraged because poor performance regarding its interaction to thermal properties especially the thermal conductivity and effusivity. The problem of this research is to investigate how much the circumferential extensibility of compression socks affects its thermal comfort properties. Here, gradual increase in extension values of strips depicts the different circumferences of the legs. For extension, we introduced novel extension frame attached with movable gears and revolving handle. The aim of this research is to analyze effect of gradient elastic elongation [%] on thermal effusivity [W.s$^{1/2}$/m^2.K] and thermal conductivity [W/m.K] in relaxed (0% extension) and extended state (up to 70% extension). To extend the compression socks a novel extension frame was used. Conclusively, we found that as elastic elongation increases, thermal conductivity and thermal effusivity changes significantly. We also have concluded for extension above 70% that the trends changes and comfort properties started to decline. Out of three socks samples, the best one was rib structured compression socks sample.*

Key words: *Compression socks, thermal effusivity, thermal conductivity, novel extension frame.*

1 INTRODUCTION

Compression socks are a highly acclaimed textile garment for pressure exertion on the lower part of the leg. It is used to reduce venous hyper pressure [1]. Physical and constructional properties of compression socks are the most important because their properties directly relate to the type of patient and intensity of the disease. The extent of compression, that a patient can easily manage, depends on stage (limb size and shape) of venous disease and his activities (mobility, age) [2]. Socks, worn inside the shoes, are used to stabilize wearer's comfort, level of interaction and ease against its rasping with footwear. They must exhibit excellent mechanical (extensibility and elasticity recovery) along with optimized comfort properties (sensorial and thermo-physiologic features). Excellent stretch and recovery properties do not restrict the wearer's movement during activities and provide positive feeling over skin by transferring optimum heat, moisture and air through fabric [3, 4].

Socks selection keeps foot dry and cool, no accumulation of moisture but prompt flow of generated sweat, abstain maceration of skin and inhibit bacterial growth that can cause blisters and athletic deceases. To develop such type of dry-socks, it must possess good wicking action necessary to keep the foot dry and warm. The transport of both moisture vapor and liquid away from the body is called moisture management [5, 6] and is mechanized by two processes named as vapor's conduction (diffusion) and by convection processes.

Seshadri et al. studied the use, compliance and efficacy of compression socks. In this research, they analyzed 3144 patients for tertiary venous practice and concluded that only 21% patients uses stockings on daily basis, 12% most days, 4% used less option, 63% don't use; inquired the reasons were: 30% unable to give reason, 25 not recommended by physician, 14% did not help, 14% binding off, 8% too hot to wear and 2 % limb soreness, 2% due to itching, 2% others (cost and work station). As far as pressure exertion and graduation (%) in socks plays an important role to control re-occurrence of venous ulcer and venous insufficiency, it should exhibit optimum comfort properties to regulate heat and moisture transfer (comfortness) generated during different physical activities of patients [7].

Gupta et al. (2011) studied the comfort properties of pressure garments at different extension levels from 0 to 60%. They extended the fabric by designing a frame (30×30 cm^2) made up of acrylic sheet and took sample of 14.4×20 cm and marked square of 10×10 cm^2. But for compression socks this frame cannot be recommended as socks circumference at ankle is very low and higher at calf. For Compression class III and IV it is very hard to extend to 60% precisely [8]. Wang et al. (2013) mentioned the same while investigating dynamic pressure attenuation of elastic fabric for compression garment [9].

Fundamental parameters which govern the thermo-physiological properties of fabrics are fibre type, fibre conductivity, fibre moisture regain, yarn count, yarn twist per inch, yarn structure, spinning process, fabric structure, fabric loop length, fabric thickness, fabric porosity and finishing treatments [10].

As compression socks are directly in contact with skin, normally known as second skin. Heat flow through the socks takes place through conduction which relate to the parameters especially thermal conductivity, air permeation, thermal effusivity influenced by area through which heat is conducted and difference of temperature between skin and environment and thickness of fabric, fabric porosity (fibers and yarns packing density).

Thermal effusivity is also known as thermal absorptivity. Warm and cool feeling at the time of contact to textile fabrics can be described by thermal effusivity values. It means initial feelings when a human body touch to a textile fabric was introduced by Hes [11]. He rated that higher the thermal absorptivity of the fabric, the cooler it will be in its feeling. Thus derived thermal absorptivity *b* [$W.s^{1/2}/m^2.K$] relation as given below:

$$b = (\lambda.\rho)^{1/2} \quad (1)$$

As far as thermal absorptivity is concern, thermal conductivity is also considered as main parameter used to evaluate thermo-physiological properties of compression socks. It is transfer of heat from one part of a body to another. It can be defined as ability of material to transmit heat and it is measured in watts per square meter of the surface area for a temperature gradient of 1 K per unit thickness of 1 m. It is denoted by λ [12].

Marmarali proved that thermal absorptivity depends on the surface profile of the fabric. Smooth surface provides maximum contact points, and heat freely transfers between the skin and the fabric. More heat transfers mean higher thermal absorptivity and intensified warm-cool feeling [13].

The aim of this study was to investigate the effect of gradual increase in elastic elongation of compression socks using novel extended frame on thermal effusivity and thermal conductivity. These are necessary parameters required to get rid of sweat accumulation between garment and skin in relaxed and extended state.

2 MATERIALS AND METHOD

Three type of compression socks were purchased and structurally analyzed with great precision and accuracy.

2.1 Visualization of knitted loops

All the three socks samples were evaluated structurally using digital highly magnified microscope at magnification of level of 30X. Compression socks being more compact were stretched to 100% extension prior to peer inside the loops to investigate its structure and path of the knitted loops. So we adopted the same procedure and stretched the socks to 100%. Stretched loop's unit cell of scanned knitted images was drawn using 3D-Texmind software as shown in Figure 1.

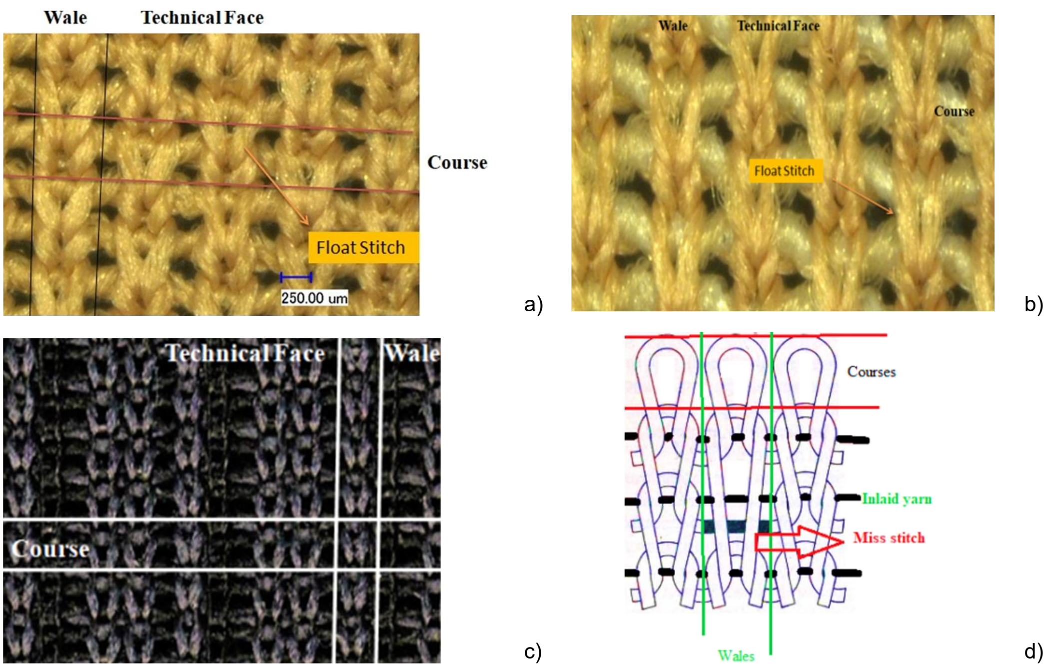


Figure 1 Knitted scanned images (a, b, c) and drawn loops (d) [14]

2.2 Physical testing of compression socks

Table 1 Physical testing of compression socks in relaxed state (0% extension)

Sample codes	Position	BIISJ*	BIIISJ*	DGIIRIB*
Socks Circumference [cm]	ankle/calf	16.6/23	16/25.6	16.4/26
Courses/inch	ankle/calf	57/58	49/49	56/58
Wales/inch	ankle/calf	52/42	49/36	42/27
Stitch/inch^2	ankle/calf	460/277.6	372/273	364/343
Thickness b [mm]	ankle/calf	0.75	0.95	1.20
Areal Density (GSM)	ankle/calf	308.80/291.80	378.47/368.47	350.97/292.47

*B= Beige, II, III= compression class, SJ= single jersey, RIB= rib structured

2.3 Marking and cutting of socks

All the three socks samples, BIISJ, BIIISJ and DGIIRIB, were marked with a square line on their surface to dimensions (8×8 cm^2) of each. All the three socks strips were washed afterwards and then installed on novel extension frame to extend it equal to circumference of plastic leg (circumference: 23 cm) simultaneously

2.4 Washing procedure

Prior to extend the socks using novel extension frame, tensile and pressure characterization, we washed the socks as per European guideline i.e. hydro-extraction for 2 minutes. After that socks samples were dried (flat drying), relaxed and conditioned for 24 hours under standard atmospheric condition (RH 65±5%, temperature 20±2°C) (Wegen-Franken, Roest, Tank, & Neumann, 2006).

2.5 Novel extension frame

This frame is designed to extend the socks to maximum 70% relates to intensity of the disease. This frame is drived using combination of three gears as shown in Figure 2. Middle gear, connected with revolving handle, drives the two movable jaws in opposite direction.

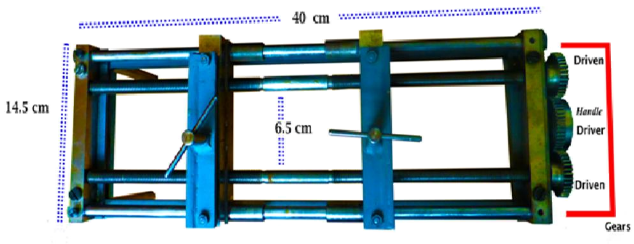


Figure 2 Novel extension frame

Maximum distance between jaws can be achieved up to 36 cm. As we rotate the handle, the jaws move apart and extend the fabric to required level (up to 70% and more). Total length of frame is 40 cm; width of jaws is 14.5 cm.

2.6 Thermal properties tester (TCi)

C-Therm (TCI tester) was used to analyze thermal properties of compression socks. This system consists of an external sensor, software for computer and control electronics. The standard test method EN 61326-2-4:2006 was used for this testing using TCI [16]. This test was performed under room temperature. The results are reported in Table 2.

Table 2 Thermal effusivity, conductivity and stitch density results in relaxed and extended state

Socks code	Position	Parameters	Elongation [%]							
			0 (Relaxed)	1	20	30	40	50	60	70
BIISJ	ankle	Thermal effusivity [W.s$^{1/2}$/m^2.K]	264.43	263.15	261.87	260.70	259.530	256.61	253.70	248.50
	calf		242.22	240.16	238.09	237.30	236.520	230.28	224.05	219.37
	ankle	Thermal conductivity [W/m.K]	0.1166	0.116	0.1157	0.1153	0.11495	0.1139	0.1129	0.1122
	calf		0.1090	0.1085	0.108	0.1076	0.1071	0.1050	0.1029	0.1013
	ankle	Stitches/inch^2	460	431	411	390.70	368.74	350	339	323.50
	calf		377.6	357	335	312	298	279	266	250
BIIISJ	ankle	Thermal effusivity [W.s$^{1/2}$/m^2.K]	219.20	218.05	216.91	212.77	208.63	203.65	198.68	195.50
	calf		216.24	215.62	215.01	212.20	209.39	203.90	198.41	193.05
	ankle	Thermal conductivity [W/m.K]	0.1012	0.101	0.1004	0.0991	0.0977	0.09600	0.0943	0.0929
	calf		0.0999	0.100	0.0999	0.0989	0.0980	0.0962	0.0943	0.0850
	ankle	Stitches/inch^2	372	351.51	330	309	288	270	252	232
	calf		273	252	230	208.2	194	179	164.4	150
DGIIRIB	ankle	Thermal effusivity [W.s$^{1/2}$/m^2.K]	170.71	178.68	186.66	190.35	194.04	198.70	200.90	210.20
	calf		190.38	193.41	196.44	199.35	202.27	201.77	201.27	200.60
	ankle	Thermal conductivity [W/m.K]	0.0850	0.088	0.0903	0.0915	0.0928	0.0934	0.0940	0.0950
	calf		0.0916	0.093	0.0936	0.0946	0.0955	0.0949	0.0952	0.0975
	ankle	Stitches/inch^2	364	340	315	299	283	258	232	207
	calf		243	226	209	201	183	166	157.6	149

Table 3 Statistical analysis of thermal properties

Parameters	Socks Code	Position	Socks Code	R-Square Value	p-Value <0.05	Correlation	Regression Model
Thermal effusivity [W.s$^{1/2}$/m^2.K]	BIISJ	ankle	BIISJ	91.61	*0.001	-0.96	Y=265.9 - 0.2093X
		calf		89.83	*0.001	-0.95	Y= 244.5 - 0.3151X
	BIIISJ	ankle	BIIISJ	96.57	*0.001	-0.98	Y= 221.9 - 0.3651X
		calf		91.44	*0.001	-0.96	Y= 219.8 - 0.3387X
	DGIIRIB	ankle	DGIIRIB	97.29	*0.001	0.99	Y= 173.5 + 0.6507X
		calf		75.33	*0.005	0.87	Y=192.8 + 0.1545X
Thermal conductivity [W/m.K]	BIISJ	ankle	BIISJ	95.66	*0.001	-0.98	Y= 0.1169 - 0.00001X
		calf		89.64	*0.001	-0.95	Y= 0.1100 - 0.00010X
	BIIISJ	ankle	BIIISJ	96.34	*0.001	-0.98	Y= 0.102 - 0.000127X
		calf		69.12	*0.011	-0.83	Y= 0.126 - 0.000172X
	DGIIRIB	ankle	DGIIRIB	91.93	*0.001	0.96	Y= 0.086+ 0.000132X
		calf		87.70	*0.001	0.94	Y= 0.092+ 0.000068X

3 RESULTS AND DISCUSSION

3.1 Effect of elastic elongation on thermal effusivity at ankle and calf portions

Table 2 and Figure 3 (a, b) depicts that as elastic elongation increases from 0% extension to 70% extension while thermal effusivity of BIISJ and BIIISJ samples decreases from 264.438 and 219.207 to 248.50 and 195.50 [W.s$^{1/2}$/m^2.K]

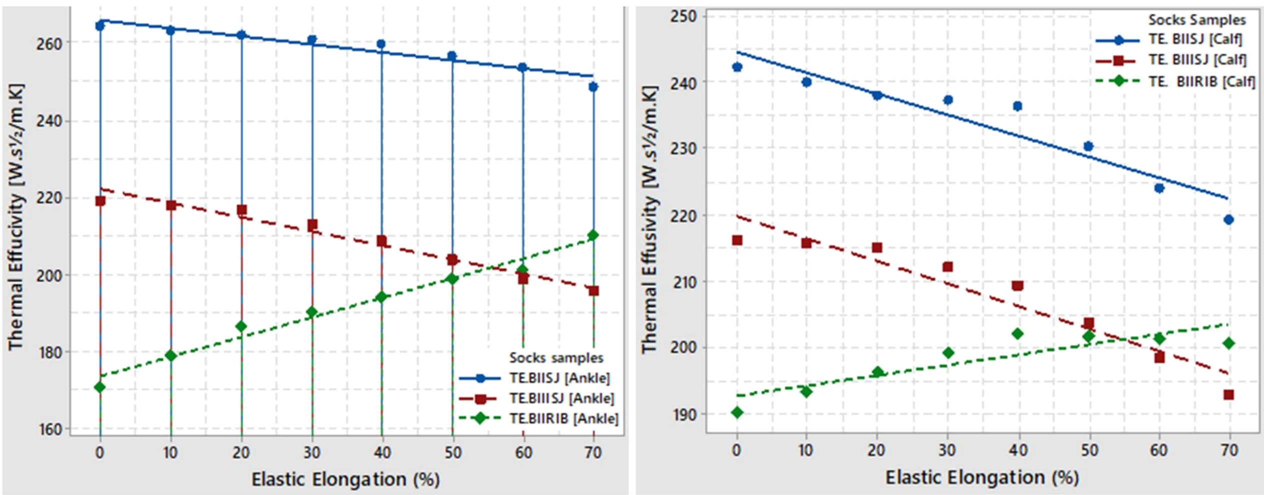
For DGIIRIB, it increases from 170.71 to 210.20 [W.sec$^{1/2}$/m^2.K]. The same trend was observed for thermal effusivity at calf portion which also decreases for BIISJ and BIIISJ from 242.22 and 216.40 to 219.37 and 193.056 [W.s$^{1/2}$/m^2.K]. For socks sample DGIIRIB, it increases from 190.38 to 200.20 [W.s$^{1/2}$/m^2.K].

Regression analysis of effect of elastic elongation on thermal effusivity was evaluated using Minitab 17 and are given in Table 3.

3.2 Effect of elastic elongation on thermal conductivity at ankle and calf portions

In Figure 4 we found that as the elastic elongation increases at ankle from relaxed state to extended state, thermal conductivity of samples BIISJ and BIIISJ decreases from 0.11660 and 0.10127 to 0.11223 and 0.09292 [W/m.K]. While thermal conductivity of socks samples DGIIRIB increases from 0.085 to 0.09504 [W/m.K] as elastic elongation increases. Thermal conductivity at calf portion which also decreases of samples BIISJ and BIIISJ from 0.1090 and 0.0999 to 0.1013 and 0.0850 [W/m.K].

While thermal effusivity increases of samples DGIIRIB, as elastic elongation increases, it increases from 0.085 to 0.0904 [W/m.K]. The reason of decrease in thermal conductivity of samples BIISJ and BIIISJ is due to decrease in stitch density and increase of pore size. Higher pore sizes because more air entrapped inside the fibers of yarns.



a) b)

Figure 3 Thermal effusivity affected by different extension levels (a) ankle and (b) calf

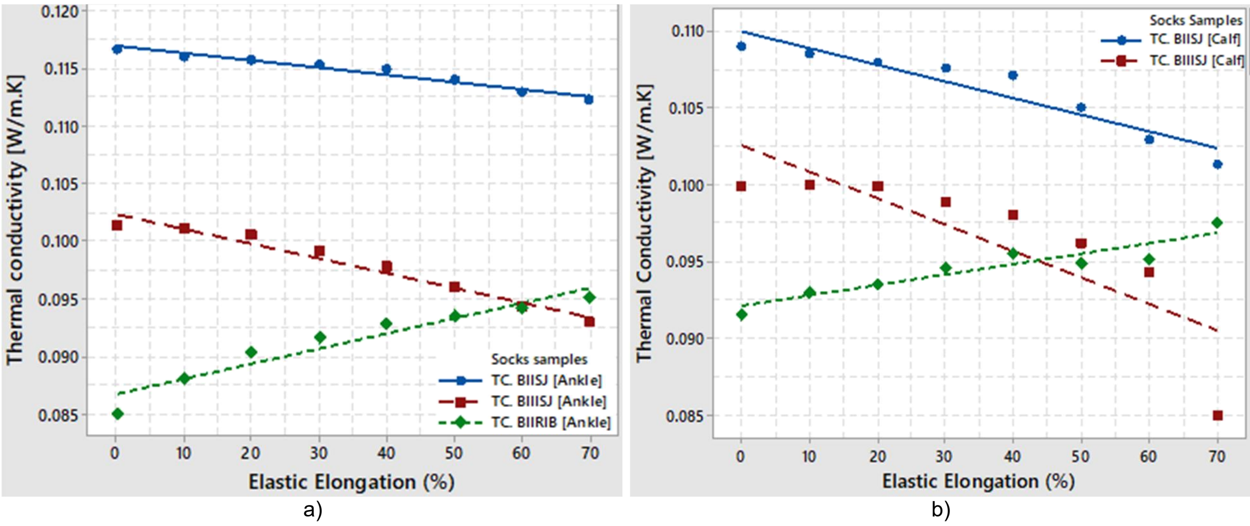


Figure 4 Thermal conductivity affected by different extension levels (a) ankle and (b) calf

4 CONCLUSION

In this research the comfort properties, thermal effusivity and thermal conductivity, of all three socks samples were evaluated and finalized and the socks sample DGIIRIB exhibited excellent results of thermal effusivity and thermal conductivity as elongated to 70%. Out of all three socks samples we found the best one regarding the easiness and optimized comfort level and DGIIRIB socks sample can be recommended as best to encounter hot microclimatic environment.

ACKNOWLEDGEMENTS: *This work was supported by the Technical University of Liberec, Czech Republic, under the project of student grant scheme 2019. SGS reference number is 21309.*

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WEEDS AS A SOURCE OF DEVELOPMENT IDEA ON BATIK MOTIVE

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Abstract: *Batik is a cultural heritage textile that becomes creative economy based on local advantage in Indonesia. The purpose of this study is to develop batik motives by using weeds as a source of ideas derived from the ecological wealth of Indonesia. The development of weed motive is done in the form of repeated and free pattern. Data were analyzed descriptively. The results showed that weeds can be used as a source of ideas for batik motives. The diversity of weed species makes the choice of a very rich motive. Weeds can be the main ornament or companion (isen-isen). The results of this study broke the World Record of the Indonesian Record Museum (MURI) as "The Proponent of Making Batik with the Staining of the Most Common Weeds" on March 1, 2016, through mordan-assisted weed extracts.*

Key words: *batik, weed, motive, local wisdom*

1 INTRODUCTION

Batik is original and traditional textile in Indonesia. In the research, batik is an ideas and philosophy of motive depart from conservation values, such as the preservation of natural resources and the preservation of local art and culture, the context with local potential and the traditional values of society. Conservation batik motifs can be derived from what is contained in nature, such as trees, plants, flowers, fruits or animals, including the art of carving, dance and traditional ornaments. In addition, the coloring and process of Batik Conservation must be environmentally friendly, using materials with recycled concept, low cost and no cost material.

Batik is a local name for textile products supplied in Indonesia for the technique of applying dyed-to-cloth patterns, using canting tools [1]. Batik is a craft that has high artistic value and has been a part of Indonesian culture (especially Java) since a long time. Batik is a traditional textile product of Indonesia that has been inherited between the begerasi. "Batik" is a word derived from the Javanese language. Batik comes from the word "amba" which means drawing and "tick" which means small (Suwarto, 1998: 8). Batik can also be interpreted as a craft art that refers to how to decorate the fabric with a wax cover to form its ornament, forming a dyeing field by dyed with a dye can [2].

The protection of batik can be done with continuous efforts to develop and maintain batik existence through scientific studies and innovation [3]. Research related to the development effort of batik industry sector, can be said as an effort to raise the image of arts and culture based on local wisdom [4]. As one of the creative industries, the development of creative motives is needed. But the creativity of the batik industry in developing the motive is still very low (National Strategic Issues). Many craftsmen only imitate the motives that sell in the market [5]. This research focuses on developing creative ideas of motive development with the demands of society today.

Weeds are found all over Indonesia. This plant is defined as wild plants or weeds, plants that interfere with cultivated crops or plants that are not obviously beneficial. Hundreds and even thousands of weeds have not been explored well. This research develops weeds as a source of ideas for the manufacture and development of batik motives, with the aim of:

1. identifying the characteristics of weeds to be explored into batik motives;
2. develop the design of batik motive with the source of the idea of weed, in the form of repeated pattern and free pattern, in accordance with the principles of design and the concept of making batik motive manually.

The benefits of this research in general are to add the treasures of the source of ideas for unique and creative batik motives, also can be applied in the batik industry. In addition, this research is useful for:

1. implement safeguarding efforts on batik as a cultural heritage, especially the traditional values held;
2. to increase the reproduction of batik motives and environmentally-based batik products on an ongoing basis;

3. encouraging the creation of ideas and innovative motives for the batik industry, as an industry driving tourism and creative economy.

2 METHODOLOGY

This research is a research oriented to the development and creation of works, therefore the approach used for this is the artistic approach of "Art Practice Based Research". This is related to the general purpose of research that is to produce batik design based on local resources as a source of ideas [6]. The research was conducted in batik/textile laboratory of Textile Department in Universitas Negeri Semarang. The exploration of weed species is conducted in the fertile medini tea plantation areas. The object of this research in the stage of basic research and development is batik with weeds as a source of ideas. The research focuses on the exploration of batik motives of suket as the richness of Indonesian motives based on local natural-physical resources. The steps of development batik motive are:

1. Literature study and direct observation about weeds;
2. Preparation of batik motive design with the source of weed idea manually or with computer aid;
3. Validation of motives to art experts and batik experts;
4. Applying the design of motives on batik cloth;
5. Assessing the quality of weed batik motive.

Early data collection on weed species and characteristics was done through literature study, direct field observation. For validation of ready-made motives and assessment of the results of application of motives on the fabric to experts used questionnaires. Data were analysed using qualitative descriptive analysis technique.

3 RESULTS AND DISCUSSION

3.1 Batik and batik motive characteristics

Batik has been known throughout the world as a traditional Indonesian cloth. Batik is Javanesse process of resist printing, where molten wax is poured over patterns before dyeing which leaves the waxed portion unaffected in dyeing [7]. Batik is also the indigenous wax resist dye process of Indonesia gradually yielded rich, sophisticated fabrics [8]. It is also said ".... today, batik has become a generic term referring to all categories of wax resist dyeing in the world". Thus, batik can be defined as a traditional Indonesian cloth with a distinctive motive, made with dyeing techniques, using the night as an obstacle. UNESCO asserts that batik's characteristics lie in "the use of night as an obstacle" and canting and copper stamp as a tool to attach the night on the surface of the fabric [9]. The uniqueness of the next batik is the motive. Traditional batik motive consists of two components: (1) main ornaments and (2) filler ornaments (*isen-isen*). *Isen-isen* also found in two kinds, namely: (1) *isen-isen* ornament and (2) background. Batik motive consists of repetition of motive units in all directions, into a unity of motives [10]. These motive units are also called patterns. In accordance with the pattern classification, there are types of patterned motives:

1. diagonal such as slopes, machetes, lyrical udan;
2. diagonal boxes such as sido mukti, sido asih, sido nuh,
3. irregular ferment, like ceplok, jlamprang;
4. hoarse;
5. buketan;
6. tumpal, etc.

3.2 Weed as source of batik motive idea

Weeds that are always around the cultivated plants can inhibit growth and suppress the end result of agriculture, because it utilizes growing facilities (such as nutrients, water, light and growing space) similar to cultivated plants. As a result of the behavior of the weeds, humans control or eradicate weeds from the yard, gardens, parks, sidewalks with:

1. mechanical means, such as pulled, burned;
2. biological methods, used as animal feed or made natural fertilizer;
3. chemically, using selective or no selective herbicides [11].

Weeds can be classified according to where they growth, their leaf shape, length of life and the level of malignancy. Based on the growth site, it is known:

1. land weeds, such as grasses;
2. aquatic weeds, such as water hyacinth (Eichornia Crassipes);
3. weeds that live parasites ride on other plants, such as parasites [12].

3.3 Developing weed for batik motive

This research succeeded in developing 50 kinds of motives with the source of weed idea and applied it to batik motive, among others:

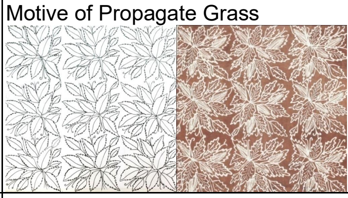
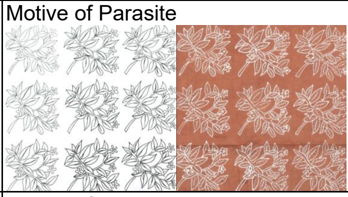
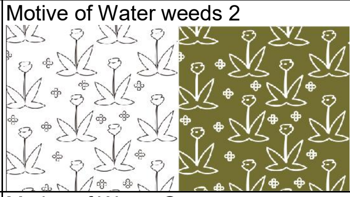
(1) *Wudelan* (Cyperus Kyllingia Endl); (2) Broken Steering (Emilia Sonchifolia L.); (3) *Dadahan* (Fagus Sylvatica); (4) *Cacalincingan* (Oxalis Corniculata L.); (5) *Tumbaran* (Fimbristyllis Littoralis Gaudich); (6) *Kremah* (Alternanthera Brasiliana); (7) Purple buttoned grass (Borreria Laevis); (8) *Pletekan* (Ruellia Tuberosa L.); (9) *Brambangan/Aur-aur* (Commelina Diffusa Burm); (10) *Kemangi* (Spigelia Anthelmia); (11) Putting Weed (Clibadium Surinamense L.); (12) *Grintingan* (Cynodon Dactylon); (13) *Godong Puser* (Synonym H. Capitata Jacq); (14) *Pulutan* (Urena Lobata); (15) Pait Grass (Paspalum Conjugatum); (16) *Getih-getihan* (Rivina Humilis L.); (17) *Liman* (Elephantous Scaber); (18) *Meniran* (Phyllantus Niruri); (19) *Patikan Kebo* (Euphorbia Hirta L.); (20) Spinach Thorns (Amaranthus Spinosus L.); (21) *Genjoran* (Digitaria Adscendens (HBK)

Henr); (22) Rendering (Cyperus Iria L.); (23) Water Boyfriend (Impatiens Balsamina L.); (24) *Keris* (Sceleria Sumatrensis Reyz); (25) *Sintrong* (Erechtites Valerianifolia); (26) *Urang-aring* (Elipta Alba L.); (27) *Sidagori* (Sida Rhombifolia L.); (28) Crocodile Wild (Portulaca Oleracea L.); (29) *Patikan Emas* (Euphorbia Prunifolia Jacq); (30) *Jebungan* (Cyperrus Difformis L.); (31) *Tuton*, Black Face (Echinochloa Colonum); (32) *Mamam* (Cleome Rutidosperma); (33) *Kirinyuh* (Choromolaena Odorata L.); (34) *Songgolangit* (Tridax Procumbbens); (35) *Malela* (Brachiaria Mutica); (36) *Teki* (Cyperus Rotundus L.); (37) *Bengal* (Panicium); (38) Clover (Marsilea Crenata); (39) *Tiwai* (Eleutherine Palmifolia); (40) *Sembung Rambat* (Mikani Micranta); (42) Acoustical Plants (Acalypha Australis) (43) *Rerumputan* (Acalypha Indica L.); (44) *Kokosan* (Lansium Aqueum); (45) *Jambe-jambean* (Setane Plicata (Lamk) T.Cooke); (46) *Kumis Kucing* (Utricularia; (47) *Enceng Gondok* (Eichorna Grassipes); (48) *Rumput Air* (Hydrilla Verticillata); (49) *Tuan Putri* (Cassyta Eiliformis); (50) *Benalu Mindi* Tree (Melia Azedarach).

Not all types of weed plants were developed as inspiration for batik motives. Some of the following motives in Table 1 are developed based on the source of ideas and apply it to batik motives.

Batik as a cultural heritage in one way has the traditional values that are unique and at the same time become the identity of the community so not willing to be released. The implication is that traditional batik with motives and cultivation techniques that have been in existence need to be preserved from one generation to the next. On the other hand, the development of civilization of society with the modernity it carries is also important to be faced, accommodated, and faced as a condition of existence of batik in Indonesia. The implication, batik development efforts with the creativity and innovation is the necessity.

Table1 Weed motive design with repeating patterns

No	Plats	Developing Motive	Description
1		Motive of Grass 	• Motives structure use rotation repeat technique, consists of *isen-isen* and main motives. Colour design uses white fabric for *isen-isen*, orange for main motive, and dark brown for background. • This type of weed often lives in the low and medium land *(Axonopus compressus)*. This grass is classified as wild and strong with roots that are also strong. The nature of these grass plants with a spacing of about 5-10 cm.
2		Motive of Propagate Grass 	• Motive structure use full repeat technique, only in the form or main motive. There is no *isen-isen*. Colour design uses white for main motive, and brown for background. • This type of weed called *Sembung Rambat* in Indonesia (*Mikania Micranta*) often lives on medium and high plains. This grass is classified as wild and strong with roots that are also *strong*. The nature of these grass plants spreads with a spacing of about 10-30 cm.
3		Motive of Water weeds 	• Motives structure use full repeat technique, consists of main & *isen-isen* motives. Colour design uses white for *isen-isen* and main motive, and brown for the background. • This type of weed is called *Eceng Gondok* in Indonesia, with the Latin name *Eichornia Crassipes*. This type of weed often lives in the low and medium land, especially in marshes or fresh water. These weeds are classified as wild with a fairly strong stem.
4		Motive of Parasite 	• Motives structure use full repeat technique, only in the form of main motives. There is no *isen-isen*. Colour design uses white for main motive, and brown for background. • This type of weed is called the mango tree parasite (*Dendrophthoe Pentandra*) that often lives in the lowlands, medium and high. This parasite is classified as wild and strong.
5		Motive of Water weeds 2 	• Motives structure use half full repeat technique, consists of main & isen-isen motives. Colour design uses white for isen-isen and main motive, and purple for the background. • Called *Eichornia Crassipes*. The development of this weed motive can be done by taking leaves and leaves as the main motive, and some form variations as a supporting motive. *Isen-isen* uses stylization of leaf bone
6		Motive of Water Grass 	• Motives structure use random repeat technique consists of main & *isen-isen* motives. Colour design uses white for *isen-isen* and main motive, and green for the background. • The development of this motive comes from the sea with the scientific name *Hydrilla Verticillata*. The development of the weed motives of this plant can be done by using the basic as the main motive, and also as a motive for support.

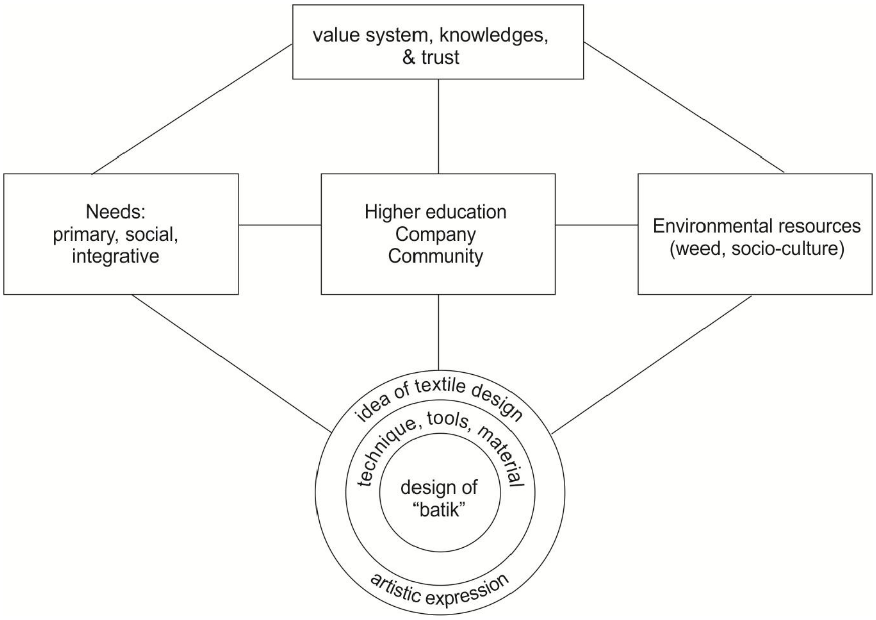


Figure 1 Chart of batik in the context of socio-cultural and nature-physical environment

In the context of culture, batik development always cannot be separated from the value system, knowledge and belief that surround it [13]. In this context batik is in a paradoxical position. Batik as a cultural heritage in one way has the traditional values that are unique and at the same time becomes the identity of the community so not willing to be released. The implication is that traditional batik with motifs and cultivation techniques that have been in existence need to be preserved from one generation to the next. On the other hand, the development of civilization of society with the modernity it carries is also important to be faced, accommodated and faced as a condition of existence of batik in Indonesia. The implication, batik development efforts with the creativity and innovation is the necessity.

Thus, the development of batik motifs with the source of sugar ideas need to be done by not breaking away from the cultural framework.

In Figure 1 is presented a chart showing the framework of batik development with the source of the idea of weeds in the cultural context.

3.4 Results of expert assessment of batik

The assessment was carried out by 7 respondents consisting of an ecology-linguistics expert, a botanist and five batik artisans using structured interview techniques. This interview took five responses from cultural experts about weed names in a local perspective in Indonesia. Five responses were also taken from botanists about the habitat and characteristics of weed species as a source of ecological ideas for the creation of batik designs. The next five responses were taken from traditional batik artisans about the potential and strategy of applying weeds as a batik motif design.

The results of product assessment to batik and art experts show that weeds are very feasible to be a source of batik motive ideas. *Firstly*, since weeds have the original name of the area (oral tradition) such as paitan grass, cacalincingan, patikan kebo, parijoto, kung wungu, etc., so the name of batik can easily take the original name of the plant from the original language of the region. *Secondly*, people generally recognize some usage of weeds that have not been researched, but commonly used by the community for medicines, such as roots of tares are usually used for hot medicine, parijoto fruit for pregnant women to give birth to beautiful, handsome and healthy children, which uses certain weeds as symbols or symbols of fertility. *Third*, the placement of weeds as batik motives can be "ornaments" and can also be isen-isen. This causes the creations to be made to vary greatly in ornaments and *isen-isen*. *Fourth*, the repetition of the motive rapot can be done in parallel or in diagonal form, thus adding to the diversity of the motive.

Implementation of research results in the course of Textile Design with the approach of Project Based Learning held on December 6 to 7, 2016 in Kampung Budaya of Universitas Negeri Semarang, Indonesia. The exhibition was attended by Chairman of "Dekranasda" of Central Java Province. The exhibition features batik shawl products with "*gulma"* (weeds)" as the source of ideas, with the theme "*Luhuring Sampur Wasiat Agung ing Bawana Konservasi*". Visitors of the exhibition responded through questionnaires as well as oral statements. In general, visitors feel batik products with the source of the idea of weeds are very rich, because weed species very much reach hundreds of species and will produce a variety of motives that will not be exhausted to be excavated.

4 CONCLUSION

This research produces 6 kinds of motives derived from the source of the idea of weeds, which is can applied directly in the form of staining using the weed material itself as a natural dye. Weed diversity can be the source of ideas for making motives, which are: motive of grass, motive of propagate grass, motive of water weeds, motive of parasite, motive of water weeds 2 and motive of water grass. Making weed batik motives are done in four structures: rotation repeat technique, full repeat technique, half full repeat technique and random repeat technique.

Not all weeds can optimally make into design, because they are have different ecological characteristics, shape and aesthetic. The resulting color fastness is considered good, as evidenced by the lack of color at the time of *dilorod* (melted) using boiling water with the addition of a bit of alkaline ash. The conclusion that can be taken is that weeds are very potential to be a source of batik ideas. Further research needs to be done for each type of weed on the coloring.

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METHODOLOGY FOR ASSESSMENT THE EFFICIENCY OF PRODUCTION CAPACITIES MANAGEMENT AT TEXTILE ENTERPRISES

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Abstract: *The article describes the method for determining the efficiency of production capacity management in textile enterprises. The methodology is based on a weighting factor and expert assessment. Despite the fact, that there are many methods of assessment efficiency of production capacities usage, much of them based on financial results of enterprise and this do not always shows causes of the problem in performance of production capacity usage. In this paper, have been elaborated method based on integral rate of results and quality of the performance of production capacity management in textile enterprises. For choosing criteria of all performance process were involved five experts in textile area, including leading engineers and managers. Proposed in article the technique is universal and it can be used in other industries. At the end of the article, the methodology was tested on the basis of real textile enterprises. According to author`s opinion, proposed method does not reflect the influence of indicators of production capacity management efficiency on the financial results of enterprises, that approved the space for further research in this area.*

Keywords: *production capacity, utilization, effectiveness, production process, assessment, textile.*

1 INTRODUCTION

In modern conditions, the problem of reliable assessment of the production capacity of the enterprise and the level of equipment load (jobs) has become particularly important and is very important. In the development of technology, production technology under the influence of technological progress there are significant changes, changing their quality part. They are reflected in the complication of technology, in its computerization, automatic control, increasing unit capacity. Large systems of machines are being created and implemented, which increase the efficiency of equipment of enterprises and accelerate the production process due to its threading, continuity and flexibility. As a result, qualitatively new opportunities arise for the creation and growth of the production capacities of existing firms and enterprises.

The purpose of this article is to improve the methodology for assessing the efficiency of managing the use of production capacity in textile enterprises.

It should be noted that characteristic for textile production is the construction of production structures on the technological principle, the presence of a large number of consecutive technological transitions. For example, cotton yarn is ready for transfer to weaving after 8-11 transitions, wool - after 20; In the process of finishing cotton fabric goes through about 40 operations. Such a multi-stage production process makes it difficult to assess the efficiency of production capacity management in enterprises. Based on this, we decided to develop a methodology that will be able to evaluate the effectiveness of the process and the results of production capacity management. The technique is based on expert assessments and an appropriate scale.

2 METHODOLOGY OF RESEARCH

The issues of management, specialization and optimization of production capacities are reflected in the scientific works of the following foreign scientists: V.J. Stevenson, R. Chase, R.F. Jacobs [14], W. Clein, [3], C.G. Dickerson [4], Juvong Lee [10], D.J. Strickland, M.M. Ahmad, N. Dhafr [2], C. Forza, F. Salvador [8] and others. A significant contribution to the development of the theory and practice of production capacity management was made by economists from the CIS countries: G.A. Aleksandrov, M.S. Abryutin [1], R.A. Fatkhutdinov and others. Aspects of the organization of the use of production capacity in industrial enterprises and its management were studied by Russian scientists K.S. Krivyakin [11] and M.V. Dadalova [5].

The study of this problem is devoted to the work of many domestic scientists, economists, such as S. Iskandarov, A. Ulmasov, S. Gulyamov, M. Sharifhodzhayev, M. Boltabaev, Z. Khakimov etc., which are considered mainly the theory of reproduction of basic production assets and improving the competitiveness of textile enterprises based on marketing approaches.

E. Milewska researched problem of manufacturing process flexibility in view of a company's material and information flow stream management, were discussed IT tools supporting the process of production planning, organization and control, as well as MRP II/ERP, MES and APS. She scientifically approved that the automation of information flow in a production control system makes it possible to increase the level of production capacity use and optimize the size of the company's intensive and extensive reserves [13].

A performance indicator can be defined as "a variable" that quantitatively expresses the effectiveness or efficiency, or both, of a part of or a whole process or system against a given norm or target [12]. The desired global production objectives in the context of a production management system can be more objectively defined as the reference values for significant measures of plant efficiency, production plant productivity, mean product quality and others. These production objectives are often called implicit objectives as they usually can be expressed only implicitly as functions of the measurable and manipulatable variables [15]. Since implicit objectives are not directly measurable, their translation into a set of output production process variables should be provided. These output production process variables should have the following properties [16]. Issues of utilization of key performance indicators in production control were investigated by Vladimir Jovan, Sebastjan Zorzut and Alenka Žnidaršič. In their work was proposed an approach to measuring and presenting the attainment of production objectives in the form of introducing production KPI [17].

However, despite the considerable attention paid to solving the issues of using the production capacity of an enterprise, a single point of view regarding the determination of the content of production capacity has not yet been developed and a comprehensive assessment of the management efficiency of the production capacity of textile enterprises has not been studied.

In current research were used expert assessment, analysis and economic-mathematical methods. For assessment of criterias were chosen five experts from textile branch, and has been checked the degree of reliability of the expert assessment for each group of indicators was calculated the coefficient of concordance. For evaluating production capacity management in textile enterprises elaborated the special scale, which consist of five criteria's.

3 RESULTS OF RESEARCH

The category of "production capacity" is one of the keys to economic science. It reflects the potential of associations, enterprises, production shops and therefore, the level of competitiveness of enterprises.

Professor of the Turkish Social Institute Kahramanmaraş Ö. Güneçıkan [9] gives the following definition regarding production capacity: "Production capacity of an enterprise is the production quantity that the enterprise is capable of realizing by using the available production factors in a rational manner within a certain period of time".

Determining the value of production capacity occupies a leading place in identifying and evaluating production reserves, and its planning is one of the strategic directions of development.

In scientific works of M. Dadalova [7] and K.S. Krivyakin [6] various classifications of factors influencing the size and capacity utilization are given. Analyzing the classification data, it should be noted that it highlights not only the factors influencing the size and level of capacity utilization but also:

1. Conducted an enlarged grouping of these factors;
2. Their influence on individual elements associated with the calculation of production capacity is measured.

The disadvantages of the considered classification of factors include the following:

1. The grouping of factors is not well constructed, i.e. it mainly relies on the analysis of the influence of elements on the calculation and use of capacity;
2. The previous drawback is caused, in our opinion, by the fact that the proposed grouping of factors does not properly take into account the influence of factors of production on the size and degree of utilization of production capacity;
3. The reliability of the influence of individual factors on the size and level of capacity utilization raises certain doubts. For example, the possible unscheduled operation of equipment (i.e., use of Saturdays, Sundays and holidays, the third (fourth) shift, lunch breaks, as well as the transition to a continuous week) should be taken into account in the process of calculating the production capacity. In other words, this only characterizes the shortcomings of the existing methods for calculating and planning capacities, but cannot be an objective factor that requires consideration of its influence in the classification. In addition, the methods used in various industries for determining the size of production capacities do not involve taking into account such subjective factors as reducing losses from marriage, reducing losses in working time,

improving forms and systems of labor in enterprises, developing competition and others;

4. This classification of factors also implies consideration of the features of machine-building production only. We can single out a whole number of classification factors cited in it, which are characteristic of this type of production and do not affect the production capacity of instrumental or aggregate production:
   - increase in the number of production areas;
   - involvement in the production of unused space;
   - use of more modern tooling and tools;
   - introduction of methods of scientific organization of labor;
   - rationalization of labor practices of production workers;
   - professional development of production workers;
   - reduction of unproductive loss of working time;
   - reduction of losses from marriage;
   - improvement of rationing and wage systems;
   - expansion of socialist competition;
   - increase in shift coefficient and equipment load due to reduction of unproductive losses in the use of equipment and an increase in the number of key production workers;
   - an increase in the production program in proportion to assortment;
   - an increase in the production program disproportionately set assortment (change of nomenclature) due to production in accordance with the developed optimal production plan;
   - an increase in the production program due to the expansion of deliveries from the cooperation.

In our opinion, this and other (noted above) classifications need further development by highlighting the interrelation of factors with individual elements of the production process. It is also necessary to take into account those factors influencing the size and degree of use of production capacity, which reflect the specifics of the activities of textile enterprises.

The classification we propose the main factors influencing the size and degree of utilization of the production capacities of enterprises in this industry is presented in Table 1.

This approach to the classification of factors allows you to:

- to distinguish factors taking into account their influence on the size and degree of capacity utilization;
- takes into account the peculiarities of textile enterprises related to aggregate concentration (manifested in the periodic replacement of basic technological devices with more productive ones), flow continuity (in cotton processing) and their complexity;
- takes into account the relationship of factors with individual elements of the production process.

The amount of production capacity is influenced by entrepreneurial abilities, labor and capital. Entrepreneurial skills determine management decisions on the development of existing and the creation of new production facilities. These solutions are implemented in practice using the labor of employees of enterprises. The three elements that make up the capital directly affect the amount of production capacity - the active part of fixed assets, intangible assets and part of current assets, presented in the form of stocks. The development of the first element is manifested in an increase in the number of leading equipment units and the replacement of basic technological devices with new, more productive industrial units. Intangible assets are associated with the improvement of the existing technology and the introduction of advanced technologies (Table 1).

In Table 1 was presented functional control units of production capacity in textile enterprises, which was divided into two parts: external and internal factors. The peculiarity of this classification is that it was developed taking into account the specifics of the enterprise of the textile complex and includes the specifics of a continuous production process.

The main factors that determine the level of production capacity are considered to be: the number of available equipment, the size of production areas, the progressiveness of technology, the number of qualified personnel, the quantity and quality of material resources used and the advanced organization of production.

In the course of the study, the author came to the conclusion that "the effective use of production capacity implies a rational distribution of the production resources available to the enterprise, which are necessary for the flow of interrelated processes in space and time by means of installed technology, advanced technology and skilled personnel". A key factor in the level of capacity utilization in a market economy is the position of the enterprise in the market, the level of competition and the level of demand for products.

Table 1 Functional control units of production capacity in textile enterprises

PC value	Functional blocks of planning and management	PC usage level
External factors		
1. The technical level of purchased equipment	Technical block	1. Provision with spare parts and components for equipment repair
1. The degree of progressiveness of borrowed technology 2. Installed process schedules	Technological block	1. Restrictions on the supply of materials, tools, providing the technological cycle
1. Availability of state programs for subsidizing the development of the PM industry	Economical block	1. The need for the company's products from the market
	Resource block	1. Logistics of the enterprise 2. Level of energy supply
1. Legislative and regulatory acts restricting the activities of enterprises	Management block	1. Malfunctions in infrastructure operation
Internal factors		
1. Equipment performance 2. Available production area 3. The level of proportionality in the bandwidth of equipment groups	Technical block	1. The intensity of input of new capacities 2. Mode of use of equipment 3. Excessive downtime
1. The degree of automation and mechanization of production processes 2. The degree of development of technology workers	Technological block	1. The technical level of purchased equipment
1. The level of investment in the means of production and in its organization	Economical block	1. The technical level of purchased equipment
1. The depreciation policy of the enterprise 2. Entrepreneurial activity	Resource block	1. The technical level of purchased equipment

Source: author`s elaboration.

In the work of M.V. Dadalova [5] a methodology is presented for assessing the efficiency of production capacity management at enterprises in the glass industry, but there are some drawbacks:

- the absence of a valid point scale for the results of qualitative and quantitative assessments;
- in the parameter of quality of production capacity management there is an item “quality of production capacity planning”, which does not exactly indicate what kind of planning was meant (calendar, tactical, strategic);
- in the parameter of quality of production capacity management there is an item "Performance of functions on the management of production capacity" and in the manual it is not specified how to determine the degree of fulfillment (or non-fulfillment) of management functions in the enterprise;
- the points for the quality parameters and the effectiveness of the definition of the production capacity are divided into three: 0, 2.5 and 5. The presence of a 2.5 point partially complicates the calculation process in multiplying by the significance of the parameter.
- in the parameter for determining the effectiveness of production capacity management in textile enterprises, there is an item "product competitiveness level", which is based only on the product quality level, which does not fully reveal the competitiveness of products.

According to the theory of famous modern economists as M. Porter, the first factor of competitiveness is quality and the second factor is the price of products. Therefore, to evaluate the competitiveness of products only on the basis of quality is not entirely true. In addition, it is necessary to evaluate the effectiveness of the use of equipment and not the competitiveness of products, which is the marketing function.

4 DISCUSSION

Considering a number of shortcomings of the method of M.V. Dadalova we have presented a methodology for evaluating the efficiency of managing production capacity in textile enterprises (Tables 1, 2). One of the advantages of the methodology is the inclusion of the item “Average coefficient of total efficiency of all equipment (OEE)” in the quality control parameter of production capacity. Another distinctive feature of the methodology is the reassessment of the significance of the parameters of the scale by experts in the textile industry. In addition, the scores for the quality parameters and the performance of the definition capacity management to simplify the calculations are divided into three integers: 0, 5 and 10.

In order to improve the methodology for assessing the competitiveness of light industry enterprises, a questionnaire was developed and an expert assessment of the factors of enterprise competitiveness was conducted. In the course of the study, experts evaluated on a five-point scale the weight of each of the four proposed groups of factors assessing the competitiveness of an enterprise, namely, the competitiveness of a product, financial, production and marketing factors. A ranking of the main indicators for evaluating each factor was also carried out.

To check the degree of reliability of the expert assessment for each group of indicators, the coefficient of concordance W was calculated, which shows how much the experts' opinions are coordinated, that is, belong to the same general population of estimates. The coefficient of concordance is calculated by the formula:

$$W = \frac{12 \sum_{i=1}^{n} (r_i - \overline{r})^2}{N^2 (n^3 - n)} \quad (1)$$

where: 12 is a constant in the formula for calculating the coefficient of concordance proposed by Kendall; n is the number of indicators; N is the number of experts; r_{ij} is rank of the i^{th} indicator determined by the j^{th} expert; r_i is the sum of the ranks of the i^{th} indicator for all experts; $\overline{r}$ is average score of all indicators ($r = N(n+1)/2$); W is Kendall coefficient of concordance [14].

The value of the coefficient of concordance can vary in the range from 0 to 1, where its equality to one means complete consistency of expert opinions and equality to zero indicates that there is no connection between the estimates.

In the case when $0.2 \leq W \leq 0.4$, there is a weak consistency of expert opinions and with $W \geq 0.6$ it can be said that there is a strong consistency of expert opinions. In addition, to determine the weights of each factor we used the Fishbourne formula (for all i from 1 to n):

$$a_i = 2*(n-r_i+1)/n*(n+1) \quad (2)$$

where: a_i is the weight coefficient of the i^{th} criterion, n is the number of evaluation criteria, r_i is rank assigned to the i^{th} indicator.

The results of the expert assessment of the importance of competitiveness factors and checking the consistency of expert opinions are presented in Tables 2 and 3.

On Table 2 is presented expert assessment of the importance of quality factors of production capacity management in textile enterprises and on The number of indicators (n) is 5. Five experts (N) were involved.

The average score of all indicators ($\overline{r}$) is 15. Then we get:

$$W = 12*111/25*(125-5) = 1332/3000 = 0.44 \quad (3)$$

The degree of consistency of expert estimates can be considered acceptable, since W=0.44 > 0.40.

According to experts, the most significant is the financial factor and the least - the production factor. Similarly, we find weighting factors for the effectiveness of production capacity management in textile enterprises.

Table 3 is showed expert assessment of the importance of factors of productivity of production capacity management.

Here, too, n is 5, and N -5. The average score of all indicators ($\overline{r}$) is 15. Then we get:

$$W = 12*189/25*(125-5) = 2268/3000 = 0.75 \quad (4)$$

The degree of consistency of expert estimates can be considered complete, since W = 0.75 > 0.60.

And the most significant, according to experts, is the average total efficiency ratio of all equipment and the least is the investment provision of production capacity.

Table 2 Expert assessment of the importance of quality factors of production capacity management in textile enterprises

Evaluation Criteria/ /Experts	Quality of capacity planning	Performance of capacity management functions	The motivation of staff in the use of production capacity management	Staffing	Methodical security
1 expert	5	4	4	2	1
2 expert	4	3	2	1	2
3 expert	5	3	5	4	3
4 expert	4	5	3	4	1
5 expert	4	5	2	4	2
Overall	***22***	***20***	***16***	***15***	***9***

Source based on expert`s assessment.

Table 3 Expert assessment of the importance of factors of productivity of production capacity management in textile enterprises

Evaluation Criteria/ /Experts	Sustainability of production plans	Investment provision of production capacity	The ratio of production capacity (annual)	Average total efficiency ratio of all equipment (OEE)	Utilization of equipment
1 expert	4	1	3	5	4
2 expert	5	1	2	4	2
3 expert	4	3	3	5	2
4 expert	5	1	3	5	1
5 expert	4	2	3	5	3
Overall	***22***	***8***	***14***	***24***	***12***

Source based on expert`s assessment.

We have presented a methodology for assessing the efficiency of production capacity management in textile enterprises (Tables 4 and 5). On Table 4 we presented methods for assessing the quality of production capacity management in textile enterprises and on Table 5 are showed methods for assessing results of the performance of production capacity management in textile enterprises.

The assessment is carried out by the expert commission, which includes leading experts with extensive experience in the field of textile industry. And the answers to the questions of staff motivation in the use of production capacity management can be purchased only through a questionnaire.

To determine the values of the parameters of the investment support of production capacity, the sustainability of the implementation of production plans, the calculation of the rate of renewal of production capacity and the level of use of production capacity must be based on the primary documentation of the enterprise. And as an indicator of the competitiveness of products manufactured at these facilities, product quality has been selected and this item is faced with the task of determining the share of quality products complying with state standard (GOST) or ISO standards.

Table 4 Methods for assessing the quality of production capacity management in textile enterprises

Quality parameters capacity management	Parameter value	The significance of the parameter	Points
Quality of capacity planning	- there is no plan for the development of production capacity - there is a plan, but not linked to common enterprise strategy - the plan for the development of production capacity is an organic part of the overall strategy of the enterprise	0.27	0 5 10
Performance of capacity management functions	- not performed - partially performed - fully implemented	0.24	0 5 10
The motivation of staff in the use of production capacity management	- not motivated - poorly motivated - high level of motivation	0.20	0 5 10
Staffing	- not enough security qualified personnel - partially qualified personnel - fully qualified staff	0.18	0 5 10
Methodical security	- missing - partial security - full security	0.11	0 5 10
Capacity management quality ratio			K_{qCM}

Source: author`s elaboration.

Table 5 Methods for assessing results of the performance of production capacity management in textile enterprises

Quality parameters capacity management	Parameter value	The significance of the parameter	Points
Sustainability of production plans	Absolute value actual deviations from planned: - above 10% - about 5 to 10% - up to 5%	0.21	0 5 10
Investment provision of production capacity	Investment in PM in total investment structure: - up to 30% - from 30 to 40% - over 40%	0.11	0 5 10
The ratio of production capacity (annual)	- from 2 to 5% - from 5 to 10% - over 10%	0.21	0 5 10
Average total efficiency ratio of all equipment (OEE)	Average total efficiency ratio of all equipment - to 0.4 - 0.41-0.79 - 0.8-1	0.28	0 5 10
Utilization of equipment	Utilization of equipment: - less than 60% - 61-80% - 81-100%	0.19	0 5 10
The capacity management performance efficiency ratio			K_{rCM}

Source: author`s elaboration.

After determining the values of the relevant parameters of quality and effectiveness of production capacity management, we will calculate the integral efficiency factor of capacity management:

$$K_{CM} = \sqrt{K_{qualCM} \cdot K_{resCM}} \quad (5)$$

where K_{qualCM} is quality factor PCM and K_{resCM} is a coefficient of performance PCMP.

The calculation of the quality factor PCM is made according to the formula

$$K_{qualICM} = \frac{\sum_{i=1}^{n} K_{val.qual} * d_i}{K_{qual.max}} \quad (6)$$

where d_i is the significance of this parameter, $K_{val.qual}$ *is* value of this parameter*;* $K_{qual.max}$ *is* a maximum value of this parameter.

The calculation of the coefficient of the effectiveness of the UPM is made according to the formula:

$$K_{resCM} = \frac{\sum_{i=1}^{n} K_{val.res} * d_i}{K_{res.max}} \quad (7)$$

where d_i is the significance of this parameter; K_{resCM} *is* value of this parameter; $K_{res.max}$ *is* a maximum value of this parameter.

After calculating the integral index we need an appropriate scale for analyzing the level of management of the use of production capacity in textile enterprises. In the course of the dissertation research we developed a scale for evaluating the management of production capacity in textile enterprises based on expert assessments; leading experts in the textile industry were selected as experts: chief specialist of the "Uztekstilprom" association, chief technologist, chief engineer, head of the production department and a financial manager of textile enterprises that have solid experience and rich experience (Table 6).

On Table 6 proposed scale for evaluating production capacity management in textile enterprises, experts devided evaluation value into five levels, as well as: critical, unsatisfactory, satisfactory, good and perfect.

The proposed necessary measures to improve the management of production capacity are not exhaustive; they only indicate the main direction of identifying the reasons for the decline in production capacity. Here, in our opinion, it would be appropriate to use the cause-and-effect method of Eliyahu Goldratt [6] and based on this methodology to construct a diagram of the current reality tree and to determine the root causes.

The approbation of the methodology for assessing the level of efficiency of use of production capacity of textile enterprises was carried out at three enterprises operating in Namangan region on the basis of calculation and statistical data for 2017, the results of which are given on Table 7.

Table 6 Scale for evaluating production capacity management in textile enterprises

The result of the integral indicator	Evaluation value	Necessary activities to improve production capacity management
from 0 to 0.30%	Critical	There is an urgent need to audit the financial and marketing activities of the enterprise and make a technical inventory. Analyze the possibility of diversification of production. Urgent measures should be taken to increase the level of capacity utilization.
from 0.31 to 50	Unsatisfactory	It is necessary to calculate the break-even point of production. Measures should be taken to increase the level of capacity utilization.
from 0.51 to 70	Satisfactory	Conduct continuous monitoring of equipment downtime, identify bottlenecks of production capacity. Take measures to ensure the balancing of production capacity.
from 0.71 to 0.85	Good	It is necessary to conduct continuous monitoring of equipment downtime, identify bottlenecks of production capacity. Take measures to ensure the balancing of production capacity and to ensure the connectivity of the equipment fleet. It is advisable to create a development strategy for the use of production capacity.
from 0.86 to 1	Perfect	You can expand the scale of production; consider attracting investment in fixed assets of the enterprise. It is advisable to improve the development strategy of the use of production capacity.

Source: author`s elaboration.

Table 7 The results of the evaluation of the level of efficiency of use of production capacity of research enterprises

Enterprises name	The ratio of the quality of production capacity management	Capacity management performance factor	The result of the integral indicator	Evaluation value
"Namangan Tukimachi Sanoat" LLC	0.78	0.76	0.59	Satisfactory
JV LLC "Uchkurgonteks"	0.85	0.86	0.73	Good
"Namangan Tukimachi Sanoat Textiles" LLC	0.73	0.84	0.61	Satisfactory

Source: author`s calculations based on research.

As can be seen from the Table 7, the results of the integral indices of Namangan Tukimachi Sanoat LLC, JV Uchkurgonteks LLC, Namangan Tukimachi Sanoat Textile LLC are respectively 0.59, 0.73 and 0.61. Judging by the evaluation results, it is clear that only at JV LLC Uchkurgonteks the level of efficiency of managing production capacity is good, while at Namangan Tukimachi Sanoat LLC and Namangan Tukimachi Sanoat Textile LLC the level of efficiency of managing capacity utilization is satisfactory that confirms the availability of reserves to improve the efficiency of management of capacity utilization.

5 CONCLUSIONS

Thus, the use of the methodology proposed by the authors for evaluating the management of production capacity in textile enterprises, based on the application of a point method for evaluation and characterized by the use of weights, will determine the level of efficiency of the production capacity management process in textile enterprises, and justify possible ways to improve competitiveness for each product.

In the case of a low level of the coefficient of efficiency of management of the use of production capacities, a number of measures should be taken to improve the management efficiency of the use of production capacities in enterprises.

The method proposed by us is distinguished by the strength of a comprehensive assessment of the entire process of managing the use of the production capacity of textile enterprises and it can also be applied in other industrial sectors such as mechanical engineering, light industry and food industry. But along with the advantages, this method has its drawbacks: the method does not reflect the influence of indicators of production capacity management efficiency on the financial results of the company. In addition, it will not be able to assess the competitive advantages of an enterprise in any way, which is very important in increasing the share of an enterprise in the market. In our opinion, should continue research in this area.

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