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Sumar

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Comparison of the mechanical behavior spacer knit cotton and flax fabric reinforced composites

GULSAH PAMUK FATMA CEKEN

REZUMAT – ABSTRACT

Comparație între comportamentul mecanic al tricoturilor din bumbac conturate spațial și cel al compozitelor ranforsate cu țesături din in

Fibrele naturale oferă multe avantaje pentru compozitele textile ranforsate. Principalele obiective ale acestui studiu constau în transformarea fibrelor din bumbac şi in în preforme tricotate şi utilizarea lor ulterioară în calitate de ranforsări pentru compozite, precum şi analiza avantajelor ecologice şi de mediu ale acestora. Scopul lucrării îl constituie studierea diferenței dintre compozitele din in şi cele din bumbac, în ceea ce priveşte rezistența la tracțiune, compresie şi impact, şi evidențierea comportamentului mecanic al acestora, în urma inserării de fibre şi fire naturale în aceste compozite.

Cuvinte-cheie: compozite, ranforsări textile, proprietăți mecanice, preforme tricotate, fir de bumbac, fir de in

Comparison of the mechanical behavior spacer knit cotton and flax fabric reinforced composites

Natural fibers offer many advantages in textile reinforced composites. The main purpose of this study was to turn cotton and flax fibers into knitted preforms, then to use these preforms as reinforcement to examine their ecological and environmental advantages that they provided to the knitted preforms. Our aim was to analyze the difference of flax and cotton fabric composites in terms of tensile, compression and impact strength, also to understand the mechanical contribution of fibre and yarn inlay in these composites.

Key-words: composites, textile reinforced, mechanical properties, knitted preforms, cotton yarn, flax yarn

The advantages of using natural fibers as reinforcement material in composites include low cost, high toughness, low density, good specific strength, reduced tool wear, reduction in CO_2 emissions and biodegradability [1]. For instance, glass fibers have a density of 2.6 g/cm^3, and cost between $ 1.30 and $ 2.00/kg as being a conventional reinforcement material [2]. The energy consumption to produce a glass fiber mat is 54.7 MJ/kg [3]. However, a natural fiber like flax, have a density of 1.5 g/cm^3. It costs $ 0.22 – $ 1.10/kg [2] and the energy consumption to produce a flax-fiber mat is 9.55 MJ/kg (including cultivation, harvesting, and fiber separation) [3]. The lower density of natural fibers is a big advantage in the application areas where even a small amount of weight reduction is significant. Such a case stands out especially for automotive sector which is a major composite material user. According to an estimate, about 25% reduction in the weight of a vehicle is equivalent to a saving of 250 million barrels of crude oil and reduction in CO_2 emissions to the tune of 220 billion pounds per annum [4]. In addition to the advantages of natural fibers, quantified targets for the reuse and recycling and recovery of end of life vehicles, established by European Union and Asian countries, played an important role for the automotive sector to become an important area that marks out a future in natural fiber usage. The European Union published a directive in 2000 by the aim of increasing the rate of re-use and recovery from 75% to 85% in terms of average weight per vehicle/year by 2006, and to 95% by 2015, and to increase the rate of reuse and recycling over the same period to at least 80% and, respectively, 85% in terms of average weight per vehicle/year [5].

Recently, the potential of natural fiber reinforced composites has been attractive for researchers, and the researches have widely studied interfacial properties of composites and worked for modifying the natural fiber for better matrix-fiber adhesion or the resultant performance of the natural fiber reinforced composite [6–22]. In these studies the natural fiber reinforcements are in the form of random mat, nonwoven mat or basic woven fabric. Only Carvalho et al. [12, 15] used jute flat knitted fabrics for the reinforcement of composites. The objective of the present work is different from those of the studies given above. Our aim is to analyze the difference of flax and cotton fabric composites in terms of tensile, compression and impact strength, also to understand the mechanical contribution of fibre and yarn inlay in these composites.

EXPERIMENTAL PART

Preform manufacturing

The flax yarn used in the present work is 49.56 × × 2 tex and has 0.029 kgF/tex specific strength while cotton yarn is 49.7 × 2 tex and 0.017 kgF/tex specific strength. Two types of spacer fabrics were knitted in order to produce preform on 7E Stoll CMS 440 electronic knitting machine. To improve the fibre weight fraction in the preform, weft insertion was made between two spacer fabric layers. Also we managed to insert fibre inlay between two fabric layers of spacer fabrics. This way we were able to examine the effects of fibre inlay.

As can be seen from figure 1 the knitting report of the first type spacer fabric is composed of four courses. In the first course the yarn knits on front, in the second course yarn knit on the rear, in the third course yarn or fibre inlay is inserted and the two layers of fabric is connected by tuck stitches in the fourth course.

In figure 2, knitting report of the second type of spacer fabric is displayed. It consists of eight courses, and making the knitting action both on short and long needles is the difference of this spacer fabric from the first one. By using the second type of spacer fabric preform we aimed to improve the stability of the preform and consequently to make the resultant strength performance of the composite better. The knitting parameters of preforms and properties of ultimate composites are given in table 1.

Fig. 1. The knitting report of the first type spacer fabric preform

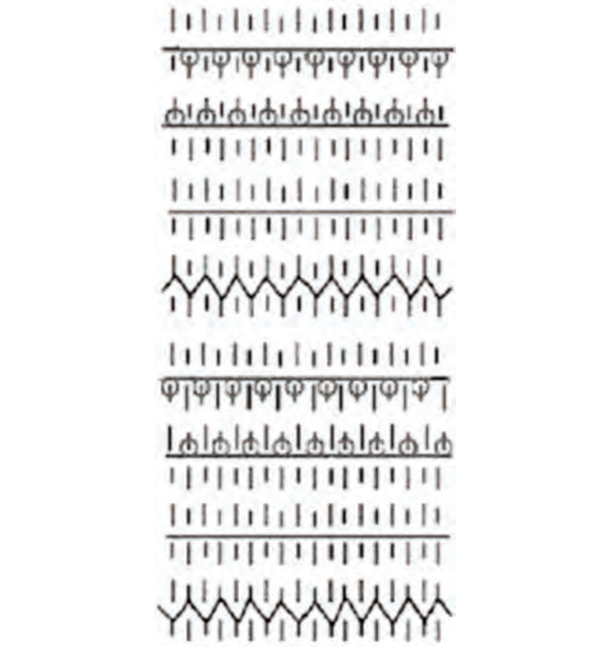

Fig. 2. The knitting report of the second type spacer fabric preform

Composite manufacturing

The thermoset composites were manufactured from the preforms mentioned above. Epoxy resin was used as matrix material. Four layers of preforms and epoxy resin were transformed into composites via the hand laying up method. They were cured at 120ºC for three hours under a pressure of 250 kPa.

Material testing

Tensile tests were performed according to ASTM D 3039-76, and were conducted in both course and wale directions under displacement control at a rate of 1 mm/minute. The dimensions of tensile test specimens are depicted in figure 3. Specimens were measured 230 mm in length and 12 mm in width for the course wise tests and 25 mm in width for the wale wise tests [23]. The tensile testing machine was operated at a crosshead speed of 1 mm/minute and five specimens from each composite were tested.

Table 1

PRODUCTION PARAMETERS OF THE SPACER FABRIC PERFORMS AND PROPERTIES OF THE ULTIMATE COMPOSITES

Composite type	**Preform type**	**Knitting yarn**	**Weft in-lay**	**Knitting speed**, m/s		**Yarn tension**, cN		**Stitch cam setting**		**Fibre weight fraction of composite**, %
				Knitting yarn	***Weft insertion yarn***	***Knitting yarn***	***Weft insertion yarn***	***Knitting***	***Tucking***	
F_1	Type I	Flax yarn	Flax yarn	0.75	0.40	1.5	11.0	11.6	9.6	48.00
F_2	Type II	Flax yarn	Flax yarn	0.75	0.40	3.5	8.0	11.8	9.8	52.00
C_1	Type I	Cotton yarn	Cotton yarn	0.75	0.40	1.0	5.5	11.3	9.3	37.30
C_2	Type I	Cotton yarn	Cotton fibre	0.75	0.40	1.0	12.5	11.3	9.3	42.25
C_3	Type II	Cotton yarn	Cotton yarn	0.75	0.40	2.5	7.0	11.8	9.8	51.80

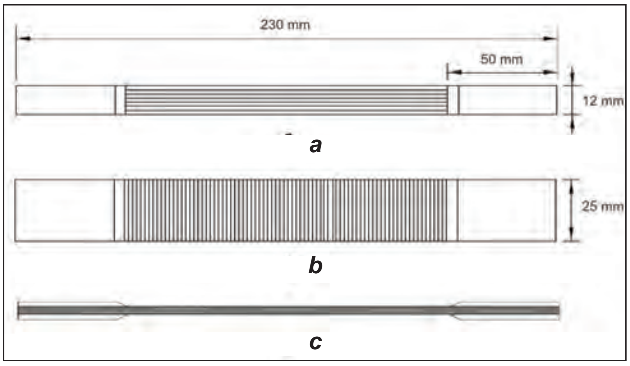

Fig. 3. The dimensions of tensile test specimens:
a - tensile strength specimen in course wise (parallel to yarn inlay) direction;
b - tensile strength specimen in wale wise (vertical to yarn inlay) direction;
c - side view of tensile specimens

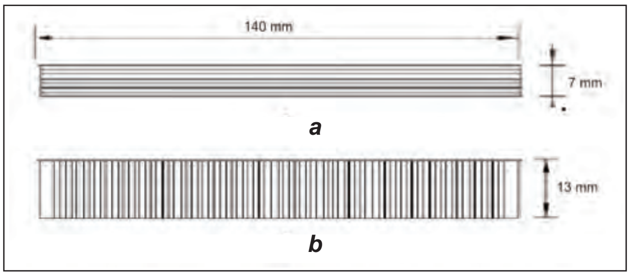

Fig. 4. The dimensions of compression test specimens:
a - compression strength specimen in course wise (parallel to yarn inlay) direction;
b - compression strength specimen in wale wise (vertical to yarn inlay) direction

Compression tests were conducted by using a modified IITRI test rig according to ASTM D 3410. The dimensions of compression test specimens are shown in figure 4 [24]. Compressive loads were applied at a nominal displacement rate of 1 mm/minute, and each of the five specimens was tested for course-wise and wale-wise directions.

The impact resistance of composites was determined on unnotched Charpy specimens by a procedure outlined in ASTM standard D 5942-96 and using a test machine with a pendulum of 4J impact or potential energy [25]. The testing machine is a pendulum type, has a rigid construction, and is capable of measuring the absorbed energy of a test specimen. The value of this energy is defined as the difference between the initial potential energy of the pendulum and the energy remaining in the pendulum after breaking the test specimen. A total of five samples from each composite were tested to determine the mean impact resistance.

RESULTS AND DISCUSSIONS

In this study, the composites showed better tensile strength values in course wise tensile direction (fig. 5), although it is well known that the wale wise tensile strength is higher than the course wise tensile strength in weft knitted fabric reinforced composites.

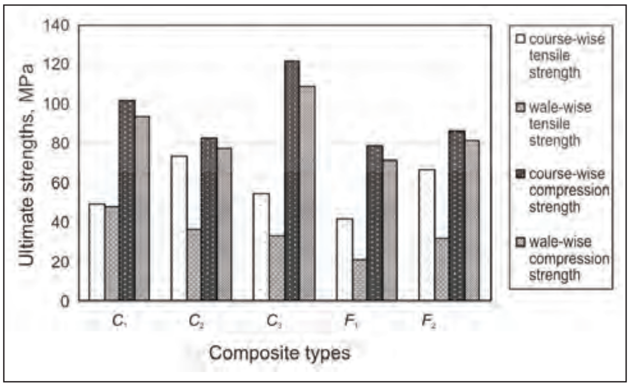

Fig. 5. Tensile and compression strengths of composites

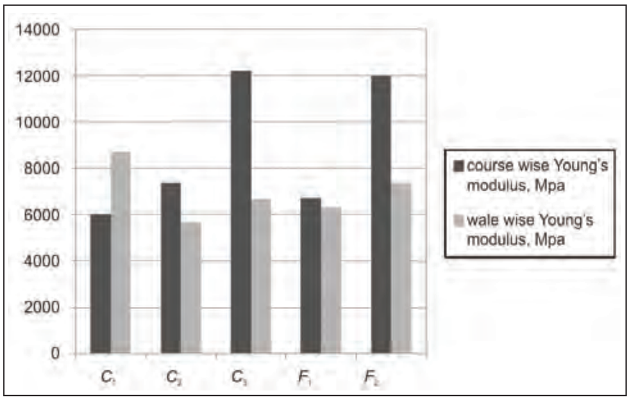

Fig. 6. Young's modulus of composites

This means that weft inlay made contribution to the strength in course wise tensile direction as we expected.

As highlighted in Section 2.1, type II preform made better contribution to the tensile strengths of composites in both directions then type I preform.

If the cotton composites, that contain type I preforms (C_1, C_2), are compared each other, C_2 has the highest course wise tensile strength value. During knitting the preforms yarn inlays and fibre inlays were made in C_1 and C_2, respectively. Although fibre has actually poorer performance than yarn, in our composite it performed better than yarn since it is more difficult for the resin to penetrate into yarn because of the twist. This fact is also supported by the higher wale wise tensile strength of C_1.

Figure 6 shows the measured tensile modulus of the composites. As can be seen in this figure, C_1 and F_1 has lower course wise tensile modulus than C_3 and F_2 both of which were registered 12 GPa in course wise direction. However, an increase was observed in course wise tensile modulus with the increment of fiber weight fraction (table 1).

Based on the results of the current study, flax composite containing type I preform F_1 showed inferior compression strength compared to cotton composite including type I preform C_1 and C_2 while flax composite containing type II preform F_2 showed inferior

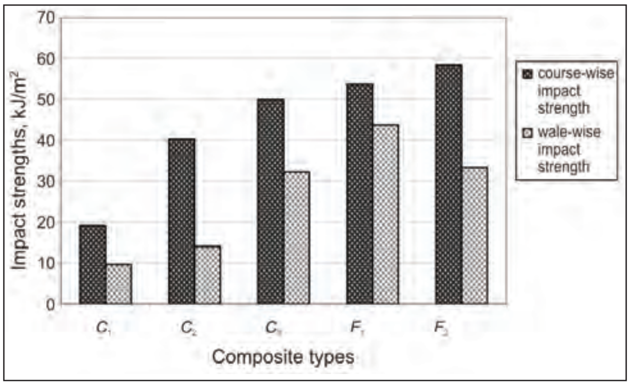

Fig. 7. Impact strengths of composites

compression strength compared to cotton composite involving type II preform C_3.

In this study, all type of composites showed higher compression strengths in course wise direction. This result is in accordance with those obtained by tensile strength tests. If we also compare compression strengths of the preforms, it is seen that type II preforms give better values than type I preforms. On the other hand, although C_2 has better course wise tensile performance than C_1, yarn inlay provided advantage to C_1 in terms of compression.

Impact strengths of the composites are given in figure 7. This figure exhibits that impact strengths of the flax composites are superior than cotton ones. Parallel with the results obtained by compression tests, composites that contain type II preforms, F_2 and C_3, which have the highest fiber weight fractions (table 1), showed the highest impact strength values.

CONCLUSIONS

Cotton and flax fibers are widely used natural fibers in textile industry. The main purpose of this study was to turn these fibers into knitted preforms, then to use these preforms as reinforcement to examine their ecological and environmental advantages that they provided to the knitted preforms, because due to our comprehensive literature review, there seems there weren't any studies examining these advantages on the knitted preforms. Based on the results of the current study we conclude that:

- Fiber inlays can be made during preform knitting;
- If the weft inlays were made into preforms, better tensile, compression and impact properties are obtained in course wise direction;
- The fiber inlay, made into cotton preform, is more effective in terms of strength than yarn inlay;
- Composites which contain spacer preform that is both knitted on short and long needles showed better performance than composites containing spacer preforms that is knitted with needle cancel;
- Cotton composites may be preferred for treatments that need high tensile and compression strengths, but flax composites may be considered if high impact strength is required.

It must be noted that tensile, compression and impact failure mechanisms in composites that are produced from natural fiber knitted preform are rather complicated and call for further investigation. This investigation should include different knitted fabric types, natural fibers and several matrix combinations. More knowledge on these parameters will allow us designing composites with better performance.

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In situ synthesis and loading of silver nanoparticles on cotton fabric

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SAYYED SADRODDIN QAVAMNIA

REZUMAT – ABSTRACT

Analiza in situ şi impregnarea cu nanoparticule de argint a ţesăturilor din bumbac

Nanoparticulele de argint sunt tot mai mult folosite în diferite aplicaţii, datorită proprietăţilor lor antibacteriene. Fibrele de bumbac pot acţiona ca matrice pentru stabilizarea şi controlul generării de nanoparticule de argint. Nanoparticulele de argint au fost încorporate în fibrele de bumbac prin metoda in situ, în prezenţa nanoparticulelor de TiO_2. Ca agent reducător a fost utilizat hipofosfitul de sodiu. Ca tehnici de analiză a caracteristicilor suprafeţei ţesăturii de bumbac tratate, s-au folosit microscopia electronică de baleiaj la tensiune scăzută şi spectrometria de absorbţie în infraroşu cu transformată Fourier şi înregistrarea spectrelor prin atenuarea reflexiei totale. Ţesăturile din bumbac impregnate cu nanocompozite pe bază de Ag/TiO_2, la diferite concentraţii ale nanoparticulelor de TiO_2, au fost analizate prin metoda analizei termogravimetrice (TGA) şi prin metoda spectrometriei de absorbţie atomică (AAS). Prezenţa nanoparticulelor de TiO_2 alb a îmbunătăţit proprietăţile ţesăturii de bumbac impregnate şi a redus indicele de îngălbenire a ţesăturii de bumbac impregnată cu nanoparticule de argint.

Cuvinte-cheie: in situ, impregnare, nanoparticule, TiO_2, bumbac

In situ synthesis and loading of silver nanoparticles on cotton fabric

Silver nanoparticles are being used increasingly in various applications due to their antibacterial properties. Cotton fiber can act as a template to stabilize and control the growth of silver nanoparticles. Silver nanoparticles were synthesized on cotton fibers by in situ method in presence of TiO_2 nanoparticles. Sodium Hypophosphite (SHP) ($NaPO_2H_2$) was used as a reducing agent. The surface of loaded cotton fabric was characterized by low voltage scanning electron microscopy, and attenuated total reflection-Fourier transform infrared spectrometry. The cotton fabrics loaded with Ag/TiO_2 nanocomposite at different TiO_2 nanoparticles concentrations were examined by thermo gravimetric analysis (TGA), and atomic absorption spectrometer. The presence of white TiO_2 nanoparticles enhanced the properties of loaded cotton fabric and reduced the yellowness index of cotton fabrics loaded with silver nanoparticles.

Key-words: in situ, loading, silver nanoparticle, TiO_2, cotton

Fabrication of functionalized textiles by applying nanoparticles is an interesting approach for surface modification of textiles [1–5]. As means of creating new properties a considerable amount of research has been carried out for immobilization of various nanoparticles on textile materials, while each of these nanomaterials are able to provide special effects. Among of them, silver nanoparticles (AgNPs) are widely used to create antibacterial properties because of their wide-spectrum antibacterial activity [6–11]. Especially, Ag exhibits non-toxicity to human cells when it is used in a reasonable amount [12].

Several methods have been applied for synthesizing silver nanoparticles [13]. The synthesis methods of nanosilver must correspond to its application in order to obtain antimicrobial fabric with a broad antibacterial spectrum, strong antibacterial activity, short action time, and good washing fastness [14]. Silver nanoparticles can be deposited on the textile surface substrate by various coating methods or can be absorbed by exhaustion method. In addition, it is possible to synthesize silver nanoparticles on textile substrate by in situ method [6, 12, 15–17]. Cotton fiber contains hydroxyl groups on its molecular structure which is able bind to positive charged species of organic or inorganic materials. The presence of these characteristic groups makes them ideal for the selective binding of metal ions. Therefore, the cotton fibers' hydroxyl groups can be a suitable template to grow metal nanoparticles.

The aim of this study was to synthesize silver nanoparticles inside the cotton fibers obtaining durable nanosilver loaded substrate. In this case, cotton fiber can act as a template for synthesizing and growing the silver nanoparticles. Sodium hypophosphite (SHP) ($NaPO_2H_2$), which is often applied as a reductant in nonelectrical deposition, was used as a reducing agent. In addition, TiO_2 nanoparticle was loaded to cotton fabric before synthesizing silver nanoparticles to enhance the antibacterial effect of silver nanoparticles and reduce the yellow color appeared due to presence of silver nanoparticles. The cotton fabrics loaded with Ag/TiO_2 nanocomposite at different

TiO_2 nanoparticles concentrations were examined by thermogravimetric analysis (TGA) and attenuated total reflectance infrared Fourier transform (ATR-FTIR) spectroscopy. In addition, the effect of Ag/TiO_2 nanocomposite concentration on yellowness Index of loaded cotton fabrics was studied by measuring reflectance spectra. Furthermore, the water contact angle of loaded samples was examined.

EXPERIMENTAL PART

Materials used

All chemicals used in this study were of analytical grade and distilled water was used throughout the work. Silver nitrate ($AgNO_3$ extra pure, > 99.8%), sodium hypophosphite ($NaPO_2H_2$), and citric acid ($C_6H_8O_7$) were purchased from Merck Company (Germany). TiO_2 nanopowder (Degussa P-25) was provided by Sigma–Aldrich.

Fabric sample

A plain woven, 100% cotton fabric with an area weight of 240 g/m^2 was used in this study. In order to clean the fabrics from the impurities, all samples were immersed in a solution containing a nonionic detergent (1 g/l) for 30 minutes at 60°C (L:G = 40:1), then rinsed with tap water and dried at room temperature.

Methods used

Synthesis of Ag/TiO_2 nanocomposite: The scoured cotton fabric was immersed in the silver nitrate solution with liquor-to-goods ratio of 1:50 for 30 minutes at room temperature. Silver ion concentration was adjusted at 400 ppm, while the TiO_2 concentration was varied from 0 to 1.5% owf (on weight of fabric). After that, the wet fabric was dried in oven at 100°C for 20 minutes. Reducing agent concentration was adjusted more than the silver ions concentration on the cotton fabrics. So, it's guaranteed that the total absorbed Ag^+ in to cotton fabric was reduced to $Ag^\bullet$. Moreover, the higher reducing agent concentrations create higher nuclei which lead to smaller Ag nanoparticles. The cotton fabrics impregnated with silver nanoparticles and Sodium Hypophosphite were cured at 130°C for 10 minutes. This is lead to reduce Ag^+ to $Ag^\bullet$ atom and to the synthesis of silver nanoparticles. Synthesizing silver nanoparticles on cotton fabric changes the color of cotton fabric to brownish yellow.

The surface of loaded cotton fabric was characterized with low voltage scanning electron microscopy (PHENOM SEM, FEI Company, Eindhoven, The Netherlands). This guarantees the uncharged imaging of non conductive materials without sputter coating.

Silver loading efficiency on cotton fabric was determined by an atomic absorption spectrometer (Unicam 939). Approximately 1 g of each sample was put in a porcelain crucible and burned. Temperature was increased from room temperature to 650°C in an hour and burning was continued for two hours. After that, the burnt samples were cooled in the desiccators and ash weight was recorded. Then, 1 ml of hot concentrated Nitric Acid was added to the porcelain crucibles to dissolve all the silver content. Finally, the concentration of each solution sample was determined with the atomic absorption spectrometer.

Thermo gravimetric analysis (TGA) of treated and untreated cotton fabrics was performed with Perkin-Elmer 7 thermal analyzer. Approximately, 7 mg of pieces of fabric was placed on the plate and heated from 25°C to 650°C by heating rate of 10°C/minutes with nitrogen purging.

The surface of all cotton samples were analyzed by the Attenuated total reflection-Fourier transforms infrared spectrometer (ATR-FTIR, Perkin Elmer Spectrum 100 series). ATR-FTIR spectra were recorded at a resolution of 1 cm^{-1} and the scanning range was 650–4 000 cm^{-1} and an average of 20 scans was recorded.

The reflectance spectra of the treated and untreated cotton fabrics were measured in the range of 400–700 nm with 10 nm intervals (Color Eye 7000 A, Gretag-Macbeth). The CIE terms namely, L^*, a^*, b^* and C^* color coordinates under illuminant D_{65} and 10° standard observer were measured for evaluating the color of samples. The change in color of a loaded sample from untreated cotton to yellow brownish can be described by yellowness Index which was calculated from the spectrophotometer data. The yellowness index of the loaded fabric was determined according to the ASTM E313 by equation (1) under illuminant D_{65} and 10° standard observer:

$$YI = 100(1.3013\,X - 1.1498\,Z)/Y \qquad (1)$$

RESULTS AND DISCUSSIONS

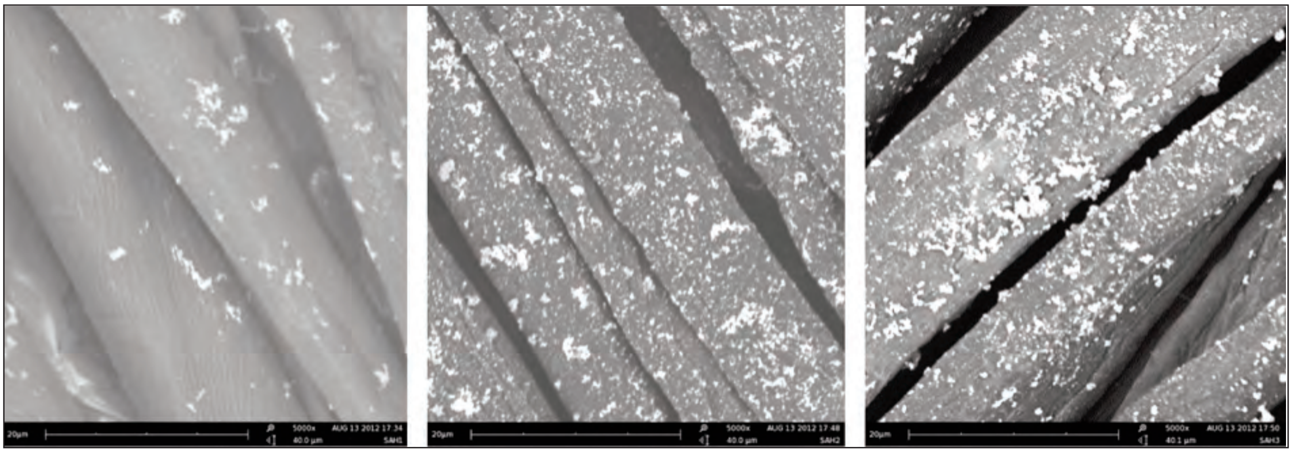
Synthesis of silver nanoparticles

Most textile fibers as well as cotton fiber have a negative zeta potential in neutral and alkali aqueous solutions [18]. Cotton fibers have a negative zeta potential due to acidic groups in their chemical structure such as carboxyl or hydroxyl groups [19]. Silver ions with positive charges can adsorb and diffuse into the cotton fiber due to the electrostatic interaction of negative charge groups and positive charge of silver ions (2). Silver ions can be converted to silver atoms and nanoparticles in presence of sodium hypophosphite as a reducing agent and cotton fiber acts as a template and controls the growth of silver nanoparticles [12].

$$\text{Cotton} - OH \xrightarrow[aq]{} \text{Cotton} - O^-$$

$$\text{Cotton} - O^- + Ag^+ \rightarrow \text{Cotton} - O^- Ag^+ \qquad (2)$$

$$\text{Cotton} - O^- Ag^+ + NaPO_2H_2 \rightarrow \text{Cotton} - O^- Ag$$



a *b* *c*

Fig. 1. LVSEM image of loaded cotton fiber by in situ method with:
a - silver nanoparticles and the loaded fibers with Ag/TiO_2 nanocomposites; ***b*** - at different concentrations of TiO_2;
c - 0,5–1% on weight of fabric

Low voltage scanning electron microscopy (LVSEM)

The morphological changes of cotton fibers surfaces caused by synthesizing Ag and Ag/TiO_2 nanocomposites were followed by LVSEM. Images of cotton fibers loaded with silver nanoparticles and Ag/TiO_2 nanocomposites are presented in figure1. These fabrics were immersed in a solution containing 400 ppm silver nitrate in presence of sodium hypophosphite. It can be seen obviously that the formation of nanocomposites on the surface of cotton fibers has led to change the uniform and homogeneous cotton surface to a rough surface [16]. In addition, the silver nanoparticles were well-dispersed on fiber surfaces. LVSEM image of loaded cotton fiber by in situ method with silver nanoparticles and the loaded fibers with Ag/TiO_2 nanocomposites are presented in figure 1*a*.

However, the surface morphology and the Ag nanoparticles density on cotton fabrics varied with the concentration of the TiO_2 in the solution (fig. 1*b*). The presence of TiO_2 nanoparticles in loading solution led to increasing of the Ag/TiO_2 nanocomposite density on the surface of cotton fabrics. In addition, increasing the TiO_2 concentration enhanced the density of Ag/TiO_2 nanocomposites on the surface of cotton fabrics (fig. 1*c*).

Silver content of loaded cotton fabric

The amount of the loaded silver on the cotton fabrics is presented in table 1. The obtained results showed that the amount of silver nanoparticles on the fabrics in the presence of TiO_2 is much greater than the loaded sample without TiO_2 (AT0). It is obvious that the higher concentration of TiO_2 in the recipe of immersing solution results to greater silver content and the silver content of fabrics increased from 3.67 g kg^{-1} for without TiO_2 sample (AT0) to 12.98 g/kg^{-1} for the fabric treated with 1.5% owf of TiO_2 (AT1.5).

It has been reported that the colloidal solution of TiO_2 (1 wt%) has a negative zeta potential (– 35.5 mV) [20] and it has a negative surface charge even at weak acidic media [21, 22]. So, the electrostatic interaction of Ag^+ to the negative surface charge of TiO_2 resulted to the higher silver content in presence of TiO_2. It can be assumed that loading cotton fiber with higher TiO_2 concentrations caused the formation of more negative sites on the surface of cotton fibers and is suggested a more hydrophilic fiber surface [23], facilitating the subsequent interaction and adsorption of Ag^+. Consequently, the amount of synthesized silver nanoparticles on the cotton fabrics increased. This result was confirmed with SEM images that presence TiO_2 lead to formation of higher nanocomposites density on the surface of loaded cotton.

Thermogravimetric analysis

The thermal properties of the loaded cotton fabrics were analyzed and compared to untreated sample as means to estimate the amount of Ag/TiO_2 nanocomposites on the loaded samples. The TGA curves of untreated and treated cotton fabrics with Ag and Ag/TiO_2 nanocomposites are presented in figure 2. It can be seen that sample loaded with Ag/TiO_2 (AT1.5) presented a more weight loss at the initial temperature range compared to the other sample which corresponds to the vaporization of H_2O adsorbed physically on the surface of loaded fabric [23] due to more

Table 1

THE SILVER NANOPARTICLES CONTENT OF LOADED COTTON FABRICS DETERMINED BY ATOMIC ABSORPTION SPECTROMETER

Sample code	Recipe component concentration		Silver content, gkg^{-1}
	Ag, ppm	***TiO_2,*** % (owf)	
AT0	400	0	3.67
AT0.5	400	0.5	7.42
AT1	400	1	9.12
AT1.5	400	1.5	12.98

hydrophilic surface of treated cotton fiber [24]. It can be seen that a sharp weight loss begins at about 350ºC, and continues till 700ºC, which can be attributed to a significant thermal decomposition of cotton fiber. However, the weight loss of sample treated with Ag/TiO_2 (86%) is lower than the sample treated with Ag nanoparticles (AT0, 89%) and untreated sample (92%).

ATR-FTIR analysis

Fourier transform infrared with attenuated total internal reflectance (ATR-FTIR) mode analysis was employed to examine the chemical composition of cotton fiber surface until the depth of 500 nm [25]. So, in order to investigate the loading mechanism, ATR-FTIR measurements were carried out on the samples over 1 800 – 4 000 cm^{-1}, as shown in figure 3. The spectra of the Ag (AT0) and Ag/TiO_2 (AT1.5) nanocomposite loaded cotton fabric presented a higher transmittance intensity compared to untreated cotton fabric, due to deposition of nanoparticles on the surface of cotton fibers. The peak at 3 300 cm^{-1}, associated with the –OH groups located on the surface of the fabrics, got weaker, suggesting the mount of OH groups became less. Generally, Ag and TiO_2 have high affinity toward hydroxyl groups. Therefore the –OH groups take part in the loading process and consequently to be consumed by loading procedure [26].

Color measurement

The yellowness indexes of the untreated and treated cotton fabrics with different concentrations of TiO_2 are presented in figure 4. The yellowness indexes are measured primarily to study the yellowing effect of the processing. The yellowness index measurements show that loading of Ag nanoparticles on cotton fabric leads to increase in yellowness. Higher TiO_2 concentration led to lower yellowness indexes [27]. The presence of white TiO_2 nanoparticles which are attached on the cotton fabric surface resulted in increasing of the fabric whiteness. Therefore, the higher applied concentration of TiO_2 nanoparticles on the loaded cotton fabrics led to appear whiter.

CONCLUSIONS

Negative surface charge of cotton fibers can absorb silver ion with positive charge due to the electrostatic interaction. Sodium hypophosphite reduced the absorbed silver ions to silver atom and formed Ag nanoparticles. Ag/TiO_2 nanocomposites formation on the surface of cotton fibers changed the uniform and homogeneous cotton surface to a rough surface, while well-dispersed on the surface of cotton fiber. Presence of TiO_2 in loading solution resulted in the formation of more negative site charge on the surface of cotton fiber and led to higher loading efficiency of silver nanoparticles. However, higher loading efficiency led to enhance the thermal properties of loaded fabric with e intensity of the hydroxyl group was reduced due to absorption of Ag/TiO_2 on the surface of cotton fiber and the –OH groups took part in the loading process. Synthesizing silver nanoparticles on cotton fabric led to change the color of cotton fabric to be brownish yellow. But, the presence of white TiO_2 nanoparticles on the cotton fabric surface reduced the yellowness index of treated cotton fabric.

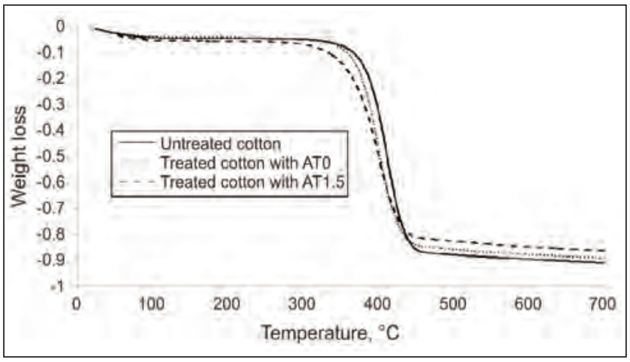


Fig. 2. TGA curves of the untreated and treated cotton fabric with Ag and Ag/TiO_2 nanocomposites

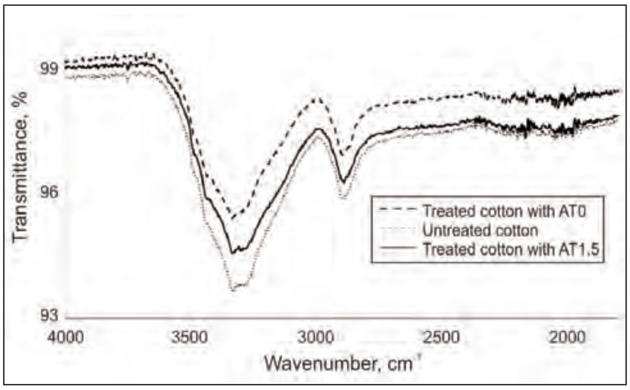


Fig. 3. ATR-IR spectra of untreated and loaded cotton fabric

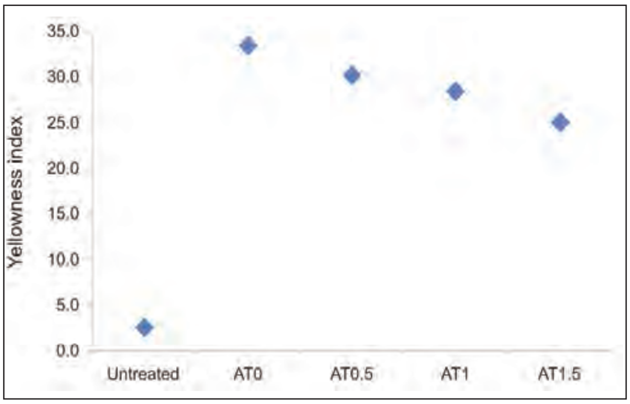


Fig. 4. Yellowness index of the untreated and treated cotton fabric with Ag/TiO_2 nanocomposites at different TiO_2 concentrations

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Performance properties of cotton fabrics treated with phase change material microcapsules

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REZUMAT – ABSTRACT

Proprietățile de performanță ale materialelor textile din bumbac, tratate cu microcapsule ce conțin materiale cu schimbare de fază

În ultimele decenii, în scopul îmbunătățirii proprietăților de confort termic ale corpului omenesc, în textile şi confecții au fost încorporate microcapsule PCM. În cadrul acestui studiu, pentru tratarea unor materiale textile din 100% bumbac s-au utilizat două tipuri de microcapsule ce conțin materiale cu schimbare de fază, pe bază de n-alcani, folosind raclu contra rolă. Morfologia suprafeței materialelor textile astfel tratate diferă în funcție de adaosul de microcapsule PCM. De asemenea, capacitatea de stocare a căldurii de către aceste materialele textile creşte odată cu creşterea cantității de microcapsule PCM. Pe de altă parte, permeabilitatea la aer şi la vaporii de apă scade odată cu creşterea adaosului de microcapsule PCM. Pe măsură ce căldura latentă a materialelor textile astfel tratate creşte, vor creşte şi coeficienții de transfer termic, însă rezistența termică va scădea. Rezultatele obținute au indicat faptul că materialele textile astfel tratate au o bună capacitate de reglare termică.

Cuvinte-cheie: microcapsule PCM, materiale textile din bumbac, morfologia suprafeței, permeabilitate la aer, rezistență termică, coeficient termic, reglare termică

Performance properties of cotton fabrics treated with phase change material microcapsules

PCM microcapsules have been applied in textile and clothing in the past decades to improve thermal performance properties for human bodies. In the research we used two types of n-alkane based phase change material (PCM) microcapsules to treat 100% cotton fabrics, by a knife over roll method. The surface morphologies of the treated fabrics were different under different add-on levels. Heat storage capacities of the treated fabrics increased as the add-on of PCM microcapsules increased. Both air and water vapour permeability became lower as the add-on increased. Heat transfer coefficients of the treated fabrics became higher as the latent heat of the treated fabrics increased, whereas heat resistances of the treated fabrics changed in a reverse direction. The results indicated that the treated fabrics had the ability to regulate thermal effect.

Key-words: PCM microcapsules, cotton fabric, surface morphology, air permeability, water permeability, heat resistance, heat coefficient, thermal regulate effect

Phase change materials (PCM) are latent heat storage materials. Unlike sensible heat storage materials, they have much higher heat storage density with a narrow temperature difference between storing and releasing heat [1]. They absorb heat in the heating process as they change phase from solid to liquid (melting process) and release heat in the cooling process as they undergo a reverse phase change (crystalizing process). During the melting and crystalizing process, the temperature of the materials remains constant [2]. Based on these merits of PCMs, they have been applied to develop smart textiles and clothes to improve thermal comfort for human bodies. Because in the melting process they will change from a solid phase to a liquid phase, these materials have to be encapsulated as PCM microcapsules [3–6] or encapsulated as PCM packs [7–10] before they are used in textile and clothing.

There are many kinds of PCMs, like hydrated salt, fatty acids, and mixed compounds of organic and inorganic [1–2, 11–12]. The most well-known PCMs for textile and clothing oriented microcapsules are paraffin wax based materials, like n-octadecane and n-eicosane etc. They have high latent heat and they are non-toxic and non-corrosive. Furthermore, their phase change temperatures are in the temperature range (about 18 to 35ºC) in which human bodies can remain thermally comfort [5]. The diameters of PCM microcapsules are only a few micrometers. Hence, they can be incorporated into fibers or textiles. Incorporating PCM microcapsules into fibers can be achieved by wet spinning or melt spinning [13, 14]. Whereas the modified fibers are confined to a limited heat capacity with low PCM microcapsule loading content. Another way to incorporate PCMs into textiles is achieved by coating process. This finishing process includes knife over roll, screen printing, pad dry cure, etc. Polymer binders, like polyurethane, are required to link the microcapsules permanently on the fabric substrate. A high loading content can be gained by a coating process [5, 11, 15].

The technology of incorporating PCM microcapsules into clothing was developed in the early 1980s under a NASA program. The purpose of the program was to improve the thermal performance of astronaut's space suits in extreme conditions [2]. Later on, PCM microcapsules were employed in textiles and clothing for ordinary people. In the same time, related researches in material science, textile and clothing science have been conducted. Sarier and Onder [6] established a manufacturing technique to accomplish PCM microcapsules that could be applied to different textiles. Shin et al. [15] reported that the add on of polymer binders and PCM microcapsules on fabric structure could lead to a change of fabric's tensile strength, drape and hand, as well as air and water vapour permeability. Kim and Cho [16] used PCM microcapsules containing octadecane to treat polyester fabrics by a knife over roll method. They found that the durability of microcapsules lasted for about ten launderings. The mean skin temperature and microclimate temperature with the treated garment were less compared with the untreated garment. Bendkowska et al. [7, 11] used a TRF (temperature regulating factor) index defined by Hittle and Andre [17] to evaluate thermal performance of fabrics treated with PCMs. Ying et al. [18] used the indices of thermal regulating capacity to describe thermal regulating performance of textiles incorporated with PCM microcapsules and found that they were strongly dependent on the amount of PCM add-ons.

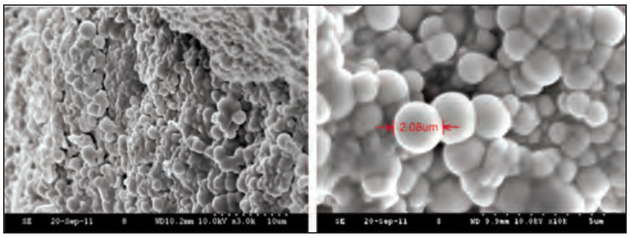
After a literature review, the authors find that the type of PCM microcapsules, i.e. the phase change temperature, the latent heat of the PCM and the add-on levels, together with the fishing process have great effect on performance properties of the treated fabrics. Hence, in the study two types of PCM microcapsules are utilized and they are treated on cotton fabrics at different add-on levels. The surface morphology, air and water vapour permeability and thermal regulating ability of the treated fabrics were investigated to give a better understanding of this technology.

EXPERIMENTAL PART

Materials used

Two types of PCM microcapsules were supplied by Beijing Julong Bofang Science and Technology Institute. The cores of the two types of PCM microcapsules were paraffin based materials. For technology right, we just knew that the core materials were n-alkane materials. The shells of the PCM microcapsules were mainly melamine-formaldehyde polymers. The average diameters of the microcapsules were less than 3 ìms (fig. 1).

Figure 1 shows the surface morphology of the PCM microcapsules. The photographs were taken by scanning electron microscope (S-3000N, Hitachi – Japan). Their heat characteristics were tested by differential scanning calorimeter (204F1, Netzsch – Germany). The melting temperatures of PCM Type I and Type II are 33.9°C and 27.2°C, respectively.



a *b*

Fig. 1. PCM microcapsules with core material of type 1 taken by SEM:
a - magnification 3000^x, 10.0 kV; ***b*** - magnification 10000^x, 10.0 kV, the average diameter was less than 3 μms

Their melting enthalpies were 139.5 J/g and 160.3 J/g, respectively.

A 100% cotton fabric (plain weave, 118 g/m^2, thickness of 0.24 mm) was used as the substrate. PCM microcapsules were first dispersed in aqueous solution of surfactant, dispersant. In a research conducted by Salaun et al. [4], they report that a polyurethane based binder is the most suitable to link melamine-formaldehyde microcapsules.

Thus we chose a polyurethane binder (PU3630, Hefei An'ke – China) to link the microcapsules on the cotton fabric's surface. The composition of the PCM microcapsules and the binder were churned up evenly to treat the cotton fabrics by a knife over roll method. The treated fabrics were then dried in room temperature.

In this research different amount of PCM microcapsules were used to treat the cotton fabrics. The add-ons of the microcapsules are presented in table 1. In the table, the treated fabric's area weight included the PCM microcapsules' weight and the polyurethane binder's weight. The add-on is calculated by equation (1) [5]:

$$add\text{-}on = \frac{a-b}{a} \times 100\% \qquad (1)$$

where:

a is the cotton fabric's weight after coating;

b – the cotton's fabric's weight before coating.

Testing methods

Scanning electron microscope (S-3000N, Hitachi – Japan) was used to observe the surface morphology of the coated fabrics.

The coated fabrics' latent heat characteristics were tested by differential scanning calorimeter (204F1, Netzsch – Germany). The heating and cooling rate was 10°C/minute under N_2 atmosphere. The heating and cooling temperature range was from minus 50°C to 100°C.

Air permeability of the coated fabrics was measured by an apparatus (YG461E, China). The testing method was in equivalent to ISO 9237-1995. Air permeability was determined by measuring the flow rate of the air passing through the tested fabric area at a pressure difference of 100 Pa.

A water vapour permeability tester (M261, SDL Atlas – USA) was applied to test the coated fabrics' water

Table 1

DIFFERENT ADD-ONS OF THE COATED FABRICS				
Fabric code	**Thickness**, mm	**Area weight**, g/m²	**Ratio of mass** $_{\text{PCM micro}}$ **to mass** $_{\text{binder}}$	**Add-on**, %
Fab-substrate	0.24	118	-	0
Fab-I/1	0.25	174	1:4	28.2
Fab-I/2	0.26	181	1:4	35.1
Fab-I/3	0.27	203	1:4	41.9
Fab-II/4	0.25	153	1:4	23.1
Fab-II/5	0.26	169	1:4	30.2
Fab-II/6	0.27	190	1:4	37.9

Note: Fab-I symbolizes the fabrics coated with PCM microcapsules of Type I and Fab-II symbolizes the fabrics coated with PCM Type 2. No. 1 to 6 means the different add-on levels.

vapour permeability. The testing method was in accordance with ASTM E96 in a temperature of 20°C, 65% RH. The water vapour permeability (WVP) in g/m^2/day is calculated by equation (2).

$$WVP = \frac{24(M_1 - M_2)}{At} \quad (2)$$

where:

M_1, M_2 are the mass of the testing assembly before and after the specimen's exposed period;

A is the area of the exposed specimen, m^2;

t – the exposed time, h;

M_1, M_2 are measured with an electrical balance capable of weighing to an accuracy of 0.001 g.

A guarded hot plate apparatus (YG606E, China) was employed to test the coated fabrics' thermal regulating effect. The apparatus consist of three hot plates, namely the testing plate, the bottom plate and the guard plate. The latter two plates prevent heat leakage and guarantee that heat loss is toward the vertical direction. The fabric samples were conditioned in room temperature (20°C, 65% RH) for 24 hours before tested. The fabric side without PCM microcapsules was toward the test plate (fig. 2). The temperatures of these plates were maintained at 35°C. The test was conducted in a temperature of 20°C, 65% RH. Heat resistances and heat transfer coefficients of the treated fabrics' were measured. The heat resistances (R_{ct}) of the samples are calculated by equation (3). Each fabric sample was tested for three times.

$$R_{ct} = \frac{A(T_s - T_a)}{Q} - R_o \quad (3)$$

where:

R_{ct}, R_o are the heat resistance of the tested fabric and the boundary air layer respectively, m^2·°C/W;

A is the specimen's area, m^2;

Q – the electrical power, W.

RESULTS AND DISCUSSIONS

The treated fabric's surface morphology

Figure 3 and figure 4 show the surface morphologies of two pieces of the treated fabrics taken by SEM. Figure 3 is a coated fabric with a 28.2% add-on. From figure 3, we can see that PCM microcapsules were embedded on the surface of the cotton fibers and in the pores between the fibers. They were linked to the fabric substrate with the help of the polymer binder. Because the add-on was not too high, the surface texture of the fabric substrate could still be seen.

Figure 4 is a coated fabric with a higher add-on level of 35.1%. As shown in the figure, PCM microcapsules and the polymer binder covered all the surface area of the fabric substrate. The substrate's surface texture could not be seen any more. Thus the add-ons of PCM microcapsules changed the cotton fabric's

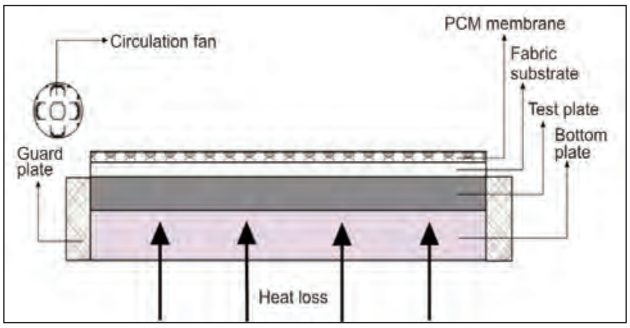
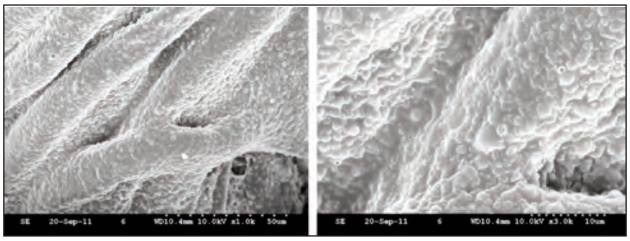


Fig. 2. The schematic diagram for thermal regulate effect test

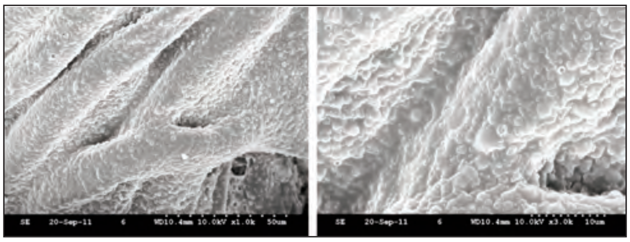


a b

Fig. 3. The surface morphology of cotton fabric treated with PCM microcapsules with a 28.2% add-on: ***a*** - magnification 1 000^x, 10.0 kV; ***b*** - magnification 3 000^x, 10.0 kV

Table 2

THE HEAT STORAGE CAPACITY OF THE COATED FABRICS				
Fabric code	**Thickness**, mm	T_m, g/m^2	**Heat storage**, ΔH_m, J/g	**Heat storage**, ΔH_m, KJ/m^2
Fab-substrate	0	-	-	-
Fab-I/1	28.2	28.5	9.49	1.65
Fab-I/2	35.1	28.8	11.69	2.12
Fab-I/3	41.9	28.9	15.3	3.10
Fab-II/4	23.1	24	12.62	1.93
Fab-II/5	30.2	23.2	19.02	3.21
Fab-II/6	37.9	23.9	21.60	4.09



a ***b***

Fig. 4. The surface morphology of cotton fabric treated with PCM microcapsules with a 35.1% add-on: ***a*** - 1 000^x, 10.0 kV; ***b*** - magnification 3 000^x, 10.0 kV

surface morphology greatly. The change of the surface morphology will bring changes in fabric's tensile strength, hand and other surface physical properties [15, 16], which will change clothing wearing properties.

Heat storage capacity of the treated fabrics

The heat storage capacity of the treated fabrics tested by DSC is listed in table 2. In the last column heat storage was expressed in kJ/m^2 by multiplying heat storage in J/g with the area weight in g/m^2 [11]. In this way the heat storage capacity per area could be achieved, which was more suitable for clothing usage. As shown in table 2, with a higher add-on level the heat storage capacity became higher. This was in accordance with other researches [15, 16]. In the research conducted by Shin et al. [15], n-eicosane is used as the core material of PCM microcapsules. The latent heat of fusion of their PCM microcapsules is 134.3 J/g. The treated fabric with a 22.9% add-on is capable to absorb 4.44 J/g heat when it undergoes phase change. In our research, the latent heat of fusion of PCM microcapsules was higher than that in Shin et. al. research. Therefore, the heat storage capacity of the coated fabrics was higher. The treated fabric with a 23.1% add-on of PCM Type II was capable to absorb 12.62 J/g heat. Furthermore, the fabrics treated with PCM Type II had a higher heat storage capacity than the fabrics treated with PCM Type I, because PCM Type II had a higher latent heat.

From table 2 it can also be seen that the melting temperatures of phase change are decreased compared with the melting temperature before coated (33.9°C and 27.2°C, respectively). The melting temperatures of phase change treated by PCM Type I decreased by 5 to 5.4°C. The other ones treated by PCM Type II decreased by 3.2 to 4°C. This phenomenon was also seen in the researches of Shin et al. [15] and Kim et al. [16]. The reason was not clear. It might be that in the coating process the PCM microcapsules were affected to some extent either by the knife over roll process or by the polymer binder.

Air and water vapour permeability of the treated fabrics

The performance properties of the treated fabrics, including air and water vapour permeability and thermal regulating capacity are listed in table 3. It can be seen from table 3 that after coating the air permeability of the treated fabrics decreased dramatically. The air permeability of the cotton fabric before coated was 1083.35 cm^3/cm^2/min, but after being coated it decreased to very low levels.

When the add-on was 28.2%, the air permeability was only 25.32 cm^3/cm^2/minute.

Figure 5 shows the change of air permeability of treated fabrics under different add-ons. We can see that under a higher add-on level the treated fabrics' air permeability became lower. The reason might be that PCM microcapsules and the polymer binder were embedded in the pores of the cotton fibers and yarns. They blocked the passing channel of the air and they made the fabrics thicker. This might be good

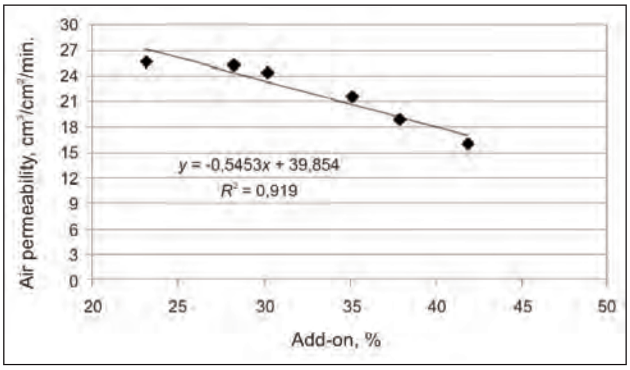


Fig. 5. Air permeability of the treated fabrics with different add-ons

Table 3

THERMAL AND MOISTURE PROPERTIES OF THE COTTON FABRICS BEFORE AND AFTER COATING					
Fabric code	**Add-on,** %	**Air permeability,** $cm^3/cm^2/min.$	**Water vapour permeability,** *WVP,* $g/m^2/day$	**Heat rezistence,** R_{ct}, $m^2 \cdot °C/W$	**Heat transfer coefficient,** $W/m^2 \cdot °C$
Fab-substrate	0	1083.35	815.774	0.0177	0.0572
Fab-I/1	28.2	25.32	561.787	0.0234	0.0429
Fab-I/2	35.1	21.61	456.230	0.0246	0.0409
Fab-I/3	41.9	16.01	389.703	0.0189	0.0537
Fab-II/4	23.1	25.70	549.073	0.0137	0.0734
Fab-II/5	30.2	24.47	527.489	0.0186	0.0540
Fab-II/6	37.9	18.91	421.045	0.0190	0.0528

in the winter situation. The coated fabrics could be used as outer wears to keep cold wind out and release heat to keep the body warm.

Like air permeability, water vapour permeability of the coated fabrics also decreased after being treated by PCM microcapsules. But compared with air permeability, water vapour permeability was decreased not as much as air permeability (table 3). The water vapour permeability of the cotton fabric before coated was 815.774 $g/m^2/day$. When the add-on was 41.9% of the highest among the add-ons, water vapour permeability was decreased by 52.2% compared with the one before coated.

Figure 6 shows the trend of water vapour permeability of the treated fabrics under different add-ons. As shown in the figure, with a higher add-on of PCM microcapsules, water vapour permeability of the coated fabrics became lower. Water vapour permeability determines how much sweat vapour can be transferred to the ambient environment. The higher water vapour permeability the more sweat vapour can be transmitted to the outside environment. Therefore, it relates greatly to human body comfort [19–21]. The purpose of coating PCM microcapsules is to improve clothing thermal regulating capability, but it should not reduce other clothing performance properties. Therefore, in the near future a better method that can improve water vapour permeability of the treated fabrics should be developed.

Thermal regulating effect of the treated fabrics

When the fabrics were tested on the hot plate, the surface temperature of the hot plate was controlled at 35°C to simulate body skin temperature at a comfort range. The ambient temperature was controlled at 20°C, so temperature gradient appeared and heat from the hot plate was lost to the environment. Because there were fabrics between the hot plate and the ambient environment, heat loss was blocked. This is how heat resistance happens. Different fabrics have different heat resistance ability, depending on the fabrics' thickness and structure [22, 23]. When normal cotton fabrics are used as heat regulating materials, their performance properties are limited. But when PCM microcapsules were used to treat the fabric substrate, this problem could be quite different, as show in table 3 of the changed heat resistances and heat transfer coefficients.

When the relationship of the heat transfer coefficient with the heat storage capacity of the treated fabrics is plotted, we can see that the higher heat storage capacity (also latent heat) the higher heat transfer coefficients of the coated fabrics were (fig. 7).

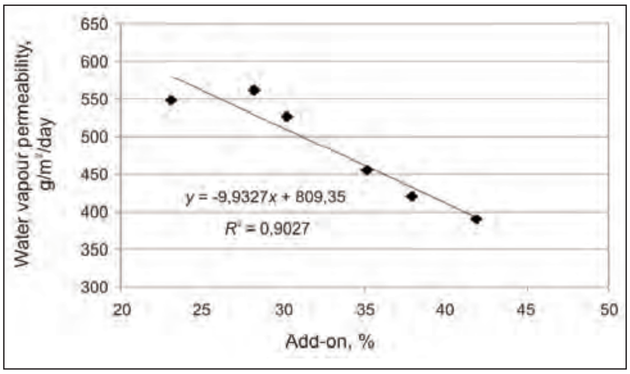


Fig. 6. Water vapour permeability of the treated fabrics with different add-ons

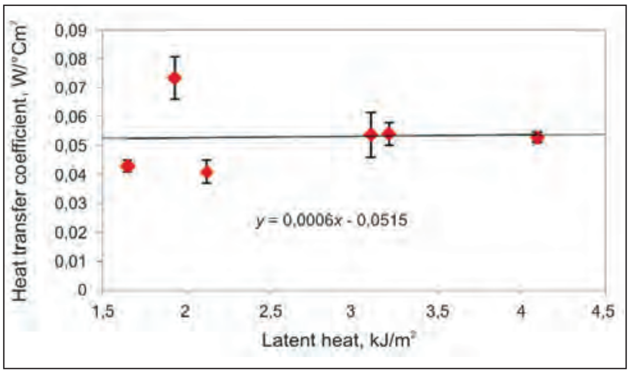


Fig. 7. The relationship of heat transfer coefficient with heat storage capacity of the treated fabrics

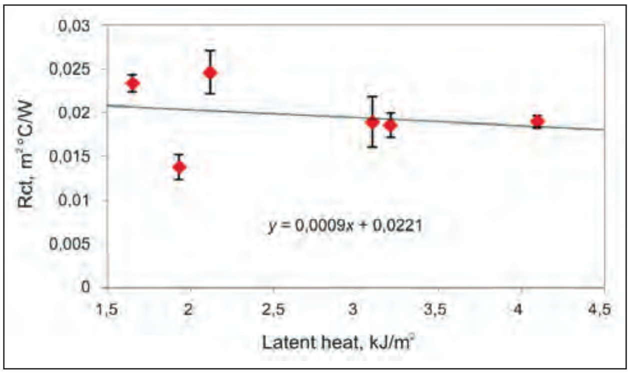


Fig. 8. The relationship of heat resistance with heat storage capacity of the treated fabrics

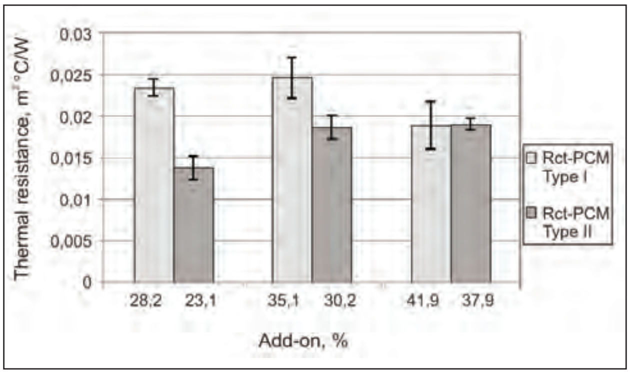


Fig. 9. Comparison of the heat resistances of fabrics treated with the different types of PCM and add-ons

However, heat resistances of the treated fabrics were in the opposite situation (fig. 8). In the test, the substrate side without PCM microcapsules was in contact with the testing plate ((fig. 2). When heat loss from the hot plate passed through the fabric substrate and reached the PCM membrane, the microcapsules began to absorb heat and stored it as the testing plate's temperature was higher than the PCM microcapsule's phase change temperature. When the PCMs melted completely, heat storage was finished and gradually a steady thermal state was reached. The higher heat storage capacity of the treated fabrics, the more heat was absorbed and stored. Hence, more heat from the hot plate was transferred to the PCM microcapsules.

Figure 9 shows the comparison of the fabrics' heat resistances treated by the two types of PCM microcapsules. From figure 9 we can see that fabrics treated by PCM Type I had higher heat resistance compared with fabrics treated by PCM Type II. This can be explained by the findings of Gao et al. [8]. In the research the authors find out that the higher of the temperature gradient between the thermal manikin's surface temperature and PCM's melting temperature the more heat is lost from the manikin to the environment. Fabrics treated by PCM Type I had higher melting temperature. Their temperature gradient between the hot plate and the PCM membrane was lower compared with that of fabrics treated by PCM Type II. Moreover, fabrics treated by PCM Type I had lower heat storage capacity than fabrics treated by PCM Type II. Thus less heat was absorbed and lost from the fabrics coated by PCM Type I.

Besides, as can be seen from figure 9 that heat resistances of the treated fabrics had no clear relationship with the different add-on levels. Fabric treated by PCM Type I with a 35.1% add-on level had the highest heat resistance. While the fabric treated by PCM Type II with a 23.1% add-on level had the lowest heat resistance. And fabrics treated by PCM Type II with 30.2% and 37.9% add-on levels had almost the same heat resistances with the fabric treated by PCM Type I of 41.9 % add-on. In a research conducted by Ying et al. [18], the authors also find that static heat resistances of fabrics treated by PCM microcapsules have no clear linear relationship with PCM load content. They are independent on PCM load content. The authors did not explain the reason. In our view, the reason might be complicated. Many factors affect fabrics' heat resistance, like the fabrics' thickness and structure, e.g. air in the fiber and yarns [22, 23]. Although fabrics after being treated by PCMs had the capability to absorb heat from the hot plate which could decrease heat resistances to some extent, they became thicker and they blocked heat loss to the environment. Furthermore, after being treated the pores of the fabrics were embedded with PCM microcapsules, so less air was trapped in the fabrics [11].

CONCLUSIONS

Two types of paraffin based PCM microcapsules were applied to treat cotton fabrics by a knife over roll method. The PCM microcapsules were embedded on the surface of the fabrics and changed the fabrics' surface morphology, air and water vapour permeability, as well as thermal regulating capacity. Still further researches on subject wear trials should be carried out to further validate the thermal regulate effect of the treated fabrics.

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Cellulase enzyme application for the cotton based woven fabrics Part I. Determination of effect of enzyme on the performance*

ONUR BALCI UĞUR GENÇER

REZUMAT – ABSTRACT

Aplicarea enzimelor celulazice pe țesăturile din bumbac
Partea I. Determinarea efectului enzimelor asupra performanței țesăturii

S-a studiat procesul de pârlire din cadrul tehnologiilor clasice de pretratare a țesăturilor din bumbac, cu scopul de a preveni formarea pilingului şi a pilozității pe suprafața țesăturii. În aplicațiile industriale, în cazul acestui tip de țesătură, chiar în prezența procesului de pârlire, se poate aplica şi un tratament cu enzime celulazice, atât pentru prevenirea formării pilingului, cât şi pentru îmbunătățirea tuşeului şi aspectului suprafeței. În lucrare s-a studiat efectul şi necesitatea aplicării enzimelor celulazice pe țesături din bumbac, alături de procedeul de pârlire aplicat în cadrul procesului de pretratare. În plus, a fost investigată aplicarea tratamentului enzimatic în funcție de vopsire. În cadrul primei părți a fost analizat efectul aplicării unui surplus de enzime asupra performanței țesăturii. S-au efectuat determinări ale proprietăților fizice, cum ar fi: rezistența, pilingul, rezistența la abraziune, şi analiza SEM, în conformitate cu standardele internaționale. Potrivit rezultatelor, aplicarea enzimelor a afectat în mod negativ proprietățile fizice şi chimice ale produsului final.

Cuvinte-cheie: rezistență la abraziune, biolustruire, celulază, piling, rezistență, țesătură

Cellulase enzyme application for the cotton based woven fabrics
Part I. Determination of effect of enzyme on the performance

There was singeing process in the classic pretreatment processes of the cotton based woven fabric to prevent forming of the pill and hairiness on the surface of the fabric studied. However, in the industrial applications, even though the presence of the singeing process, the cellulase enzyme treatment which was also made for preventing pilling could be applied to this kind of fabric to improve especially handle properties and view of the surface. In this research, the effect and necessity of the cellulase enzyme processes were investigated for the cotton based woven fabric having singeing process in the pretreatment line. In addition, the sequence of the enzyme treatment depending on the dyeing application was investigated. In this part, the effect of extra enzyme application on the performance of fabric was invesitaged. Some physical tests were implemented to the samples as strength, pilling, abrasion resistance, and SEM analysis according to the international standards. According to the results, we found out that enzyme application negatively affected the physical and chemical properties of final product.

Key-words: abrasion resistance, bio-polishing, cellulase, pilling, strength, woven fabric

Enzymatic treatment has been a focus of the interest for the cotton wet processing with different experimental study in the textile literature [1–10]. The history of the modern enzyme technology really began in 1874 when the Danish chemist Christian Hansen produced the first specimen of the rennet by extracting dried calves' stomachs with saline solution. Enzymes have been used for over fifty years to remove starch-based sizes in the textile industry. Over the last decade, the textile wet processing industry has become more familiar with the use of the several enzymes for the different processes [8, 11, 12].

Various types of the enzyme can been applied of different stages of the woven and knitted fabrics in the manufacturing process to improve the desired properties such as handle, appearance and other surface characteristic. The cellulase enzymes used for the bio-polishing and the stone washing processes can be accepted as the one of the most common applications. During the last decade, the enzymes for the cellulose as cellulase, catalase etc. have generally replaced the traditional stone-washing of the denim garments and found applications in the finishing fabrics and clothing from cotton, linen and regenerated cellulose [1, 8].

Bio-polishing applied with the cellulase enzyme employs basically cellulose action to remove the fine surface fuzz and the fibrils from the cotton and the viscose fabrics. The bio-polishing can be used to clean up the fabric surface after the primary fibrillation of a peach skin treatment and prior to a secondary fibrillation process which imparts interesting the fabric aesthetics [12, 13].

The commercial cellulase may contain mixtures of different cellulases, and the effects on the fabric properties depend on this composition. For instance, one component may decrease the pilling but reduces

* Part I

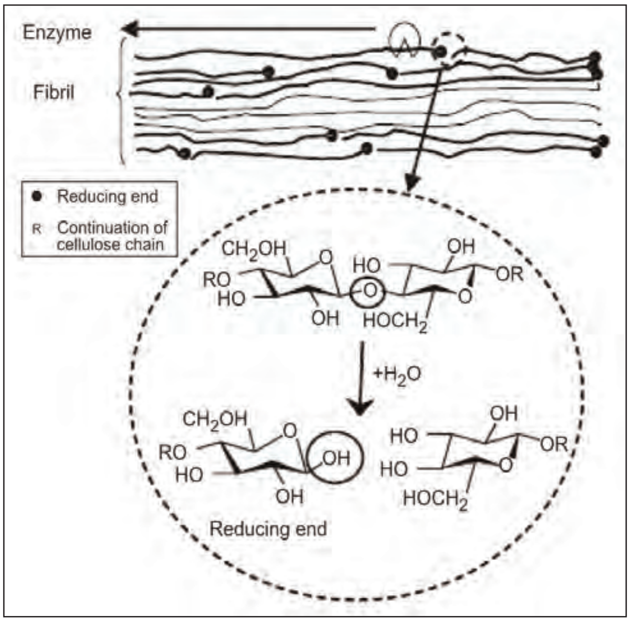


Fig. 1. Schematic presentation of the activity of cellulase on the cellulosic material [1]

the tearing strength. There are three major components in the cellulases, endo-glucanases (EG), exo-glucaneses (cellobiohydrolases – CBH), and B-glucosidases (cellobiases). A total and whole cellulase preparation contains mixtures of these three enzymes types. These enzymes degrade cellulose to the glucose by hydrolyzing β-1,4-glucosidic bonds in polysaccharide molecule (fig. 1) [1, 2]. Therefore, the short fibre ends are hydrolyzed, leaving the surface of the fibres free and providing a more even look [1, 13].
There are several benefits resulting from the enzymatic bio-polishing of the cellulosic woven and the knitted fabrics, as smoother surface, more attractive appearance, better pilling resistance, more gentle and softer feel, improved drape1ability and the use of environment-friendly technology [8].
The hairiness and the pilling is one of the major undesirable and serious problems in the apparel and textile products obtained both weaving and knitting methods. As we mentioned before, these kinds of problems can be prevented with the help of enzymatic treatments.
However, especially for the woven fabrics, the singeing is the first process, and it is obvious that singeing also reduces the hairiness of the fabric surfaces and consequently the pilling [8].
In the textile finishing mill, the singeing and the cellulase enzyme treatments can find application together or individually for the cotton woven fabrics [11, 14].
In Part I of this experimental study, we only investigated the physical effect of cellulase enzyme treatment on the cotton based woven fabrics.
As mentioned before, the main aim of the study was determining of the necessity of the cellulase enzyme treatment applied as an extra process after singeing. However, before discussing of necessity of applications, we must determine the physical performance of treated specimens. In order to test the physical performance, we carried out some tests about strength and surface character according to the international standard.

EXPERIMENTAL PART

In this experimental study, 54 processed specimens were obtained from two kinds of woven fabrics, and applied several tests to these specimens such as tensile and tearing strength and pilling.

Materials used

In the study, two kinds of woven fabrics in which technological properties were shown in table 1 were used.

Pretreatment

The pretreatment processes were implemented to the woven fabrics by order of the singeing, washing, scouring (with peroxide-caustic) and mercerizing (with 28 Be° caustic).

Enzymatic process and dyeing

The bio-polishing processes were applied to the samples along with different finishing steps using acid cellulase enzyme:

- process I (P_I) – without enzymatic process (no enzyme);
- process II (P_{II}) – enzymatic treatment after pretreatment (before dyeing);
- process III (P_{III}) – enzymatic treatment after dyeing.

In the recipe of the enzyme treatment, the wetting (1 g/l) and anti-creasing (1 g/l) agents were used with acid cellulase enzyme (Rucolaze TZE – 1 g/l). The enzymatic processes were applied by exhaust

Table 1

THE TECHNOLOGICAL PROPERTIES OF THE FABRICS

Specimens	Raw Material		Lineer density, tex		Yarn density, thread/cm		Mass per unit area (grey fabrics), g/m²	Width, cm	Weave
	Warp	Weft	Warp	Weft	Warp	Weft			
Fabric 1, *F1*	100% cotton (combed)	cotton + + elastane 78 dtex	10	20	100	32	169.6	180	4/1 satin
Fabric 2, *F2*	100% cotton (combed)	cotton + + elastane 78 dtex	10	20	107	35	150.6	180	

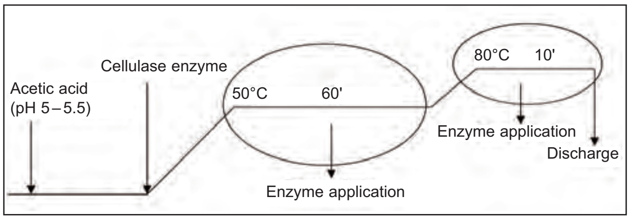


Fig. 2. The graphic of the enzymatic application

method in the industrial jet dyeing machine at *p*H 5–5.5 and 1/10 liquor ratio, according to the graphic shown in figure 2. The enzyme used in the study was supplied bu Rudolf & Duraner (Bursa/Turkey).

The cellulase enzyme was applied at 50°C during 60 minutes. The entire solution was raised to a temperature of 80°C for 10 minutes to deactivate the enzyme.

According to the P_I, we did not apply any enzymatic process. However, we implemented the enzymatic treatment, according to the figure 2, before and after dyeing in both P_{II} and P_{III}, respectively. In the Part I and Part II, with the help of these three processes, we tried to find out both the necessity of the cellulase enzyme treatment for the fully pretreated cotton based woven fabrics and the sequence of the enzyme process in the finishing line in Part II.

The fabrics were dyed in the same jet machine at 60°C (izotherm method) during 60 minutes in a dyebath containing 20 g/l salt and 10 g/l sodium bicarbonate at *p*H 11–12. We preferred Remazol Red RGB, Remazol Blue RR and Remazol Ultra Yellow RGB (DyStar) at three different owf % as 0.5% (light) –2% (medium) –3.5% (dark) in order to find out the effect of the cellulase on the CIELab values of the dyed fabrics. The Remazol Red RGB (Reactive Red Mix), Remazol Blue RR (Reactive Blue Mix) and Remazol Ultra Yellow RGB (Reactive Orange 107) reactive dyes have VS/MCT, VS/VS and VS/MCT anchor group, respectively.

According to this experimental plan, 54 specimens were obtained as shown in table 2. We did not apply any chemical or mechanical finishing process to the samples after dyeing and enzyme processes.

Investigation methods

Pilling

The pilling resistance of the fabrics was determined using a Martindale pilling and abrasion tester, according to EN ISO 12945-2 [15]. We finished the test at 2 000 revolutions for two samples.

Abrasion

The abrasion character of the samples were measured using Martindale pilling and abrasion tester, according to EN ISO 12947-2 (the breakdown of the specimen) and EN ISO 12947-3 (determination of the mass loss) [16]. With the help of this analysis, we tried to determine the abrasion resistance performance of the surface of the woven samples towards external mechanical effects.

Weight (mass per unit area) loss

The mass per unit area of the all samples were measured according to TS 251 [17]. According to the results of this test, the weight loss formed depending on the cellulase enzyme applications was determined.

Strength loss

We analyzed both tensile and tearing strengths according to EN ISO 13934-2 and EN ISO 13937-1, respectively [18].

Microscopically observations

The effects of the cellulase enzyme treatments on the surface of the cotton based woven fabrics were examined by scanning electron microscopy (SEM) at 50 x magnification. These searchs were made on a Jeal-NeoScope scanning electron microscope (Japan) established in ÜSKİM- Kahramanmaraş.

RESULTS OBTAINED

Strength properties

We measured the tensile and tearing strength performances of all samples.

Tensile strength

The results of the tensile strength of the F_1 and F_2 samples can be seen in figure 3 and figure 4, respectively. The bio-polishing process partly hydrolyses the cotton which has a negative effect on the fabric strength. According to the figure 3 and figure 4, in general, it was determined that the tensile strength decreased for both F_1 (no. 1–27) and F_2 samples (no. 28–54) depending on the enzyme applications

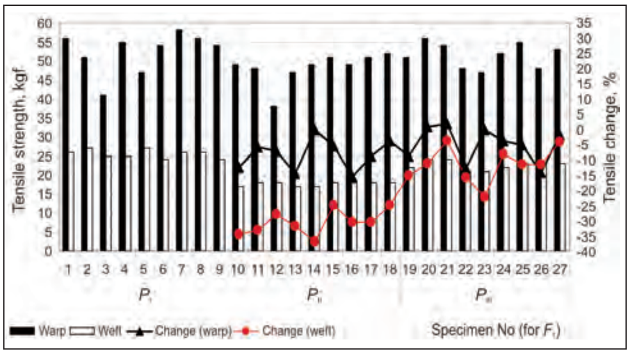


Fig. 3. Tensile strength results of F_1 samples

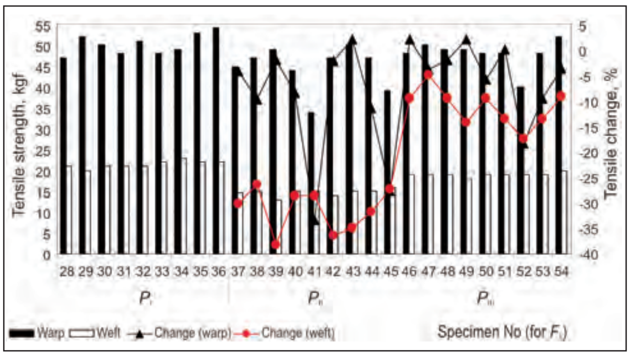


Fig. 4. Tensile strength results of F_2 samples

Table 2

EXPERIMENTAL PLAN				
No. specimen/ Fabric type (Table 1)		**The presence of enzyme process**	**Reactive dye**	**The color strength,** %
F1	***F2***			
1	28	No enzyme (P_I)	Remazol Red RGB	0.5
2	29	No enzyme (P_I)	Remazol Red RGB	2
3	30	No enzyme (P_I)	Remazol Red RGB	3.5
4	31	No enzyme (P_I)	Remazol Blue RR	0.5
5	32	No enzyme (P_I)	Remazol Blue RR	2
6	33	No enzyme (P_I)	Remazol Blue RR	3.5
7	34	No enzyme (P_I)	Remazol Ultra Yellow RGB	0.5
8	35	No enzyme (P_I)	Remazol Ultra Yellow RGB	2
9	36	No enzyme (P_I)	Remazol Ultra Yellow RGB	3.5
10	**37**	**Before dyeing** (P_{II})	**Remazol Red RGB**	**0.5**
11	**38**	**Before dyeing** (P_{II})	**Remazol Red RGB**	**2**
12	**39**	**Before dyeing** (P_{II})	**Remazol Red RGB**	**3.5**
13	**40**	**Before dyeing** (P_{II})	**Remazol Blue RR**	**0.5**
14	**41**	**Before dyeing** (P_{II})	**Remazol Blue RR**	**2**
15	**42**	**Before dyeing** (P_{II})	**Remazol Blue RR**	**3.5**
16	**43**	**Before dyeing** (P_{II})	**Remazol Ultra Yellow RGB**	**0.5**
17	**44**	**Before dyeing** (P_{II})	**Remazol Ultra Yellow RGB**	**2**
18	**45**	**Before dyeing** (P_{II})	**Remazol Ultra Yellow RGB**	**3.5**
19	46	After dyeing (P_{III})	Remazol Red RGB	0.5
20	47	After dyeing (P_{III})	Remazol Red RGB	2
21	48	After dyeing (P_{III})	Remazol Red RGB	3.5
22	49	After dyeing (P_{III}))	Remazol Blue RR	0.5
23	50	After dyeing (P_{III})	Remazol Blue RR	2
24	51	After dyeing (P_{III})	Remazol Blue RR	3.5
25	52	After dyeing (P_{III})	Remazol Ultra Yellow RGB	0.5
26	53	After dyeing (P_{III})	Remazol Ultra Yellow RGB	2
27	54	After dyeing (P_{III})	Remazol Ultra Yellow RGB	3.5

approximately for all stages. However, it was clear that the change on the strength showed differences according to the sequence of the enzyme application (before – P_{II} or after dyeing – P_{III}). In addition, we found out that the strength loss was measured bigger on the samples obtained from P_{II} than samples produced on the P_{III} line. In P_{II}, we dyed samples processed with cellulase enzyme different from P_{III}, and enzyme is possible to cause damage cellulose structure. Because of this possible damage, during dyeing process, the samples could be affected more negatively than others obtained with P_{III}. We also determined that the strength of the weft direction reduced more dramatically than warp for both F_1 and F_2, especially on the samples processed by P_{II}.

Tearing strength

The results of the tearing strength of the F_1 and F_2 samples can be seen in figure 5 and figure 6, respectively.

The tearing strength of the F_1 samples (no. 1–27) decreased after all enzyme treatments. For F_2 samples, P_{III} applications caused bigger strength loss than P_{II} processes. In addition, it could not be determined important differences depending on the sequence of the enzyme in the finishing line for the tearing strength performance for F_1 based samples. As it was seen on figure 6, the warp direction of the F_2 fabrics showed bigger resistance towards tearing force than weft after enzyme applications. According to the figure 6, we determined a little tearing strength increase (approximately 5%) for the weft side of the

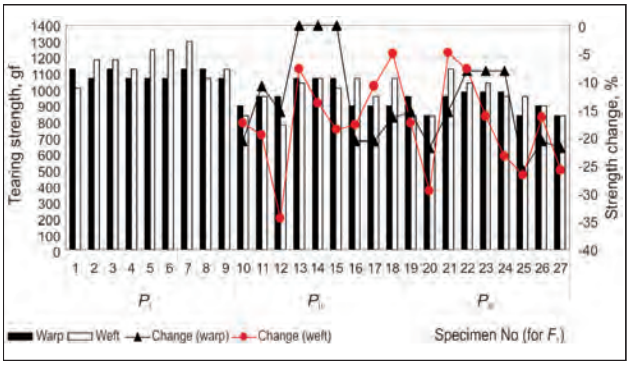


Fig. 5. Tearing strength results of F_1

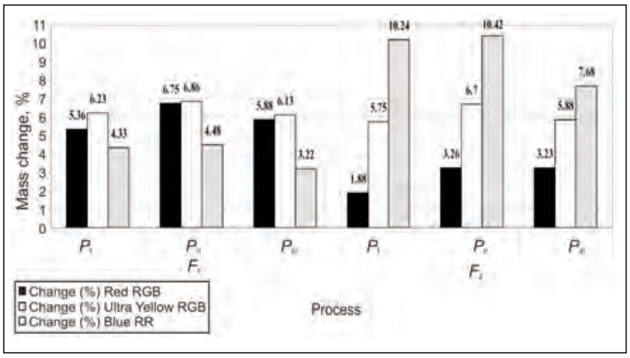


Fig. 7. The mass changes of the samples after abrasion test

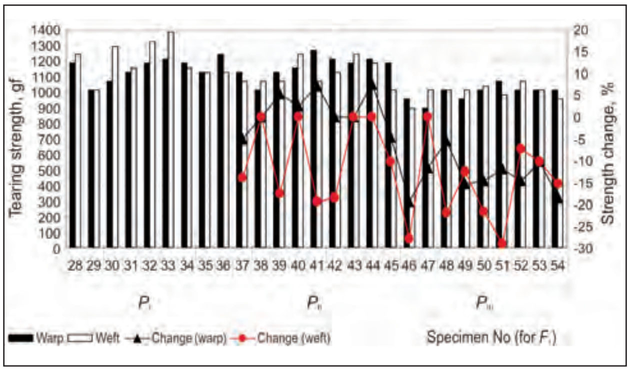


Fig. 6. Tearing strength results of F_2

some samples after P_{II} processes. We did not find these increases as important as decrease.

According to the results shown in figure 5 and 6, when the effect of the type of the woven fabric on the strength was investigated, it could be also found out that the structural properties of the fabric was another effective parameter on the tearing strength loss. The decrease depending on the enzyme applications was measured bigger on the F_1 samples (no. 1–27) than others (F_2 samples – no. 28–54).

Pilling

Martindale instrument was operated till 2 000 revolutions for all samples. After the evaluation of results, it was determined that pilling resistance ratings of the samples were similar to each other, and there was no significant difference between them. According to the qualitative analysis, the rate of the pilling was observed 4/5 for all samples.

Abrasion resistance (breakdown and mass loss)

The abrasion test was carried on Martindale Test Instrument till the 25 000 revolutions. On this circle, because any breakdown was not observed on whole samples, we ended the tests. At the beginning and end of the test, we measured the weight of the samples, and then the change on the weight was calculated.

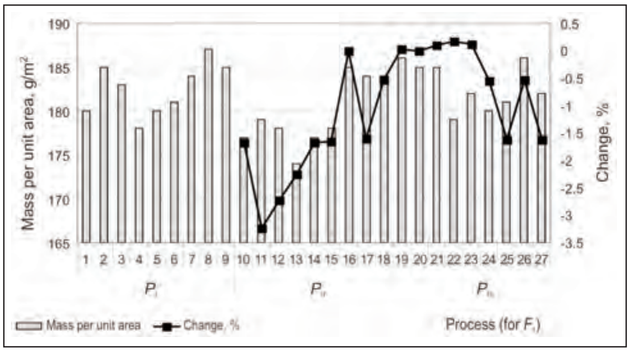
The results of the change on the weight (%) after abrasion test for F_1 and F_2 samples can be seen in figure 7.

The abrasion test was not applied to all samples. As it is seen from figure 7, the test was carried on only 18 samples in which color the strength of the dyed samples was light (0.5% owf), therefore the effect of the color strength on the abrasion resistance was neglected for this experimental study.

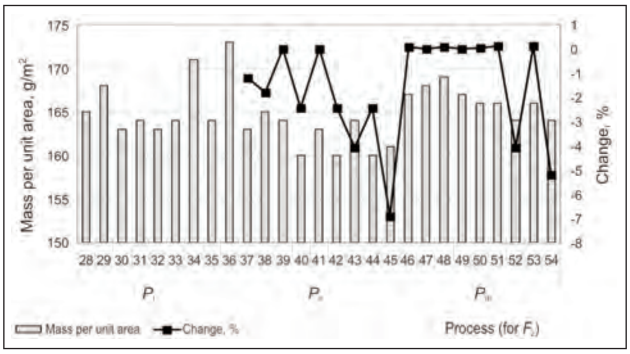
According to the results, we determined the biggest and the least weight loss on the samples processed by P_{II} (before dyeing) and P_I (no enzyme), respectively. In addition, it could be said that the type of the reactive dyestuff was effective factor on the weight loss. As an example, for F_2 samples, we could order the calculated weight loss according to the dyestuff criteria as Blue RR > Ultra Yellow RGB > Red RGB, and the similar order can be made as Ultra Yellow RGB > Red RGB > Blue RR for F_1 samples. The weight loss on the F_2 samples was measured less than F_1 ones except samples dyed with Remazol Blue RR. The dyeing of F_1 and F_2 samples was carried out at same conditions.

Weight loss

The results of the change on the mass per unit area for F_1 and F_2 samples can be seen in figure 8. After the enzymatic bio-polishing process applied with cellulase enzyme, 1–5% loss on the weight of the fabric is an expected result in order to determine the efficiency of the treatment [3]. As it seen in figure 8, we generally confirmed the weight loss depending on the cellulase enzyme applications (P_{II} and P_{III} processes). However, for some samples (especially processes by P_{III}), we did not determine important or any weight loss. We found out that weight loss showed difference according to the sequence of the cellulase enzyme treatment in the finishing line. According to the figure 8, the average weight loss of the samples processed with enzymes after pretreatment (P_{II} – before dyeing) was higher than samples implemented with P_{III} for both F_1 (no. 1–27) and F_2 (no. 28–54) fabrics. We thought that it was about sequence of the enzymatic process.



a



b

Fig. 8. The mass per unit area of the samples (for F_1 and F_2)

Microscopically observations (SEM)

The SEM micrographs allowes the researcher to examine how the surface of the fabric physically changes during the enzymatic treatments. The SEM photos are showed in figure 9 and figure 10 for F_1 and F_2, respectively.

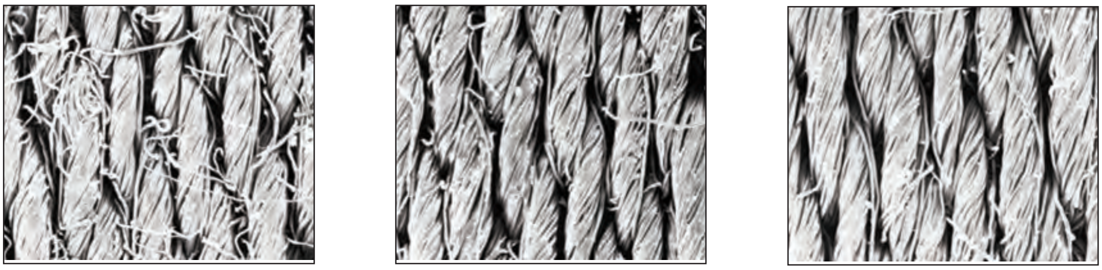
In figures 9–10 *a, b, c*, the surface of the F_1 and F_2, samples processed without cellulase enzymes, and by P_I–P_{II}, respectively. As it is shown from the figure 9 *a* and figure 10 *a*, the samples having no enzyme in the process have a lot of loose fibres not contributing the yarn and the fabric structure, and have high tendency to form pills on the surface. However, figure 9 *b, c* reveals that these fuzzy fibres can be removed from the surface with the help of enzymatic processes. It means that enzymes application could clean the surface of the fabric and by removing the individual fibres and improved the fabric quality.

CONCLUSIONS

The singeing is known a mechanical process on the contrary enzymatic processes. Especially, the fabric having polyester content (for example, PET/cotton, PET/viscose) is sensitive to the thermal processes because they are thermoplastic. There is always melting risk for polyester and similar artificial fibre. Therefore, the cellulase enzyme processes find application area for the woven fabrics although they frequently process in the singeing machine. In addition, the possible handle poverty for woven fabric can be prevented by this kind of wet processes. In this experimental study, cellulase enzymatic applications were investigated together with singeing process.

Based on the results obtained from Part I of experimental study, it could be said that:

- Strength values of the samples were reduced on both warp and weft sides. The sequence of the enzymatic process affected these performance depending on the damage occurred in the fiber structure. Therefore, the expected final and known



a *b* *c*

Fig. 9. SEM photographs of F_1:
a – P_I (no enzyme); ***b*** – P_{II} (before dyeing); ***c*** – P_{III} (after dyeing)

a *b* *c*

Fig. 10. SEM photographs of F_2:
a – P_I (no enzyme); ***b*** – P_{II} (before dyeing); ***c*** – P_{III} (after dyeing)

initial resistance before enzyme and possible change on this performance should be observed while the processes are being preferred.

- The enzymatic application was reduced the abrasion resistance of the samples.
- The pilling behavior of the enzymatic treated fabric samples did not display any significant difference whether they were processed with enzymes after or before dyeing.
- It was found out that the weight loss was occurred depending on the sequence of the enzymatic application in the finishing line.

In the second part of the study, the necessity and sequence of the enzymatic treatments were discussed in terms of handle, color change and fastness performances. These performance criteria showed the necessity of the cellulase enzyme for cotton based woven fabrics.

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The exhaust dyeing of acrylic fibers with vat dyes

GULZAR A. BAIG

REZUMAT – ABSTRACT

Vopsirea prin epuizare a fibrelor acrilice cu coloranți de cadă

Fibrele acrilice au fost vopsite cu albastru indigo, prin tehnica epuizării. Valoarea pH-ului a fost obținută prin controlul raportului dintre concentrațiile de ditionit de sodiu şi hidroxid de sodiu, din baia de vopsire. Moleculele de indigo existau în diferite forme, în funcție de pH-ul băii de vopsire, şi fiecare prezenta grade diferite de substantivitate pentru fibrele acrilice. Forma neionică a compuşilor leucoacizi ai coloranților de cadă s-a comportat ca un colorant de dispersie şi a prezentat substantivitate pentru fibrele acrilice. O vopsire optimă a fibrelor acrilice s-a obținut la valori ale pH-ului cuprinse între 5.5 şi 6. pH-ul alcalin a generat hidroliza grupelor funcționale de cianat, ceea ce a determinat îngălbenirea fibrelor acrilice. Analiza realizată cu ajutorul microscopiei electronice a revelat faptul că pH-ul alcalin este dăunător pentru integritatea fibrelor. Spectrul de reflexie a arătat că maximul de absorbție a indigoului în fibrele acrilice s-a înregistrat la 610 nm. În cazul expunerii la iluminarea casnică, fibrele vopsite au prezentat o deplasare batocromă. Proprietățile de rezistență la frecare, spălare, lumină şi sublimare au fost bune.

Cuvinte-cheie: indigo, fibră sintetică, fibră acrilică, pH, culori, valori, rezistență

The exhaust dyeing of acrylic fibers with vat dyes

Acrylic fibers were dyed with indigo blue through an exhaust technique. The pH was achieved by controlling the ratios of sodium dithionite and sodium hydroxide concentrations in the dyebath. Indigo molecules existed in different forms, depending on dyebath pH, and each exhibited different degrees of substantivity for acrylic fibres. Non-ionic leuco vat acid form behaved like disperse dye and showed substantivity for acrylic. Acrylic fibres were best dyed in the pH range of 5.5 – 6. The alkaline pH caused hydrolysis of cyanate functional groups and led to yellowing of acrylic fibres as well. SEM revealed that alkaline pH was deleterious for the integrity of fibres. The reflection spectra showed that the absorption maximum of indigo in acrylic fibres was at 610 nm. The dyed fibres exhibited bathochromic shift when exposed to household tube light. Rubbing, washing, light and sublimation fatness were good.

Key-words: indigo, synthetic fibre, acrylic, pH, colour, values, fastness

Recently, vat dyes have attracted the interest of a number of workers. The vat dyes were applied to various synthetic fibres through different techniques [1–10]. No previous work was found about the dyeing of acrylic fibres with vat dyes. Perhaps the interest did not arise due to the availability of basic dyes which were famous for excellent tinctorial strength as well as brightness properties, not to be found in any other class of colorants. Among synthetic fibres, acrylic also known as artificial-wool is known for its excellent bulk and warmth properties, at reduced weight (sp. gravity 1.18). The main applications include the knitwear, socks, fleece-wear, craft yarn, blankets, upholstery and industrial applications. It is also used in blends with wool and cotton. Acrylic is mainly dyed with basic dyes. However, disperse dyes can also be applied due to the crystalline structure and hydrophobic chemical nature of acrylic fibres. The previous work was about the dyeing of polyester, nylon and Lycra with indigo. Excellent shade depths with good overall fastness properties, except dyed polyester which exhibited poor light fastness, were reported [9–10].

Acrylic is prepared from the free-radical polymerization of acrylonitrile along with some others monomers to reduce crystallinity which otherwise had been so high that fibre could not be dyed. A general chemical composition of the acrylic polymer is: acrylonitrile (85 – 100% typically 90 – 94%), methyl acrylate, vinyl acetate, methyl methacrylate and acrylamide (0 – 14%, typically 6 – 9%), sodium styrene sulphonate, sodium methallyl sulphonate, sodium 2-methyl-2-acrylamido-propane sulphonate, itaconic acid (0 – 1%) [11–12]. When basic monomers are incorporated, acrylic fibre can be dyed with acid dyes to a very dark shade. The literature does not refer to the application of vat dyes on acrylic fibres. This work is an extension of the previous work wherein vat dyes were applied to synthetic fibres [7–10]. In the present work indigo was reduced in situ and applied to acrylic fibres. The process parameters studied were the reducing agent and alkali concentrations, temperature, time and liquor ratio. The reflectance spectra and fastness properties viz., washing, crocking, light and sublimation were also measured and the results presented.

The present work covers the theoretical aspects of dyeing acrylic fibres with indigo. From commercial viewpoint dyeing of acrylic fibres with indigo may find potential application in the dyeing of fibre blends. The hosiery industry produces acrylic-wool bends in huge amounts. The acrylic is dyed with basic while wool fibres can be dyed with a range of dyes viz., acid, basic and reactive or vat dyes. If the blends are dyed in two stages it entails huge amounts of water and energy. The present work suggests that acrylic-wool and acrylic-cotton blends can be dyed in a single-bath-single-stage with a single dye and excellent shade depth with overall good fastness properties can be obtained. In the present work dyeing of acrylic fibres with indigo was studied. The work may be extended further to study the substantivity and performance properties of other vat dyes on acrylic fibres alone and their blends.

EXPERIMENTAL PART

Materials and methods

An HT dyeing machine 75231–1992 was used to dye acrylic fabric. The dyebath *p*H was measured before and after dyeing by using a digital *p*H meter, PH-210. Reflectance and colour strength were measured on a GretagMacbeth ColorEye – 7000A spectrophotometer. Acrylic plain fabric woven from filament yarns (warp count: 88 denier, weft count: 177 denier, warp density: 124 ends/in, weft density: 78 ends/in) with mass per unit area of 109 gsm was purchased from the market. Indigo dye (85%) in a granular form was provided by DyStar in Pakistan. All other chemicals were of laboratory grade.

A light scouring treatment with 2 g/l Na_2CO_3 at 60ºC for 20 minutes was given. The samples were then rinsed with cold water followed by drying at ambient conditions overnight. Acrylic fabric samples were dyed with indigo to shade depths of 0.1 to 3% o.w.f. Sodium dithionite and sodium hydroxide concentrations were varied from 0–10 g/l and 0–4.6 g/l, respectively. Dyeing temperatures were varied from 80 to 130ºC for time intervals of 15 minutes, from 15 to 90 minutes. All of the dyed samples were then subjected to cold water rinsing. Since acrylic has a very compact structure, the dye was oxidized in hot air at 120ºC for 5 minutes. All of the samples were soaped with Sandopan DTC 5 g/l at 80ºC for 10 minutes, air-dried, and then tested for colour values and fastness properties.

The *p*H of the fresh as well spent dyebaths was measured. Colour strength, *K/S*, was measured at a specified wavelength, λ, by the single-wavelength, *SWL*, method using the following equation (1) [13]:

$$K/S = [(1.0 - R_\lambda)^2] / 2.0\, R_\lambda \qquad (1)$$

where:

K and *S* stand for coefficients of absorption and scattering of the dye respectively at λ;

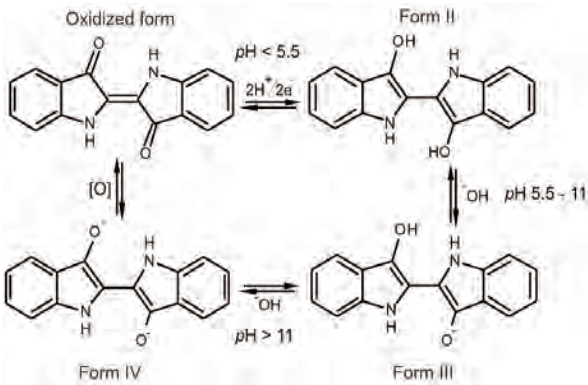
R_λ is the absorption coefficient of the specimen.

The reflectance spectra were measured at 10 nm intervals. Fastness properties that included rubbing, washing and light were measured in accordance to ISO standards while sublimation fastness was measured in accordance to a Lab-developed method [14–16] Hitachi Scanning Electron Microscope (SEM) was used to study the surface morphology of acrylic fibers. The samples were sputter coated with gold and micrographs taken at 5 kV.

RESULTS AND DISCUSSIONS

Effect of alkali

The *p*H of the spent dyebath was measured and shown in figure 1. The figure 1 showed the dyebath *p*H, *p*H difference and Δ *p*H. The results were different from the previous work carried out on polyester and nylon fibres [7–8]. In the range of 0 – 0.6 g/l of alkali concentration there was very little change in the *p*H. This behaviour was explained on the basis of sodium dithionite decomposition for polyester and nylon fibres [7–8]. In the region of 0.6 – 1.2 g/l alkali concentration the *p*H changed from 3.54 to 6.13 which derived the reduction of indigo to leuco vat acid forms to a forward direction. In this range, the alkali was present in a surplus amount. Some of the alkali amount was consumed by the acidic products, generated by sodium dithionite, while the remainder caused a steep change in the *p*H. In the range of 1.2 – 2.8 g/l alkali concentration the *p*H changed again very slowly which indicated that alkali was being consumed during the dyeing process. Reduction-oxidation cycle of indigo is presented in equation (2).



(2)

There were different reagents that consumed the alkali and these included the acidic products generated by sodium dithionite, acrylic fibres themselves and leuco vat acid molecules. It was supposed to be

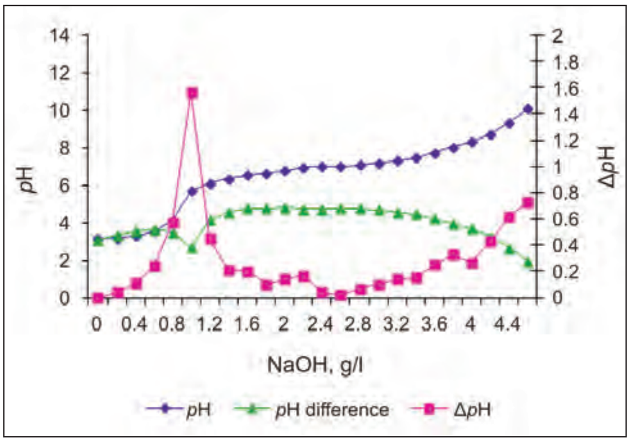


Fig. 1. *p*H measured at the end of the dyeing (1% o.w.f., 10 g/l $Na_2S_2O_4$, 120ºC, 40:1 and 30 minutes)

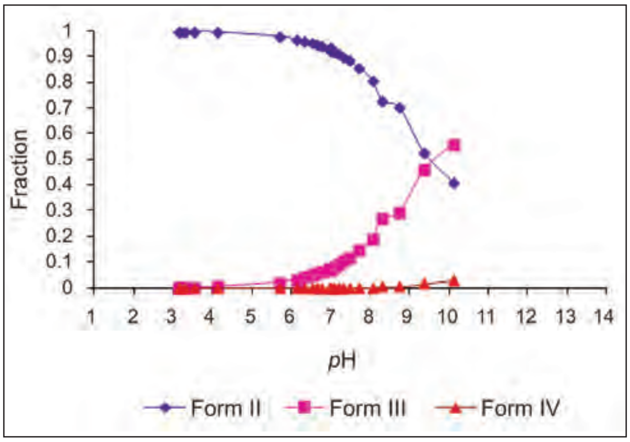


Fig. 2. Fractions of indigo as a function of *p*H (1% o.w.f., 10 g/l $Na_2S_2O_4$, 120ºC, 40:1 and 30 minutes)

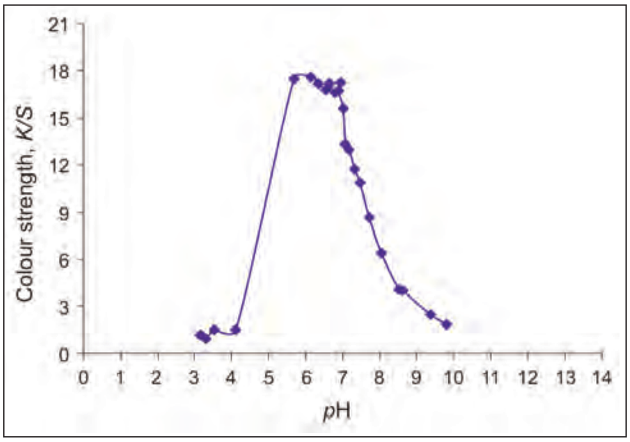


Fig. 3. Colour strength, *K/S*, as a function of *p*H (1% o.w.f., 10 g/l $Na_2S_2O_4$, 120ºC, 40:1 and 30 minutes)

the leuco vat acid that consumed the alkali in the range of 1.2 – 2.8 g/l. As the alkali concentration was increased the ratio of leuco vat acid to mono-sodium phenolate form decreased. It was possible to calculate the fractions of different forms of indigo, shown in scheme 1, as a function of dyebath *p*H by using equations 3–5, where pK_1 and pK_2 represent the dissociation constants of the forms II and III [17].

$$Fraction\ II = 1/(1 + 10^a + 10^b) \quad (3)$$

where:

$$a = (pH - pK_1);$$
$$b = (2\ pH - pK_1 - pK_2)$$

$$Fraction\ III = 1/(1 + 10^c + 10^d) \quad (4)$$

where:

$$c = (pK_1 - pH);$$
$$d = (pH - pK_2)$$

$$Fraction\ IV = 1/(1 + 10^e + 10^f) \quad (5)$$

where:

$$e = (pK_1 + pK_2 - 2\ pH);$$
$$f = (pK_2 - pH)$$

It was evident from figure 2 that leuco vat acid remained the major moiety up to *p*H ~ 7. At higher concentration of alkali the amount of leuco vat acid dropped steeply and this was in accordance with our results. Up to *p*H ~ 7, alkali was consumed by the leuco vat acid after which it did not change again. Here lie the main difference among acrylic and other synthetic fibres e.g. polyesters and nylons. Acrylic fibres contained a large number of cyanide groups pendant to polymeric backbone. These groups were liable to hydrolysis in the alkaline as well acidic *p*H regions. However, it was seen from the graphs that cyano groups were more stable in the acidic than in the alkaline region. This is one of the reasons why acrylic fibres are dyed in an acidic *p*H with basic dyes. Beyond 2.8 g/l alkali concentration, *p*H started becoming alkaline. It was slightly alkaline but even in these mild conditions, cyano groups start to be converted into carboxylic groups, scheme 2. These –COOH groups started consuming alkali forming their respective sodium salts and therefore the formation of diphenolate was suppressed.

It was suggested that acrylic polymer formed a *p*H buffer with the dyebath alkali. If controlled properly, hydrolysis could be taken advantage of in the modification of the surface chemistry of acrylic fibres. Due to anionic nature of the carboxylic acid groups the fibres were less prone to static charge accumulation. At the end of dyeing, the *p*H of dyebath could be raised to alkaline side and controlled hydrolysis carried out to generate carboxylic acid groups that would make the fibre surface prone to moisture adsorption from the atmosphere. Figure 3 showed the colour strength of indigo on acrylic fibres at various *p*H values. The dyeing behaviours of acrylic and nylons fibres were almost identical [7]. There was negligible dye exhaustion in the *p*H range of 4 – 4.5. When indigo was reduced with sodium dithionite acidic products were generated [7–8]. If these acidic products were not consumed then according to Le Chatlier's principle the reaction would not proceed further. It was suggested that in the highly acid region (*p*H 4) either the reducing agent did not work at all or if leuco vat acid was produced it precipitated out due to poor solubility. Since the oxidized form of indigo (form I) had little affinity for acrylic fibres an uneven tint was produced. As alkali concentration in the dyebath was increased there was rapid change in the *p*H. The *p*H around 6.13 helped in the reduction of indigo to the leuco vat acid molecules. Around pH 6 leuco vat acid was the sole product so a maximum shade depth was produced. As the bath pH became more alkaline the mono-sodium phenolate form also started appearing and this led to less dye build-up. In the *p*H range of 5.5 – 7 the colour strength curve formed an almost flat plateau. At still higher alkaline region although vat acid existed, it was not taken up by the acrylic fibres to the extent as speculated from figure 2. At *p*H 9 – 9.5 leuco vat acid was 40% of the total

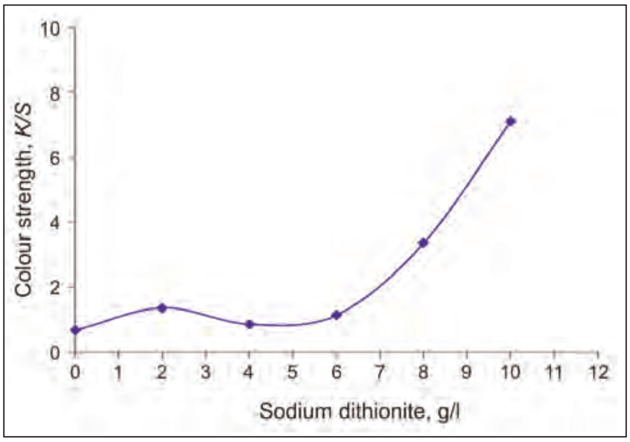


Fig. 4. Colour strength, *K/S*, versus sodium dithionite (1% o.w.f., 0.6 g/l NaOH, 120ºC, 40:1 and 30 minutes)

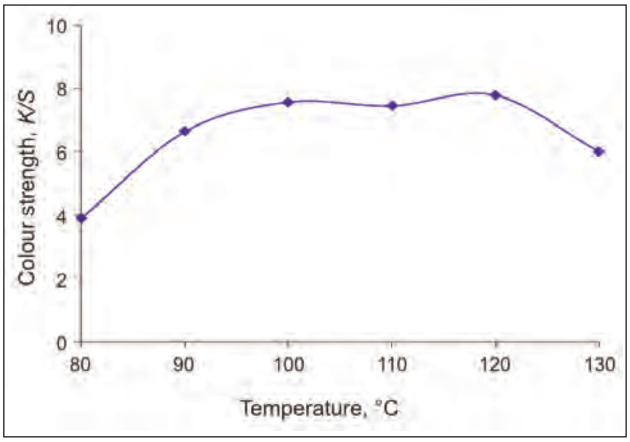


Fig. 5. Colour strength, *K/S*, versus temperature (1% o.w.f., 10 g/l $Na_2S_2O_4$, 1 g/l NaOH, 40:1 and 30 minutes)

amount of dye present in the dyebath but at this point exhaustion stopped. Since in the alkaline *p*H cyano groups were not stable and started hydrolysing the leuco vat acid molecules remained in the solution. Among the various synthetic fibres viz., polyesters, nylons and acrylic the latter was the most effected by *p*H in terms of loss in colour strength.

Effect of reducing agent

Figure 4 showed the effect of sodium dithionite on the colour strength of indigo on acrylic fibres. There was negligible change in colour strength up to 6 g/l concentration of sodium dithionite. There was a little substantivity of indigo in this range. From the above discussion it was suggested that either indigo molecules existed in oxidized state or ionized because in either case the dye molecules possessed little substantivity for the acrylic fibres. Since the dithionite concentration was very low the indigo molecules were properly reduced. As the concentration of dithionite was increased the colour strength also increased. The colour strength reached a maximum at 10 g/l dithionite concentration. At 10 g/l sodium dithionite was sufficient enough to reduce the indigo thereby bestowing substantivity to the dye molecules. At lower concentrations, sodium dithionite was not enough in quantity to reduce indigo to leuco vat acid which was the main colouring component. In comparison with polyester and nylon, acrylic required a greater quantity of reducing agent [7–9]. It was suggested that some of the reducing agent was consumed in the reduction of cyano groups to the methyl amine groups. Infrared and X-ray photoelectron spectroscopy (XPS) studies were underway to probe the effects of reducing agents on the chemistry of acrylic fibres.

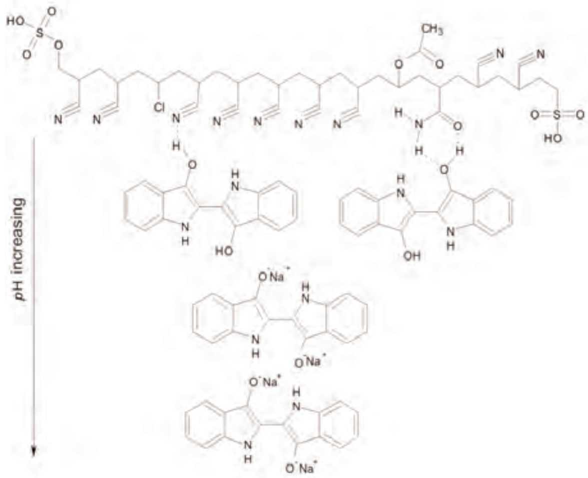
Effect of dyebath temperature

Dyeing requires heating so that the dye molecules have enough kinetic energy to penetrate into the fibre structure. At the same time, it softens the fibre structure as well. Figure 5 showed the effect of temperature on the colour yield of indigo on acrylic fibres. It was observed that the acrylic fibres developed tint at lower temperatures, however, the shade depth increased with increasing temperature up to 110ºC. At further higher temperatures the shade depth decreased. The trend was explained based on the thermal motion of polymer chains constituting the fibres. As a crystalline material the polymeric chains did not violently vibrate to generate temporary voids for the dye molecules to enter into the structure at lower temperatures. As the dyebath temperature increased up to the glass transition temperature, T_g, and beyond, the segmental mobility of polymer chains of such a high degree that the transportation of dye molecules from the solution became possible. Upon further increase in temperature the oscillations of chains were so high that dye molecules rushed away from the polymeric structure as easily as they penetrated. The net result was a decrease in colour yield. Hence, there was an optimum temperature of 110ºC at which the best colour yield was obtained. The temperature effects on polyester and acrylic are very similar.

Acrylic fibre – indigo interactions

In the acidic *p*H region acrylic fibres were more stable than in the alkaline one. In the highly acidic region (*p*H 3 ~ 4) dye molecules did not exhaust well on fibres due to the poor solubility of the leuco vat acid in water. However, at relatively high *p*H but still in the acidic side (*p*H 5.5 ~ 7) the cyano groups were stable. The cyano functional groups were now available for the dye molecules to attach to acrylic fibres through hydrogen bonding. Equation (6) suggested the possible hydrogen bonding between acrylic and indigo. There might be various forces that constitute to the substantivity between the dye and fibre but hydrogen bonding seemed to be the most important one. Acrylic fibres contained the highly polar cyano groups.

These functional groups interacted with the hydroxyl as well as secondary amine groups of the indigo molecules. Most probably these were the hydroxyl groups that contributed to the substantivity due to their being more polar in chemical character. In addition to cyano groups, carboxylic, amide and acetyl groups may also contribute to substantive behaviour of acrylic fibres toward indigo molecules. In the alkaline region carboxylic groups were ionized so that negative charge was developed on the fibre surface. This negative potential repelled the ionized indigo species i.e. fractions III and IV away and thus the fibres remained undyed. The scheme 3 suggested the possible interactions between leuco indigo dye molecules and acrylic polymer. The arrow on the left hand side represented that increasing *p*H decreased interactions between acrylic fibres and indigo dye molecules.



(6)

SEM of acrylic fibers

Figures 6*a* to 6*e* showed scanning electron micrographs of acrylic fibres dyed at various *p*H values. The results showed that washing had little effect on the surface appearance and morphology of acrylic fibres. However, when processed at *p*H 5 and 7 there was observed a little damage to the fibre surface. There were observed a number of serrations running parallel to the fibre axis. The maximum damage took place at *p*H 11, as shown in micrograph 9*e*. There were observed big slits on the surface of the fibres running along the fibre axis. The results showed that alkaline conditions caused severe deterioration to the fibre integrity. One of the reasons why acrylic fibres were dyed with basic dyes in the acidic region was the better hydrolytic stability of fibres. The other reason was the precipitation of basic dyes in the alkaline medium [14]. If acrylic fibres were to be dyed with vat dyes in the appropriate *p*H range there would be little strength losses. It was quite safe to carry out dyeing because acrylic fibres showed little changes in surface morphology.

Reflection spectra of indigo

The reflection spectra of indigo dyed acrylic were shown in figure 7. It was observed from the graphs that the absorption maxima lie at 610 nm. When measured spectrophotometricaly in dimethyl formamide solution, indigo absorbed at 610 nm [18]. This showed that indigo dye molecules existed in the fibrous matrix in an unassociated form as they existed in the solution. Figure 7 also showed the photochromic behavior of indigo molecules on acrylic fibres. It was observed that when exposed to commercial tube light indigo showed maximum absorption at 570 nm. There was a bathochromic shift from 610 nm to 570 nm.

Fastness properties of indigo

Acrylic samples were dyed with indigo to a shade depth of 2% owf and various fastness properties were measured and the results presented in tables

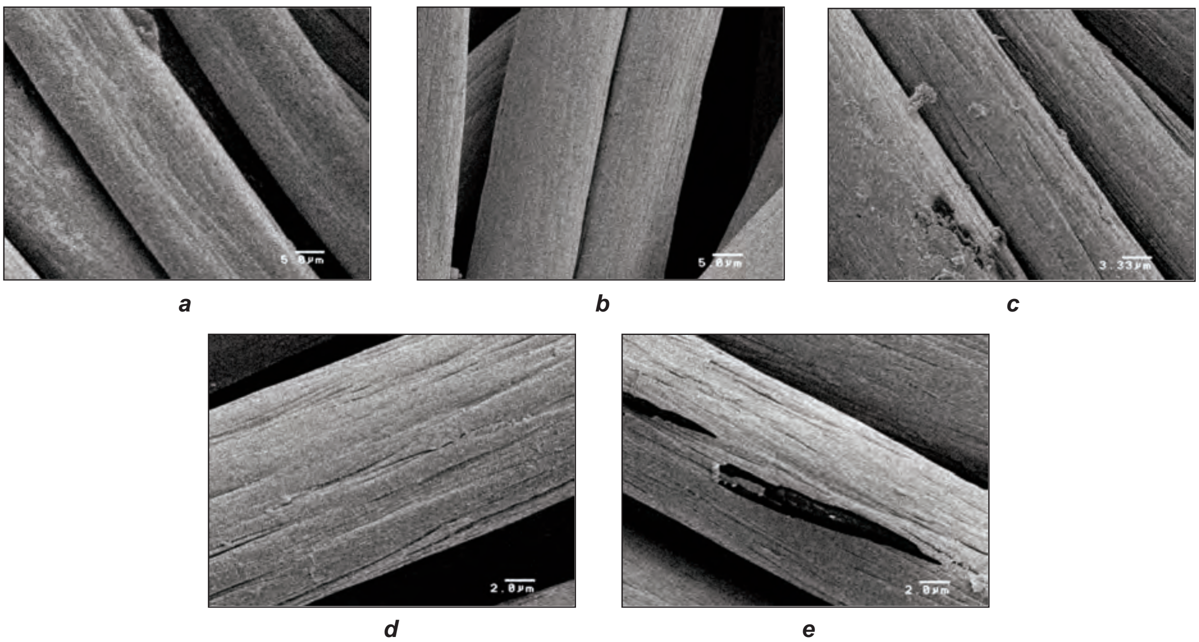


Fig. 6. SEM of Acrylic fibers dyed at various *p*H values:
a – greige; ***b*** – washed; ***c*** – *p*H ~ 5; ***d*** – *p*H ~ 7; ***e*** – *p*H ~ 11

1–3. The results showed that dry rub fastness was good while wet rub fastness was half grade lower. Light fastness of indigo on acrylic was good. Washing fastness was very good. There was some staining of nylon fibers. The sublimation fastness properties were tested for 1 minute at various temperatures and the results were excellent.

Table 1

LIGHT AND RUBBING FASTNESS		
Rubbing		**Light**
Dry	***Wet***	
4	3 - 4	6

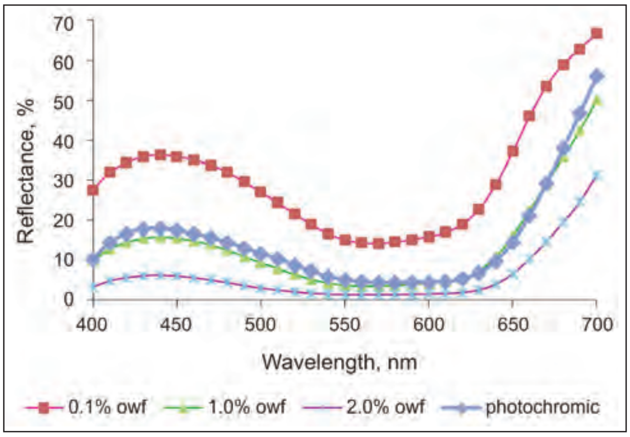


Fig. 7. Reflection spectra of indigo on acrylic fibres

Table 2

WASHING FASTNESS						
Colour change	**Staining**					
	Acetate	***Cotton***	***Nylon***	***Polyester***	***Acrylic***	***Wool***
1 GS	4	4 - 5	3 - 4	4 - 5	4 - 5	4

Table 3

SUBLIMATION FASTNESS (1 minute)							
150ºC		**170ºC**		**190ºC**		**210ºC**	
Shade change	***Staining***	***Shade change***	***Staining***	***Shade change***	***Staining***	***Shade change***	***Staining***
5	5	5	5	5	5	5	5

CONCLUSIONS

Acrylic fibres were dyed successfully through an exhaust technique by in situ reduction of indigo. The sodium dithionite and sodium hydroxide concentrations of 10 g/l and 1 g/l were sufficient for proper reduction of indigo dye. When the reducing agent was optimized the alkali concentration would bear a certain relationship with it so that optimum *p*H was achieved for dyeing. The optimum *p*H was in the acidic range (5.5–6). The *p*H should be measured and strictly monitored as it affected both the dye molecules and the fibre structure and chemistry. Indigo molecules did not exist as aggregates within the fibrous matrix which might support the solid-solution dyeing theory. When exposed to ordinary tube light indigo dyed acrylic samples exhibited bathochromic shift of 40 nm from 610 nm. The fastness properties of indigo on acrylic were good. The dyeing of acrylic with indigo suggested that acrylic-wool and acrylic-cotton blends might be dyed with a single dye. Single-bath-single-stage-single-dye might save downtime, inventory and energy requirements.

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DOCUMENTARE

Confecții textile

MATERIALE TEXTILE CU CARACTERISTICI ACUSTICE

Testele acustice efectuate la *Institutul Hohenstein* asupra unor materiale fonoabsorbante, care au coeficienți diferiți de absorbție, situați la interfața dintre reducerea zgomotului şi blocarea completă a sunetelor, ajută la optimizarea articolelor de îmbrăcăminte sport.

Cu toate că capacitatea de a auzi sunetele este deosebit de utilă, uneori aceasta poate fi extrem de iritantă, în prezent zgomotul fiind una dintre principalele cauze ale stresului.

Potrivit studiilor ştiințifice, chiar şi sunetul produs de un radioreceptor, care corespunde unui nivel de 40 de decibeli, poate reduce nivelul de concentrație cu 30–40%. Însă, în acelaşi timp, capacitatea de a auzi un sunet este importantă pentru detectarea în timp util a unor pericole.

Aceşti doi factori trebuie luați în considerare în producția de îmbrăcăminte, deoarece un articol de îmbrăcăminte care fâşâie sau o pereche de pantofi care scârțâie trădează, de obicei, prezența unei persoane, în timp ce purtarea unor pălării groase sau a unor glugi împiedică utilizatorii să audă zgomotul produs, de exemplu, de un vehicul care se apropie.

Toate acestea au reprezentat un motiv întemeiat pentru ca Institutul Hohenstein, din Bonningheim, să măsoare, să evalueze şi să optimizeze caracteristicile acustice ale produselor textile. Pe lângă absorbția zgomotului din mediul înconjurător, un obiectiv important al cercetărilor realizate de dr. Ian Beringer şi echipa sa l-a constituit studierea zgomotului generat chiar de materialele textile. Legat de aceasta, dr. Jan Beringer afirma: "Am efectuat teste individuale şi specifice, în funcție de utilizarea finală a produselor... De exemplu, în cazul corturilor şi a prelatelor, amortizarea activă a zgomotului ambiental este la fel de importantă ca şi atenuarea zgomotelor de fond produse de materialul textil. Totodată, am studiat zgomotul generat în timpul purtării unor articole de îmbrăcăminte sau încălțăminte, a utilizării sacilor de dormit, ori în cazul purtării căştilor de protecție, a pălăriilor şi a glugilor, care trebuie să asigure o anumită izolare fonică şi, nu în ultimul rând, să ajute utilizatorul să se concentreze, fără ca că avertizarea zgomotelor de fond să fie blocată complet".

Prin efectuarea testelor acustice, experții din cadrul Institutului Hohenstein sprijină clienții din întreaga lume să dezvolte noi materiale cu caracteristici acustice performante, care să ofere niveluri diferite de atenuare a zgomotului, în vederea asigurării unui confort acustic corespunzător.

Kettenwirk Praxis, 2012, nr. 4, p. 40

Comfort properties of knitted fabrics with massaging effects

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REZUMAT – ABSTRACT

Proprietățile de confort ale tricoturilor cu efect de masaj

La proiectarea articolelor de îmbrăcăminte, proprietățile de confort reprezintă un aspect esențial. Caracteristicile de confort ale cosmetotextilelor cu efect de masaj trebuie să corespundă tuturor particularităților textilelor care conferă produsului acest efect. Geometria de suprafață a tricoturilor 3D, realizate din bătătură multistrat, constituie un avantaj în utilizarea acestora la producerea cosmetotextilelor cu efect de masaj. Geometria suprafeței poate fi complexă şi influențează proprietățile materialului textil. În lucrare este prezentat un studiu asupra proprietăților de confort ale tricoturilor cu o geometrie de suprafață 3D, prin care se urmăreşte modul în care structura acestora influențează caracteristicile de confort – permeabilitatea la aer, permeabilitatea la vapori de apă, absorbția capilară a apei, rezistența termică.

Cuvinte-cheie: structuri tricotate, geometrie de suprafață 3D, masaj, proprietăți de confort

Comfort properties of knitted fabrics with massaging effects

When designing garments, comfort properties are an essential aspect of this design. For massaging cosmetotextiles, the comfort characteristics must suit all fabric specifics that give the massaging effect of the product. Weft knitted fabrics with 3D surface geometry have shown a good potential to be used in cosmetotextiles with massaging effects. The surface geometry can reach high complexity and influence the fabric properties. The paper studies the comfort properties of knitted fabrics with 3D surface geometry and follows the way the fabric structure control the fabric behaviour with regard to comfort characteristics – air, vapour and water permeability and thermal resistance.

Key-words: knitted structures with 3D surface geometry, massage, comfort properties

The developments of the last three decades in the field of knitting technologies, especially the use of electronics and CAD systems, have allowed for the enlargement of the structural range and an increase in machine efficiency. Apart from the traditional applications, both weft and warp knitted fabrics started to be used more and more in technical applications and also in the domain of intelligent textiles (http: //facultate.regielive.ro/proiecte/alte-domenii/structuri-textile-tricoturi-43152.html).

A new destination that started recently is cosmetotextiles, textile materials and products used for cosmetic purposes. One interesting application, with market potential is the use of textile fabrics with massaging effects as support for cosmetic/antibacterial/aromatic products, replacing the massaging sessions.

When designing a textile (knitted) material for a certain domain, one must consider the product specific functions and the way the fabric properties satisfy these functions within the product. For normal and special clothing, one of the most important functions is related to comfort.

Comfort is defined as ‘a condition or feeling of pleasurable ease, well-being, and contentment’ (http: //encyclopedia2.thefreedictionary.com/textiles – accessed at 29.01.2012).

It ensures a physiological, psychological and physical balance between the garment, the wearer and the environment [1–3].

Comfort means that the garment is designed so that ensures the physiological human needs, energy wise, during moderate to strenuous effort.

Considering the comfort characteristics of the knitted fabrics, the fabric mass is very important because it influences the energy consumption and the wearer's motility. Fabric mass per square meter also conditions the thermal adjustment the garment provides. Therefore, mass reduction while maintaining the thermal insulation characteristics represents an important design issue with positive economic aspects.

The physiological indexes take into consideration properties such as air permeability, thermal insulation, water and vapour permeability, fabric mass, porosity, hydrophilic, hydrophobicity, static charge etc.

Bamboo fibres/yarns present the advantage of a low specific mass, as well as excellent comfort characteristics, recommending them for applications where comfort is a strong requirement.

Bamboo yarns are easy to knit and the knitted fabrics produced with this type of raw material are well documented throughout the literature [4, 5]. Bamboo knitted fabrics present a good potential for cosmetotextiles with massaging effect. The fibre properties are combined with a specific 3D geometry of knitted fabrics to ensure the massaging effect at skin level.

The paper studies the comfort characteristics of weft knitted fabrics made of bamboo 100% yarns and the influence of the fabric structure on these characteristics (air permeability, vapour permeability, thermal resistance and water absorption).

Considering the end-use of these knitted fabrics, the following requirements must be met:

- low thickness;
- low mass per square meter;
- high porosity to ease the humidity transfer between the human body and environment (perspiratia insensibilis) and to increase vapour permeability;
- low thermal resistance in order to increase heat transfer through these fabrics;
- high air permeability to keep airing the layers of clothing;
- high water absorption rate, in order to prevent the formation of a perspiration layer at skin surface and a state of discomfort.

EXPERIMENTAL PART

Materials used

A number of 6 fabric variants were produced using 100% bamboo yarns, count Nm 34/2, that was produced at the Department of Textile Technology, Indian Institute of Technology, New Delhi. The fabrics were knitted on a CMS 520 6.2 Stoll flat knitting machine, gauge 12 E [6–8]. The fabrics were programmed using a M_1 station.

The fabric structures are presented in figures 1–6. The first variant is a tubular fabric connected through

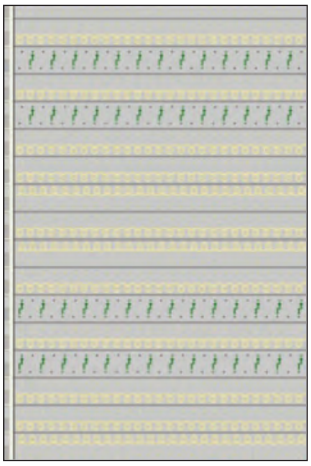

Fig. 1. Knitted structure – tubular fabric with transferred stitches (variant B_1)

Fig. 2. Knitted structure – interlock 1 x 1 with miss stitches (variant B_2)

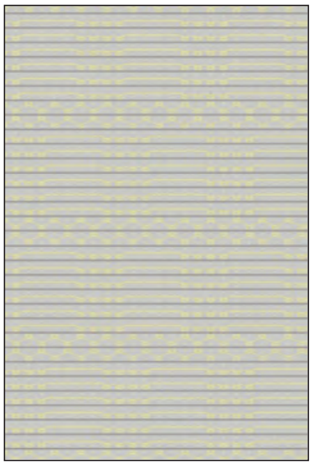

Fig. 3. Knitted structure – interlock 1 x 1 with miss stitches (variant B_3)

Fig. 4. Knitted structure – interlock 1 x 1 with miss stitches (variant B_4)

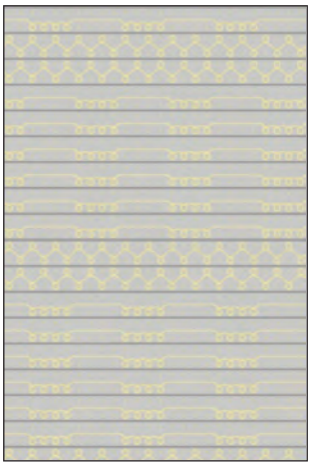

Fig. 5. Knitted structure – interlock 1 x 1 with miss stitches (variant B_5)

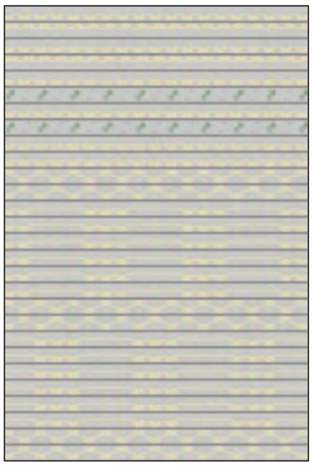

Fig. 6. Knitted structure – rib 1 x 1 with miss stitches (variant B_6)

Table 1

DIMENSIONAL PROPERTIES AND THERMAL COMFORT PROPERTIES OF KNITTED FABRICS								
Structures	**Thickness,** mm	**Roughness degree,** μm	**Mass per square-meter,** g/m²	**Volume porosity,** %	**Thermal resistance,** $m^2K/Wx10^{-3}$	**Water vapour permeability,** %	**Air permeability,** $cm^3/cm/s$	**Water absorption,** °
B_1	2.017	748	748.572	57.44	10.067	29.5	2517.06	56.59
B_2	2.73	760	674.286	68.88	21.767	29.8	3532.88	81.04
B_3	2.672	702	805.714	64.09	16.067	25.4	3392.32	72.69
B_4	2.689	719	737.143	67.22	15.067	25.7	3094.44	74.91
B_5	2.765	795	677.143	67.28	20.9	28.4	3118.01	86.22
B_6	2.771	801.8	614.286	70.17	14.00	30.3	3260.61	68.85

stitch transfer, while the other five variants are interlock fabrics with miss stitches.

After knitting, the samples were relaxed and cleaned in ultrasounds (water, detergent and sodium carbonate, t = 1 hour, temperature 60°C).

Methods used

The water capillary absorption for the 6 knitted variants was measured, using a Tensiometer 3S GBX apparatus. The measurements were conducted course wise and wale wise and the final results were expressed as the average between the two values (table 1). The water capillary absorption degree is expressed as contact angle θ that is calculated with:

$$\cos\theta = \frac{M_{menisc} \times g}{P \times \gamma_l} \quad (1)$$

where:

g = 9.8 gravitational acceleration, m/s ^{2};

$M_{menisc} = M_t - M_{capilar}$, in which M_t is the total mass, g;

P is perimeter of the contact surface between the fabric and water, mm;

γ_l – distilled water surface tension ≈ 72–72.5 mN/m^2.

The vapour permeability was determined from five measurements for each fabric variant, similar to ISO 11092 [11], using a Permetest apparatus.

Air permeability was determined according to ASTM D737 [12], with TEX TEST-FX 3300 equipment. The pressure was 200 Pa, the measuring area being 20 cm^2. The average values for each fabric variant were obtained from 5 readings.

The problem that concerned fabric thickness is related to the 3D surface geometry of the fabrics. Such geometry means there are variations in thickness that cannot be expressed using the classic measurement method that involves compressing the fabrics under certain weight and therefore their deformation. The results thus obtained are not significant for the fabrics included in the present study. When the classic measurement method was used, the results were the same for variants $B_2 - B_6$, due to fabric deformation.

Furthermore, the fabric thickness was also used to calculate volume porosity for the fabrics.

Fabric thickness was estimated starting from the thickness of the fabrics without 3D surface – jersey for the first variant and interlock for the others. The values determined for roughness were added to the thickness of the interlock for variants $B_2 - B_6$. For variant B_1, fabric thickness was considered as for a tubular fabric (two jersey fabrics).

The fabric volume porosity was determined using the pycnometric method. The volume porosity was calculated using the following relation:

$$P_z = \frac{\gamma_r - \gamma_a}{\gamma_r} \times 100 \quad (2)$$

where:

P_z is fabric porosity, %;

γ_r – specific relative density of fabrics, g/cm^3;

γ_a – apparent density of the fabric, g/cm^3.

The γ_a value is determined with:

$$\gamma_a = \frac{M_s}{1000\,\delta} \quad (3)$$

where:

M_s – the mass per square centimetre of the fabric variant, g;

δ – fabric thickness, cm.

The specific relative density of the fabrics is calculated with the following relation:

$$\gamma_r = \frac{M_m \times \gamma_l}{M_{p+m} - M_p} \quad (4)$$

where:

M_{p+m} is total mass (pycnometer + sample + toluene), g;

M_p – pycnometer + toluene mass, g;

γ_l – toluene density = 0.865 g/cm^3.

The thermal resistance was determined on Permetest, based on a method similar to ISO 11092 [11].

RESULTS AND DISCUSSIONS

Table 1 presents the average values for all measurements. The fabric thickness and fabric mass are important parameters due to their influence on comfort properties: thermal insulation, vapour permeability, air permeability.

When discussing the influence of geometrical characteristics on comfort parameters, an observation must be made regarding structure. The fabric variants can be divided into two groups – based on tubular fabrics (variant B_1) and based on interlock fabrics with wave effects (variants B_2 – B_6). The experimental data show a constant difference between the fabrics in the two groups, for all determined comfort indexes. This indicates that the main factor of influence on comfort is fabric structure.

In figures 7–12 is presented the variation of comfort properties with volume porosity and with fabric thickness. The specific trend lines were added, emphasising a linear correlation between comfort indexes and geometrical characteristics. The linear correlation is stronger when the variation is reported to fabric thickness.

This situation can be explained by the fact that the fabrics can be described as having two different zones – a zone where the fabrics are more compact, with lower porosity and a zone where the fabrics are less compact, with higher porosity (corresponding to the 3D effect caused by transfer and especially the miss stitches). This leads to variable porosity within the structures.

The experimental data emphasise the influence of the fabric structure – the results are distinct for the tubular fabric in comparison to the interlock ones. Variant B_1 presents a good characteristics comfort –

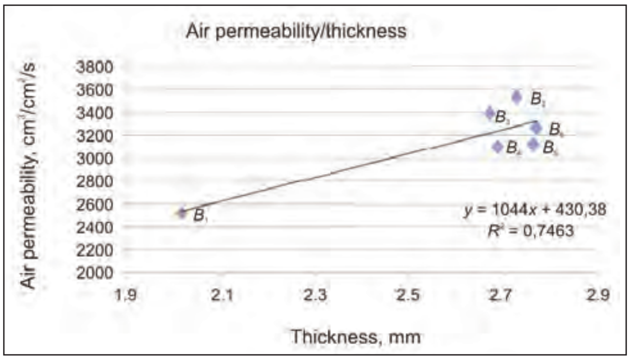

Fig. 7. Variation of air permeability with fabric thickness

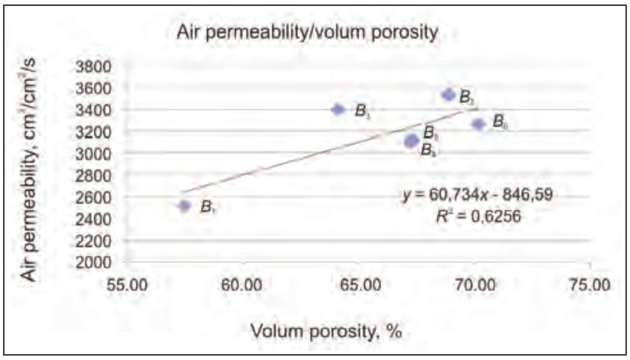

Fig. 8. Variation of air permeability with volume porosity

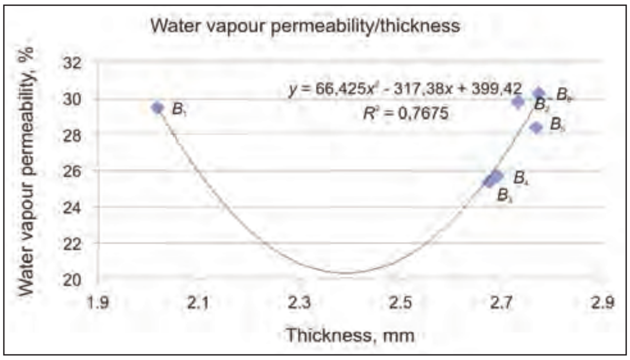

Fig. 9. Variation of vapour permeability with fabric thickness

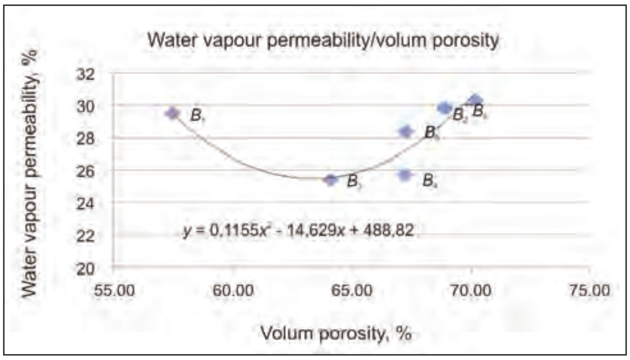

Fig. 10. Variation of vapour permeability with volume porosity

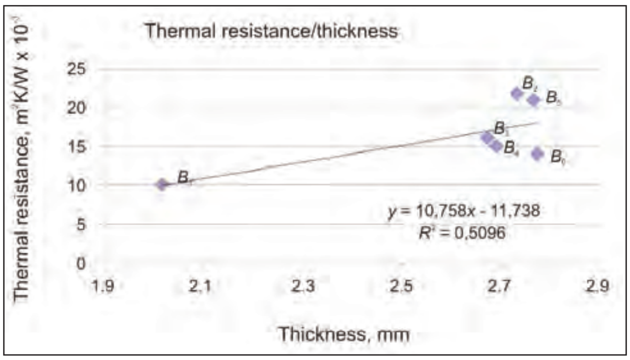

Fig. 11. Variation of thermal resistance with fabric thickness

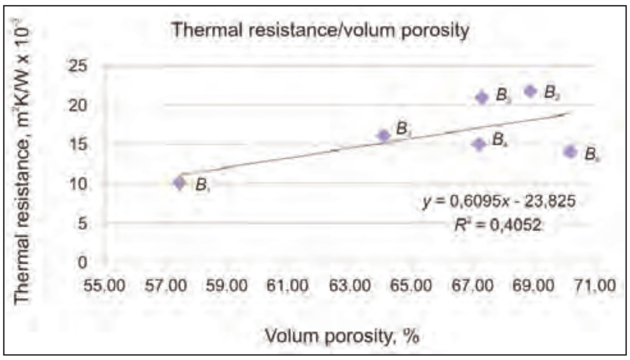

Fig. 12. Variation of thermal resistance with volume porosity

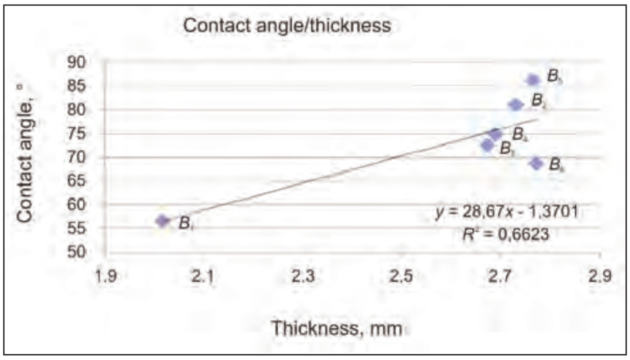

Fig. 13. Variation of contact angle with fabric thickness

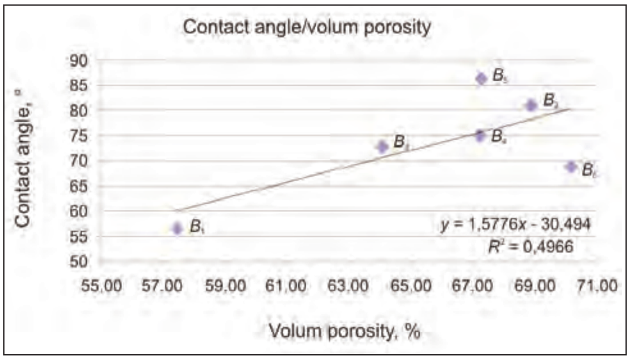

Fig. 14. Variation of contact angle with volume porosity

low mass, low thickness, low contact angle, high vapour permeability and low thermal resistance. Air permeability is low (when a higher value is needed) due to the low volume porosity.

In the second structural group, defined by interlock with miss stitches, the values for the determined comfort indexes are very close and do not exhibit a linear trend. The distribution of values suggests that the comfort indexes are influenced by the dimensions and position of the wave relief effects. The best variant in this group is variant B_6 – low mass, low contact angle, high vapour permeability (maximum) and low thermal resistance.

Best air permeability is exhibited by variant B_2 that has volume porosity close to maximum.

CONCLUSIONS

The cosmetotextiles present a developing market, with strong growing potential. Textile fabrics with massaging effect can be used to replace costly cosmetic treatments and save time.

The paper considered knitted fabrics for obtaining this massing effect, due to the complexity of their surface geometry. Miss and transferred stitches were used to generate 3D surface geometries for 6 fabric variants.

The current study shows that:

- bamboo knitted fabrics have good comfort characteristics, required when considering massaging clothing in direct contact with human skin;
- for fabrics with 3D surface geometry, structure is the most important influence factor on comfort properties;
- the correlation between geometrical characteristics (thickness and volume porosity) and comfort indexes is not very high;
- the lower correlation is caused by the variants in the second structural group that has similar experimental values influenced only by the dimensions and position of relief effects in the fabrics;
- fabric thickness has a stronger correlation with comfort indexes than volume porosity, mainly because the fact that the porosity differs in the fabrics.

Further work should consider bamboo knitted fabrics with 3D surface geometry with a wider range of structures.

Acknowledgement

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DOCUMENTARE

Nanotehnologii

COMPOZITE DIN NANOCELULOZĂ ŞI ACID POLILACTIC

Din amestecul de nanoceluloză cu un polimer se poate obține un material natural dur, ce poate înlocui fibrele sintetice pe bază de petrol, folosite în mod curent pentru compozitele de ranforsare.
Experimentele efectuate asupra compozitelor realizate din PLA şi celuloză, în cadrul Departamentului de Tehnologie Chimică, din cadrul ***Universității Aalto*** din Helsinki, au demonstrat faptul că celuloza, chiar în cantitate mică, îmbunătățeşte tenacitatea acidului polilactic. De exemplu, dacă cantitatea de celuloză din compozite este mai mică de 5%, tenacitatea va fi de aproximativ zece ori mai mare decât cea a polimerului pur.
Material compozit obținut este regenerabil şi se descompune în doar câteva luni. Într-un mediu de compost natural, acesta se descompune în apă şi bioxid de carbon.
Cu toate că PLA-ul şi celuloza sunt polimeri casanți, prin combinația acestora se obține un material dur, care poate suporta sarcini utile mari. Legat de aceasta, reprezentanții Departamentului de Tehnologie Chimică afirmau: "*Este ca şi cum sticla casantă s-ar transforma în mod miraculos într-un material plastic rezistent, dar, desigur, lucrurile nu sunt chiar atât de simple... Celuloza este hidrofilă, aceasta însemnând că se amestecă uşor cu apa şi, astfel, nu se leagă uşor cu polimerul PLA – care este hidrofob sau care respinge apa. Într-o reacția de esterificare, unele grupări hidrofile OH sunt înlocuite de grupări hidrofobe de esteri, ceea ce îmbunătățeşte compatibilitatea. Nivelul de substituție poate fi utilizat pentru a controla comportamentul mecanic al compozitelor*".
Din nanoceluloză şi PLA, cu grosimea de 70 μm, au fost fabricate pelicule compozite şi au fost testate proprietățile lor mecanice. O atenție deosebită a fost acordată studierii mecanismelor de deformare a acestora în condiții de tensionare, sub o anumită sarcină mecanică. În plus, s-a analizat structura chimică a materialului compozit prin metoda spectroscopiei Raman. Intensitatea benzilor din spectrul Raman indică o creştere a concentrației de material în compozit. Pentru obținerea unor proprietăți optime, nanoceluloza trebuie să fie distribuită uniform în polimer.
Mecanismele de deformare şi rupere a compozitelor la scară nano sunt fenomene complexe, care nu au fost încă suficient înțelese. Se află în derulare studii despre comportamentul nanocelulozei în amestec cu polimerii. În acest sens, echipa de cercetare afirma: *"Dacă reuşim să obținem o mai bună înțelegere a ceea ce se petrece într-un compozit obținut din nanoceluloză şi PLA supus unei sarcini mecanice, vom putea să ne apropiem mai mult de găsirea unui procedeu de fabricare a unor noi tipuri de materiale prietenoase mediului, dure, rezistente şi regenerabile... În plus, vom putea personaliza proprietățile acestor materiale".*
Gama posibilelor aplicații ale compozitelor din nanoceluloză este variată – ambalaje, implanturi medicale, ecrane flexibile, suporturi pentru reconstrucția țesuturilor umane etc.

__Smart__textiles and nanotechnology, noiembrie 2012, p. 7

Integrated systems of monitoring and controlling wastewater quality

FLOAREA PRICOP
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CARMEN GHIŢULEASA
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REZUMAT – ABSTRACT

Sisteme integrate pentru controlul şi monitorizarea calităţii apelor uzate

În ultimii 20 ani, ca urmare a globalizării şi liberalizării comerţului, sectorul textil european a suferit modificări din punct de vedere al modernizării proceselor de producţie, reorientate spre creşterea productivităţii, calităţii produselor adaptate la cerinţele pieţei şi protecţiei mediului. La aceste preocupări este conectată şi zona transfrontalieră România – Bulgaria, prin Programul de Cooperare Transfrontalieră, proiectul ENVICONTEH, care se adresează axei prioritare 2: MEDIU – Utilizarea durabilă şi protecţia resurselor naturale şi a mediului, promovarea unui management eficient al riscului în zona transfrontalieră. Obiectivele proiectului sunt: stabilirea unei strategii comune pe termen scurt, mediu şi lung, specifice zonei transfrontaliere, în domeniul protecţiei mediului; dezvoltarea de sisteme comune pentru monitorizarea şi controlul protecţiei mediului; dezvoltarea de materiale informaţionale şi promoţionale comune privind protecţia mediului. S-au studiat corelaţiile dintre principalii factori poluanţi, generaţi pe faze tehnologice, cu influenţe asupra indicatorilor de calitate a apelor reziduale şi modalităţile de tratare în staţii de epurare, în vederea încadrării în Normativele Naţionale şi Europene.

Cuvinte-cheie: ape uzate, poluanţi, tehnologii de epurare, monitorizare

Integrated systems of monitoring and controlling wastewater quality

For the last 20 years, due to globalization and trade liberalization, the European textile sector has undergone changes such as the modernization of production processes refocused towards an increase of productivity, of product quality in line with the market and environmental protection requirements. These concerns are also the concerns of the Romania – Bulgaria cross border area, through the Cross Border Cooperation Programme projects, project ENVICONTEH which is included in priority axis 2: Environment – Sustainable use and protection of natural resources and environment, promotion of an efficient risk management in the cross border region. The project objectives are: to establish a cross border specific joint strategy on short, medium and long term for environmental protection; to develop joint systems for environmental protection monitoring and control; to develop joint information and promotion materials referring to the cross border environmental protection. We have studied the correlations between the pollutants generated by the technological phases and their influences on quality indicators of wastewater and treatment methods in treatment plants, in order to comply with the national and European norms.

Key-words: wastewater, pollutants, wastewater treatment, monitoring

The textile materials processing uses a broad variety of chemical substances (detergents, alkali, acids, dyes, surfactants, surfactants etc.) that contribute to the significant pollution of the environment. Wastewater from textile finishing raise serious problems related to the quantity of sediments, *p*H, temperature, colour (group of dyes), content of organic substances (fibre particles, fibre materials, surfactants, phosphates, auxiliary chemical products, albumin, carbohydrates etc.), content in inorganic substances (salts, acids, alkali, chlorine, metals etc.) [1]. Due to the diversity of the production structure, the quality of wastewater varies not only from one company to another, but also within the same company.

The effluents resulted from the textile finishing generate the following pollution problems for the environment:

- concentration of pollutants in the discharged wastewater that leads to an increase of the main wastewater quality indicators provided NTPA 002/2005 and NTPA 001/2005: *p*H, matters in suspension, COD, BOD, chloride, sulphide, detergents, nitrogen;
- pollution of groundwater by a concentration of polluting minerals;
- pollution of soil in the area where textile and leather companies operate;
- pollution of natural receptors (in our cross border region RO – BG the main receptor is Danube) and the compelling of riverside industries to search for other clean water sources;
- persistence of dyes that are difficult to degrade in the natural receptors;
- impact on aquatic flora and fauna;
- decrease in photosynthesis due to water coloration;
- pollution of ground waters with dissolved solid substances, increase of alkalinity and of the content of mineral, organic substances and of soluble substances.

SOURCES OF POLLUTANTS IN TEXTILE FINISHING

Textile finishing can be defined as the multitude of operations (mechanical, chemical, biochemical) that ensure the improvement of textile properties, that is their aspect, comfort, durability and functionality. Most of the textile finishing operations can be effected over the entire technological flow on: fibre, sliver, yarn, fabric, knit and garment; however, finishing applied to fabrics or knits is predominant. In a simplified form, a textile finishing technological flow is represented in figure 1.

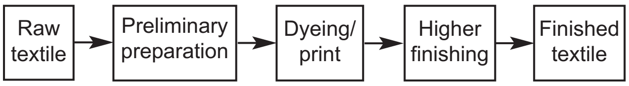

Fig. 1

In Giurgiu – Ruse cross border region the correlation between the main pollutants generated by technological phases was studied (from companies on the PTIGN platform and from companies in Bulgaria: Fashco – Byala and Freshtex – Popovo) with influences over quality indicators of wastewater and the treatment methods in wastewater treatment plants in conformity with National and European Norms. The correlations between technology stages of textile processing, polluting factors, their influences on quality wastewater indicators is presented in table 1.

PROPOSALS FOR THE UPGRADING OF WASTEWATER TREATMENT PLANTS IN THE TEXTILE COMPANIES

To increase the pre-treatment efficiency the following upgrades are necessary:

- in the grill and sieve room the existing used grills and sieves will be replaced with stainless steel grills and sieves with a greater capacity of retaining the impurities (holes smaller than 10 mm);
- mechanized scraping devices for impurities will be produced;
- automated systems for reading and adjusting the *p*H and turbidity will be mounted;
- new basins for performing coagulation-flocculation processes several stages will be built;
- introduction of aeration systems in the 2nd treatment stage;
- settling basins and additional pumping plants for sludge will be installed;
- a sludge dewatering and pressing plant will be built.

The efficiency of upgraded pre-treatment plants will be higher than those of the old pre-treatment plants by 20 – 50%. To increase the treatment efficiency it is necessary to introduce a filtering module of pre-treated water which will also contribute to water recirculation in industrial processes.

In the PTIGN upgraded aeration basin (fig. 2), wastewater, mixed with activated recirculated sludge, is oxygenated by a pneumatic aeration process (fig. 3).

Fig. 2

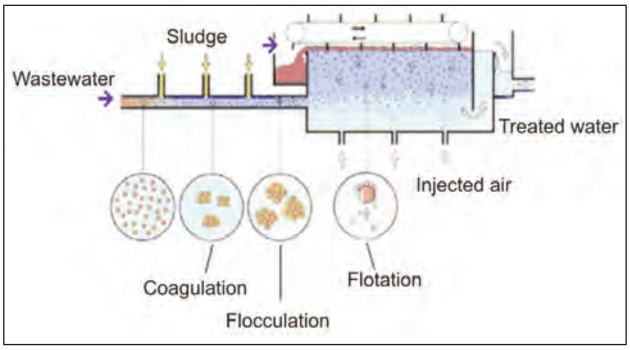

Fig. 3

Treated water, in a percentage of 94 – 97%, is separated from the flakes of activated sludge in the secondary settler.

The advantages of introducing the aeration system into the process flow are the following:

- improving the treatment degree by 10 – 26% of wastewater expressed by reducing the value of chemical oxygen consumption (COD), biochemical oxygen consumption (BOD), NH_4, total P, SO_4, detergents, degree of discoloration, reducing the amount of sludge that results from the wastewater treatment;
- reducing the amount of chemicals used for the treatment operations (coagulation, flocculation, *p*H correction, discoloration);
- reducing treatment time.

In order to point out as eloquent as possible the evolution of the wastewater parameters on the wastewater treatment station modules from Giurgiu Nord Technological and Industrial Park, were plotted both parameters compared with accepted values contained in the normatives and the values of the ecological efficiency for the wastewater main parameters (fig. 4 – 9).

TECHNOLOGY SOLUTIONS FOR WASTEWATER TREATMENT BY COMBINED PROCESSES

The use of combined treatment processes of wastewater from textile companies lead to treatment efficiency and reuse in a percentage of 50 – 70% of water treated in industrial technology processes. In figure 10 is presented an example of combined treatment diagram.

Table 1

POLLUTING FACTORS AND METHODS FOR POLLUTANT REMOVAL			
Technology stages generating polluting factors	**Polluting factors and their effect on wastewater**	**Influences on quality indicators of wastewater**	**Methods to remove pollutants**
Warping	Dust, fly	Suspended matter	-
Sizing	Sizing products Starch, polysaccharides, CMC, APV polyacrilates	COD, BOD, TSS	- physical-chemical treatment, ozonation; - biological treatment, filters; - membranes
Weaving	Dust and fly, various waxes, oils and paraffin	It does not directly influences the water indicators in this stage	
Preliminary preparation (desizing, alkaline boiling)	Surfactants, complexing agents, oils, sizing products, fibres, various waxes, mineral or vegetal impurities, enzyme products	COD, BOD, TSS, *p*H	- physical-chemical treatment, ozonation; - biological treatment, filters; - membranes
Bleaching	Chlorine or oxygen-based oxidizing agents (chlorite, hydrosulphite, thiosulphite, surfactants and complexing agents)	COD, BOD, TSS, *p*H, sulphites, sulphates, chlorine	- physical-chemical treatment, ozonation; - biological treatment, filters; - membranes
Dyeing	Wastes of sulfur dyes Wastes of indigosol dyes Chemical auxiliaries, surfactants, complexing agents, heavy metals (for dyeing with metal complex dyes), dispersing agents, mordants	*p*H, color, TSS, metals, salts, temperature, COD, BOD, metals (Cu, Cr, Co, Cd, Fe, Ni), sulphates, sulphites, accelerating substances, fixed residue	- physical-chemical treatment, ozonation; - biological treatment, filters; - membranes; - photocatalysis; - advanced treatment
Cross dyeing	Wastes of sulphur dyes Wastes of indigosol dyes Chemical auxiliaries, surfactants, complexing agents, heavy metals (for dyeing with metal complex dyes)	*p*H, TSS, metals, salts, temperature, water volume COD, BOD, fixed residue	- physical-chemical treatment, ozonation; - biological treatment, filters; - membranes; - photocatalysis; - advanced treatment
Washing/rinsing	Wastes of sulphur dyes Wastes of indigosol dyes Chemical auxiliaries	Influence in lower %, COD, BOD, water volume, fixed residue	- physical-chemical treatment, ozonation; - biological treatment, filters; - membranes; - photocatalysis; - advanced treatment
Starching	Starching products (natural and synthetic polymers)	BOD (biochemical oxygen consumption), COD, TSS	- physical-chemical treatment, ozonation; - biological treatment, filters; - membranes; - photocatalysis; - advanced treatment

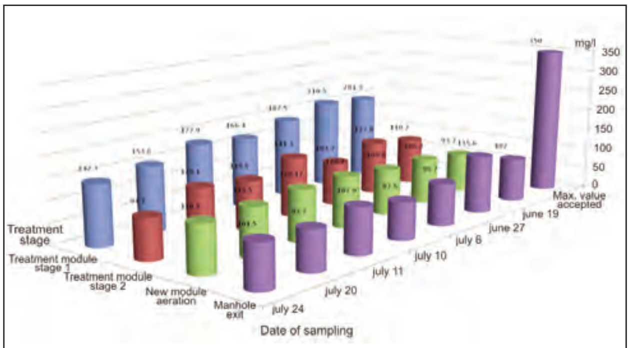

Fig. 4. The evolution of the parameter “suspended matter” during the analysis

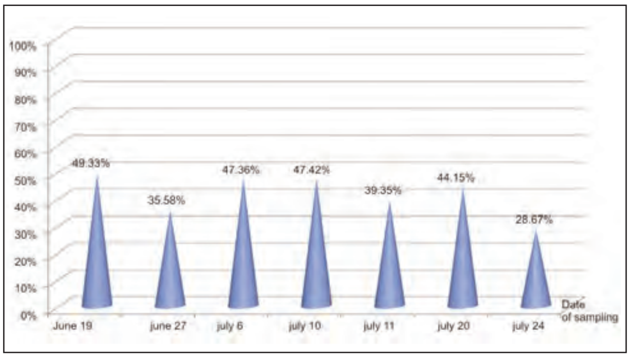

Fig. 5. The evolution of the ecological efficiency of the parameter “suspended matter”

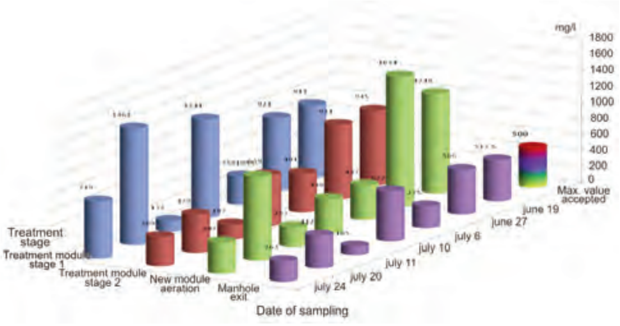

Fig. 6. The evolution of the parameter "COD" during the analysis

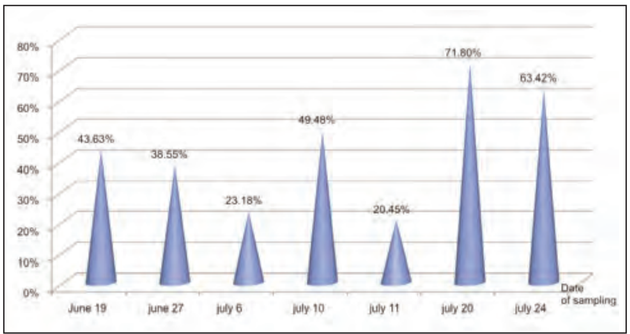

Fig. 7. The evolution of the ecological efficiency of the parameter "COD"

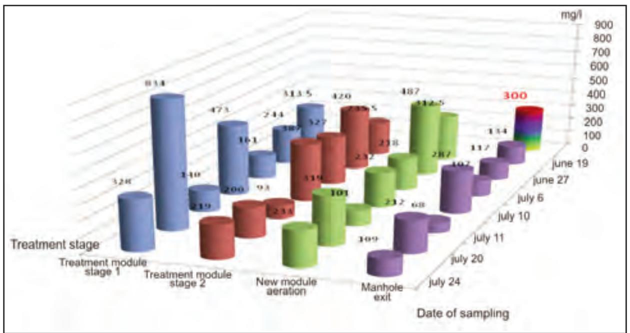

Fig. 8. The evolution of the parameter "BOD" during the analysis

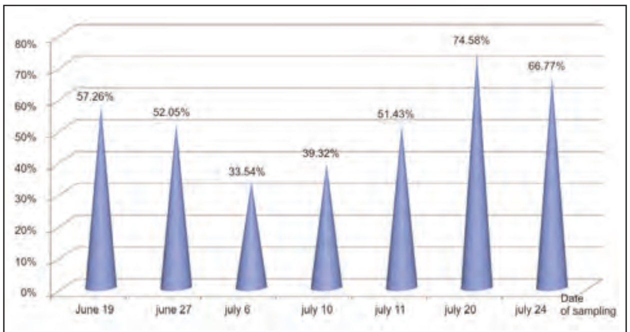

Fig. 9. The evolution of the ecological efficiency of the parameter "BOD"

Wastewater treatment plant characteristics:

- 100% water recirculation;
- recovery of chemicals in wastewater;
- reduction of total expenses by 0.6 – 0.8 €/m^3 water;

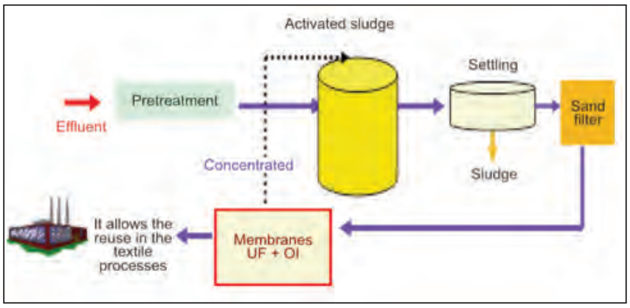

Fig. 10. Diagram of a complex treatment plant – ozonation, activated sludge, settling, filtration through sand filters, ultrafiltration and reverse osmosis

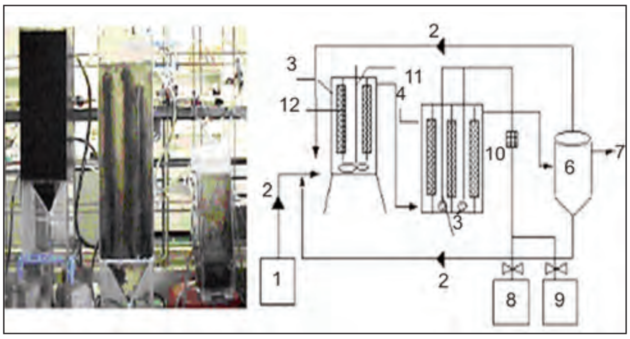

Fig. 11. Plant scheme for aerobic/anaerobic/trickling filter combined processes treatment

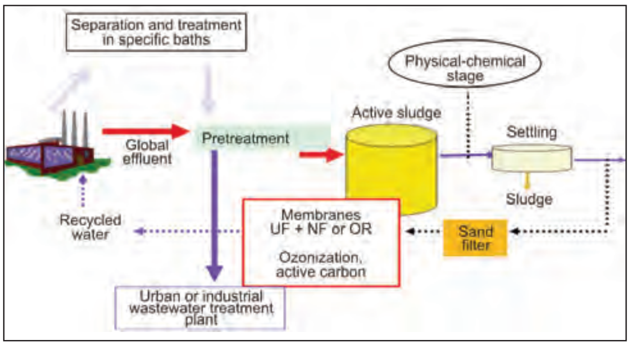

Fig. 12. Combined process scheme for aerobic/anaerobic/trickling filter treatment of collected water from specific technological processes

- compliance with the European standards.

Another possibility to treat the wastewater generated by the textile inductry is presented in figures 11 and 12 and represents a scheme for aerobic/anaerobic/tricling filter combined process.

Wastewater treatment plant characteristics for 1 000 m^3/day capacity:

- obtaining of maximum treatment efficiency assuring the recirculation possibility of treated water;
- total expenses/year 0,6 – 0,8 €/m^3;
- consumption reduction of water and energy.

The advantages of the solutions for treatment of collected water on specific technological processes are:

- reducing the use of chemicals for treatment;
- reducing the amount of sludge;
- reducing the amount of COD, BOD by 50 – 60%;
- recirculation of treated water.

Table 2

TREATMENT PROCESSES AND THEIR EFFICIENCIES			
Dyeing process	**Treatment process**	**Treatment efficiency**	**Color fading**
Dyeing with reactive dyes	Catalytic oxidation	30 - 50% (depending on the amount of dye remaining in the bath)	10 - 90% (depending on duration, 30 - 120 minutes)
	Ozonation	30 - 48%	100%
	UV/ozone radiation	85 - 90%	100%
Dyeing with direct dyes	Electrochemical	84 - 90%	99 - 100
	Biological treatment	90 - 95%	99%

Table 3

ECONOMIC ASPECTS OF WASTEWATER TREATMENT			
Method of treatment	**Performances**	**Costs***, €/m^3	**Observations**
Coagulation-floculation	Inefficient for λ = 400 nm	0.2 - 0.29	Primary treatment
Oxidation with active chlorine	Partially efective	4.06	AOX formation
Oxidation with H_2O_2/catalysts	Efficient	3.34 - 145	For the treatment of concentrates
Biological process	Partially efective	0,11	Further ozonization is nedeed
Ozonization	Efficient	0.22 - 0.44	Final treatment
Adsorbtion	Efficient	0.11 - 0.58	Requires regeneration - recycling adsorbent mass
Membrane	Very efficient	0,73 - 29	Final treatment for recycling
Electrolysis	Efficient	0.44 - 0.58	-

COMPARATIVE EFFECTS AND EFFICIENCY OF TREATMENT SOLUTIONS PROPOSED TO BE USED IN THE TEXTILE INDUSTRY

The identification of many treatment technologies (table 2) for wastewater from the textile companies is a major concern for the specialists in order to comply with EU regulations.

ECONOMIC ASPECTS OF WASTEWATER TREATMENT

Water consumption and water price represent a factor that plays an essential role in all economic decisions aimed at choosing manufacturing processes and effluent treatment plants. In the calculation of water cost, in addition to the water supply cost, the effluent treatment costs are also included.

An European study showed that there are different levels of water cost by country as follows:

- in Germany, costs range from 2.77 – 4.3 €/m^3;
- in the UK, the current cost is between 0.6 – 1.4 €/m^3;
- in France, Italy, Spain, costs range from 3 – 5.2 €/m^3;
- in Romania, the cost ranges from 2 – 5.5 €/m^3.

Costs for highly polluting effluent treatment are much higher sometimes exceeding 15.4 €/m^3. In these circumstances it is advisable to reuse a portion of the effluent. It should be noted that in countries where the cost is higher or where areas are affected by water shortages, lowest water consumption are registred.

Application of an increasingly tougher law in EU will lead to water price increasing and therefore, the measures must be taken for pollution prevention and for wastewater treatment. Wastewater treatment involves substantial costs, both for investment and for operation (table 3).

CONCLUSIONS

Through the monitoring and control of wastewater quality parameters throughout the technological process of wastewater treatment and by creating databases we will contribute to the reduction of the negative impact upon the natural ecosystems and the implementation of prevention strategies for pollution.

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DOCUMENTARE

Materii prime

FIBRE *LENZING MODAL* DISPONIBILE ÎN MAI MULTE CULORI

Fibrele *Lenzing Modal®* sunt acum disponibile în culori speciale, inclusiv negru. Avantajul acestor fibre este dat nu numai de caracterul prietenos mediului, ci şi de faptul că nu mai este necesară vopsirea, deoarece pigmenţii de culoare sunt încorporaţi direct în matricea fibrei. De asemenea, în procesul de realizare a ţesăturilor, se economisesc unele resurse, cum ar fi apa şi energia. Experimentele au demonstrat faptul că prelucrarea fibrelor *Lenzing Modal® Color,* în comparaţie cu cea a fibrelor standard, necesită un consum mai mic de energie – cu până la 80%, şi de apă – cu până la 75%, în cazul vopsirii cu jet de apă. Nu trebuie trecut cu vederea faptul că culoarea neagră are un potenţial enorm pentru aplicaţiile din domeniul lenjeriei şi al ciorapilor. Fibrele Lenzing Modal® de culoare neagră posedă proprietăţi importante, în special pentru aceste aplicaţii, cum ar fi culoarea şi rezistenţa la abraziune.

Articolele textilele realizate din aceste fibre sunt, în general, extrem de durabile. Culoarea este rezistentă şi uniformă şi nu apare fenomenul de cedare a culorii. Mai mult, pot fi dezvoltate o serie de alte concepte de design cu celelalte culori – de la amestecuri de culori până la culori inovative, cum ar fi produsele supravopsite.

Fibrele Lenzing Modal® Color sunt obţinute printr-un proces prietenos mediului, pe baza tehnologiei Edelweiss. Ele sunt produse în Austria, din lemn de fag. Fibrele sunt neutre în carbon şi până la 95% din produsele chimice utilizate în prelucrare sunt recuperate în timpul producţiei.

Sursa: www.textile-network.com

Green fashion – a new possible lifestyle for Romanians

DOINA I. POPESCU

REZUMAT – ABSTRACT

Green fashion – un eventual nou stil de viață pentru români

Cercetarea își propune o prezentare generală a conceptului "green fashion" și a implicațiilor acestuia, precum și o analiză a acțiunilor "verzi" întreprinse de marii retaileri de mass market. De asemenea, sunt menționate principalele branduri eco din lume, principalii producători eco din România – cu referire la sortimentele fabricate, modalitățile de procurare a materiilor prime, producția lunară, sistemul de procesare, acțiunile de promovare întreprinse, dar și comercianții autohtoni de produse vestimentare eco. Totodată, lucrarea prezintă direcțiile de acțiune îndreptate, pe de o parte, către încurajarea producătorilor români de "green fashion", iar, pe de altă parte, vizează informarea și educarea consumatorului român în scopul consumului de produse vestimentare eco.

Cuvinte-cheie: green fashion, stil de viață, holding in-cânepă eco, educarea consumatorilor, promovarea vânzărilor

Green fashion – a new possible lifestyle for Romanians

The study presents an overview of the concept of "green fashion" and its implications, as well as an analysis of "green" actions undertaken by the most important mass market retailers. Moreover, the major eco-brands in the world, the main eco-producers in Romania are mentioned – with reference to the assortments produced, the modalities for procuring raw materials, monthly output, processing system, promotion actions undertaken and also local traders of eco-clothing. Furthermore, the paper presents the directions of action aimed, on the one hand, at encouraging Romanian producers of "green fashion" and, on the other hand, at informing and educating the Romanian consumers to use eco clothing products.

Key-words: green fashion, lifestyle, eco flax-hemp holding, consumer education, sales promotion

One of the means by which individuals express their personality and aspirations is their consumption pattern, which, together with their set of values, with their attitudes and activities, forms their lifestyle. A variety of specialised centres even address the social values and the developing socio-cultural flows, creating lifestyle maps, highlighting observable trends, suggesting population typologies distributed by mentality, socio-style, and analysing the major collective cultural movements. Evidently, culture has a profound influence on the manner in which individuals perceive each other, how they perceive the limits imposed by society and their place within it. Even though these perceptions are often interiorised, the behaviour and, most importantly, the consumption pattern remain relevant [1, 2]. Essentially, lifestyles attempt to realise a synthesis between social determinants and personal factors. They are used in marketing in order to segment the population, as well as explain consumption behaviour and brand choice [3], the best known classification by lifestyle and values being the one that groups consumers according to health and sustainability – LOHAS [4].

P. Grégory stresses the importance of analysing the act of buying, which involves several steps: modelling the aggregate purchasing process; perceiving the resorts of the purchasing decision; understanding the "internal process", the consumer's decision centre (or "black box") [5].

Over time, theoreticians have endeavoured to formalise the consumer's behaviour through the use of a model. Amongst the numerous models found in economic literature, the classic models belonging to Howard and Sheth (1999) and to Engel, Blackwell and Miniard (1990) are illustrative for ascertaining the consumption behaviour paradigm in the eyes of the marketing specialist. The Howard and Sheth model summarises the factors that influence consumers, as well as the answers given by the latter. The Engel, Blackwell and Miniard model is the first to take the consumer's decision process into consideration, as it highlights the factors that influence the buyer every step of his decision making process.

Marketing practitioners have issued several hypotheses in order to explain the resorts behind the buyers' final choice of products. These hypotheses postulate the consumer's inclination to evaluate brands (products) on the basis of a set of criteria, thus forming preferences and consequently operating the final choice [6].

The third stage in analysing the purchasing process – namely, the internal buying process – can be understood and then influenced by actions performed by marketing specialists, through the analysis of the four

Table 1

INDIVIDUALS' LIFESTYLES IN THE VIEW OF KAZUAKI USHIKUBO		
Cognitive subspaces	**Determinants of wants**	**Lifestyles**
Change	Entertainment Knowledge Creativity	I want to change my lifestyle once in a while. I want to know more. I want to do something for self-improvement.
Participation	Family and friends Affiliation Social life	I want to feel good with my family members and friends. I want to be like others. I want to be part of a large group of different people.
Freedom	Egocentrism Individuality Voluntary solitude	I want to live as I like, regardless of what others might say. I want to distinguish myself from others. I want to have my world, separately from others.
Stability	Relaxation Safety Health	I want to rest and relax. I want to always be free from harm. I want to be healthy in mind and in body.

Source: Kazuaki Ushikubo, cited in Ph. Kotler, D. Jain and S. Maesincee (2009, p. 59)

main determinants of the consumer's behaviour: needs, motivations, perceptions and attitudes.
Kazuachi Ushikubo, hypothesising that customers' needs change according to their situation or as they enter another life phase, identifies two major social factors: "chaos and order" and "exterior and interior focus". These create a positioning framework for four fundamental wants: Change, Participation, Freedom, Stability [7]. Considered subspaces of an individual's "cognitive area", these four wants indicate diverse lifestyles presented in table 1.
Motivations are analysed as an innate or acquired pressure which a consumer tends to alleviate or satisfy by taking a position (attitude) towards a product or a firm. In the moment of a purchase, the customer's choice is not guided exclusively by positive trends (motivations), but also by negative tensions (impediments). It all revolves around a conflict of interest. According to their nature, motivations in favour of a product are classified as [8]:

– hedonistic motivations (based on the pursuit of pleasure);
– rational (utilitarian) motivations such as:
  • functionality (the need for the product to function properly);
  • economy (the best price/quality ratio);
  • security (the preoccupation for health);
– ethical motivations (feelings of duty which can make an individual consume a product or not).

Perception is defined as the process in which people select, organise and interpret information so as to form a coherent picture of the environment [9]. Attitude, seen as a buyer's emotional response, is essentially evaluative and it manifests through positive or negative feelings, preferences, intentions, judgements for a product brand/ an organisation [10].
From 1996, the European Commission elaborated the "Green Paper on European Trade", which grants special attention to consumers' preoccupations and behavioural changes equivalent to new signs of contempt towards the trading sector. Consumers are growing more and more sensitised about production methods, environmental issues. Besides its purely economic functions, the "Green paper" mentions that commerce plays an important social role. Trade, as a major determinant of social and cultural schemes, of lifestyles and area development, is the cornerstone of the socio-economic model. Consumer protection, as a form of social protection, gains the quality of a general movement, given that the consumer's behaviour affects public or private entrepreneurs.
Nuclear radiation, oil spills, forest fires, hurricanes, floods do not constitute only a series of apocalyptic images cropped out of a movie, but also a few of the ecological disasters humanity is frightfully confronting nowadays. Added to the above is the natural resources crisis. As a reaction to these phenomena, caused mainly by industrialisation, ecological produce have appeared. Regarded at first with scepticism, the eco phenomenon has gradually gained momentum and presently covers various domains, from the culinary, cosmetic, clothing industries to the decorative arts and construction works.

Ecological movement in fashion

Beyond its glamour and special charm, the fashion industry implies the use of elements harmful both to the planet and to consumers' health. In this context, a series of eco adepts have emerged in this field as well, under the banner of green fashion. According to the eco movement, among the factors that negatively influence the environment are counted: the farmers' use of pesticides in order to protect the plants destined for the textile industry, the use of chemical substances for the dying or discolouring of textiles, the enlargement of spaces allocated to waste due to the increase in the number of obsolete clothes thrown away.

Ecological clothing must fulfil several conditions. To illustrate, it needs to be produced out of organic raw materials, such as cotton cultivated without pesticides, silk obtained from worms grown in an organic environment, unbleached linen, organic linen, soy, bamboo or hemp. The latter is considered one of the best choices in the fabrication of ecological materials due to its ease of cultivation, nonetheless with the downside that its cultivation is still illegal in certain countries.
In order to fulfil the purpose of environmental protection, ecological articles of clothing can also be manufactured from recycled materials, by the re-use of second-hand clothes or residues such as PET bottles. By recycling, the clothing item is aimed to have a long-lasting life, in order to limit the consumption of raw materials, energy, and reduce the pollution from discarding them after no longer being worn. In many western states, there is a current of opinion which supports the reduction in the volume of clothes thrown away. In the UK for instance, this volume is estimated at a million tons a year. Certain brands even donate their unsalable stock to charity. Supporters of the movement believe that clothing should never be discarded, but remade, transformed, re-styled so as to correspond to present trends.
The labelling system of the ecological article of clothing must offer information concerning the organic materials used in its manufacturing and its eco-friendly fabrication conditions (considered with a minimum negative impact or with a low risk of environmental pollution). The ecological product must originate from fair trade (decent working conditions and proper salaries for the personnel involved in its production and commercialisation).
The ecological movement therefore incorporates several concepts: organic, ethical, fair trade, sustainable, recycled and vegan. All these target especially consumers who are more interested in the moral perspective on clothing production and in its functionality than in its aspect. Since the number of these consumers is rather small (how many of us go shopping whilst bearing in mind, for instance, the labour conditions of the workers in disadvantaged countries or areas?), eco fashion producers have reached the conclusion that they should come up with offers to attract true fashion addicts as well, by concentrating on design.
The proof that ecological fashion has gained significant ground is the fact that many designers have become advocates of the eco current. For example, the designer Stella McCartney does not use textures such as skin or natural fur in her collections. Her collection includes high-end pieces made exclusively out of organic materials. Designer Agatha Ruiz from Prada is another green fashion adept, by encouraging women to recycle their own wardrobes and hence purchase garments as rarely as possible, only if needed. Vivienne Westwood also militates in favour of environmental protection, the message of the 2010 spring-summer collection being “Act fast, slow down, stop climate change!” Themes such as “global warming” have been adopted in the collections of numerous brands, such as Diesel.
In 2005, the Swedish company H & M has launched “Flower”, a children’s clothing line made of organic textures. In the meantime, H & M has announced that it would also use materials other than cotton drawn from remains of old creations, for instance wool from worn and recycled clothes, or organic polyester, obtained from recycled plastic bottles.
British brands such as Oasis have already launched organic cotton collections, and Top Shop went even further by selling vintage fashion and recycled clothing, by introducing ethical jewellery and by collaborating well with brands recognised for their ecological stance, such as People Tree. The Spanish firm Inditex has also conformed to the new trends. Consequently, the group has a strategic plan which involves investment in sustainable, eco-efficient shops, in the use of biodegradable packaging, the re-use of boxes, coat hangers, etc. Inditex opened its first eco store, Zara Korai, in Athens, followed by another one in Paris, where it reduced the number of hours of shop window lighting, where only biodegradable plastic bags are used, and where the personnel is trained in the rational use of water and energy. Another brand that adhered to this current is Levi Strauss & CO, which launched the line Levi’s Eco, comprised of jeans made 100% of organic cotton and with coconut buttons. Moreover, in 2010, Levi’s adopted a programme named “Give Jeans”, throughout which clients are encouraged to donate their old jeans in exchange of a 25% discount on a new pair.
In addition to mass-market brands, which dedicate only a part of their collections to principled customers, there are firms which produce and sell only “green” clothing, not only because it is fashionable to be eco, but also because these are their managers’ convictions (to live in harmony with the environment and with oneself). One of these is Komodo, which took shape in 1988 in London, “from transforming a Levi’s pair of trousers into a patchwork jacket”. Komodo T-shirts are inscribed with logos in the manner of “Free Tibet”, or “Think, Act, Vote”. You therefore spend 20 pounds on a T-shirt, but the whole world finds out you are a person of healthy principles. Another eco brand is Howies, which is not as declarative as Komodo, but all its products are made of organic cotton. Kuyichi sells only denim made of organic fibre or obtained from recycling (it uses recycled PETs or fabric remains). Bibico is more fashion-oriented than the aforementioned brands, and their products are distributed through La Redoute catalogues. The group won first prize with its SS10 collection at the Paris Ethical Fashion Show and gets its inspiration from the creations of the Spanish designer Nieves Ruiz. The singularity of Bibico is given by the fact that all its products are sewed by women working in cooperatives certified by the World Fair Trade Organisation [11].
A series of events are already dedicated to eco fashion, some examples being: The Green Shows Eco-Fashion Week (New York Fashion Week), London

Eco Fashion Fair, Paris Ethical Fashion Show, International Fair for Natural and Organic Textiles INNATEX in Germany (2 editions every year) and so on. Considering that the process of fabricating ecological garments is complex and rather costly, one cannot yet affirm that many designers have exclusively adopted ecological fabrics in their collections.

Green fashion in Romania

In Romania, there are few firms that fabricate ecological garments and there is no education with regards to the use of eco clothing. Presently, besides three firms that produce ecological wear for newborns under the lohn regime, S.C. Harmatric SRL from Vaslui manufactures under its own brand (Pifou), addressing exclusively to the internal market. The organic cotton supplier of the Pifou brand is a Romanian based firm, the branch of a Turkish company. The Pifou investment would have never been possible, however, without the continuous support received from its main activity, which consists in the production of outfits from other fabrics. In an interview for "Adevărul de Seară" newspaper, posted on 8th July 2010, the firm's manager declared that the Pifou sales during the first quarter of 2010 (the year the brand was launched) were relatively small, their cashing in being obtained with difficulty, due to the fact that the final clients (those of the partner shops) were not informed about the organic cotton. This is the reason why the company invested in promotional banners, which were distributed free of charge to these stores. Moreover, personalised Organic Pifou bags, containing information on the benefits of organic cotton, and Organic Pifou labels made of textile materials were produced (www.stiridebine.ro/ Economic, 6 iulie 2010).

Currently, Harmatric fabricates over 1000 organic cotton articles of clothing under the Pifou brand on a monthly basis, being the only local producer of ecological wears for newborns to manufacture exclusively for the internal market. The distribution of all the firm's products (including the ecological ones) is ensured in over 200 shops throughout the country, as well as online. Starting with the end of 2010 and up to the present day, orders for Pifou petite eco clothes have known an increase, pursuant both to the promotional activities mentioned above and to the products' very attractive price-quality ratio.

PIF SRL, based in Timişoara, launched in 2008 the collections "Eco-nature" and "Return to nature", which contained children's and adults' clothing manufactured from natural fabrics, mainly flax and hemp, purchased from FI-RI Vigonia S.A. Timişoara, having simple cuts and placing value on folk tradition. These ecological products represented less than 10% of PIF Timişoara's production and were sold alongside its basic production line (school uniforms, women's and men's apparel manufactured from other fabrics), online and via the firm's own shop. Starting with the summer of 2011, the firm was compelled to drastically reduce the manufacture of the ecological products, due to the shrink in the activity of its organic fabrics supplier FI-RI Vigonia SA. Currently, PIF SRL produces only folk costumes made of natural fabrics procured from peasants' households. Bearing in mind the small quantity of ecological raw material available to the firm at present, and also the reduced demand for this type of garment, the management's estimations concerning the company's eco production are of roughly 10-20 folk customs per year. The customers for these products are artistic ensembles, but also Romanians settled abroad. The price of a folk costume may vary between 200 and 400 euros, depending on its complexity.

The manager of PIF SRL, who is also a designer, established the Cultural Association for Traditions, Identity and Success (A.C.T.I.S.) which counts among its objectives: the promotion of craftsmanship and the organisation of craft and auction stores, with natural fibre products hand made by traditional artisans, both in the country and abroad. In addition, the firm organises fashion design courses, on the manual fabrication of diverse decorative textile objects and of eco apparel. These courses take place either at the company's headquarters or during class activities, upon schools' requests. Up to the present, ten elementary schools and four high schools have formulated such requests. The promotional ad for these courses at the Banat High school, for example, posted on the company's website as well, runs as follows: "Each Wednesday, between 3-5 PM, in the Festivity Hall, Aesthetic Education classes will be taking place, with an accent on Romanian art and tradition. If there are grandparents willing to help us with their presence, knowledge, objects, we welcome them with pleasure. We wish for our grandchildren to know how we spoke, how we danced, how we dressed in few but healthy clothes, that we loved each other and respected our parents and grandparents, and that we would like them to pass on what was and is the best in ourselves" (www.pifandenadesign.ro).

Beginning with 2010, during the period 21 June – 1 July, the firm organised and still organises the "Traditions and Identity" Summer Camp, where lectures on clothing aesthetics are held, focusing on Romanian art and tradition. The summer school's activities end with a series of presentations of folk costumes and ecological garments. Another event for educating the Romanian consumer towards the use of eco clothing was the one organised by Metarsis on 12th of July 2011, at the "Bookmark" Bookshop in Reşiţa, Caraş Severin county. It involved urban culture and contemporary art activities, with the support of the county's Coordinating Office for National Culture and Patrimony and of the Caraş Severin Centre for the Conservation and Promotion of Traditional Culture, and promoted by the Reşiţa Regional Radio Station. Besides book releases, the event also included a selling exhibition for natural fibre apparel belonging to the collection entitled "Yearning", of folkloric inspiration (men's shirts, women's dresses and blouses).

In 1990, the firm Ecolution was founded in Cluj-Napoca, with an entirely American share capital and having as objective the manufacture of hemp ecological wares, mainly women's, men's and children's clothing. Initially, the company used Romanian hemp fibre, then on account of the drastic decrease of cultivates areas, started to import ecological hemp fibre. The firm produces on average 2 000 clothing items every month. Over 95% of the production is destined for export (traditional clients with small orders of up to 100 clothing items, from the USA, EU, Japan, Australia, South Africa). Less than 5% of the production is purchased by local distributors. The price of an Ecolution garment (blouse, skirt, pair of trousers) varies from 20 to 40 euros. The company's management has identified the causes of the Romanian consumer's lack of interest for the Ecolution clothing articles as being: the lack of information on the advantages of ecological products and, not the least important, the price. Every year, Ecolution presents its collections at the International Fair for Natural and Organic Textiles INNATEX Germany, and on 29 September – 1 October 2011, it took part in the BIO-VITA Cluj-Napoca Salon of natural and organic products (3rd edition, with the dominant theme of bio food and cosmetics, and a 2011 addition of a section dedicated to eco clothing).

Moreover, out of the numerous online stores that sell eco products we would mention: Misena, Greencert, Kids/Shop, BebeNatura which markets ecological apparel for babies and children, Elemental which sells eco wares for children and adults, the online shop (*www.ecologiceonline.ro*) which offers hemp, cotton, bamboo and organic soy T-shirts, anoraks etc. All these stores sell imported eco garments with a good price/quality ratio (www.magazineeco.ro).

In addition to the aforementioned, there are also shops that sell eco garments for women, men and children, most of them located in the major malls throughout the country. The best known among them is The Earth Collection, a store that sells eco products belonging to the eponymous Danish firm. This company has a chain of over 500 shops in the EU, and in Romania has stores in Bucharest (on Magheru Boulevard and in Băneasa Shopping City), Cluj, Braşov, Mamaia and Vama Veche. The fibres used are cotton, hemp, ramie and silk. The labels are made of natural fibres, and the packaging is recycled carton. The product prices vary from 69 to 110 lei and there are also discounts for the older collections.

Romanian designers have not created fashion collections containing only pieces of clothing out of organic textures. The attempts concerning fashion collections comprised of articles exclusively from recycled materials are timid, materialised in several young Romanian creators' presentations.

For instance, in the spring of 2011, a presentation of fashion collections made of recycled materials, PETs etc. took place in Cluj-Napoca. The public's reaction was an unfavourable one, the majority considering that it was all about creators at their debut, intending to shock in order to capture their attention.

Table 2

PROJECTS FINANCED BY THE MINISTRY OF ECONOMY, TRADE AND BUSINESS (OHSAS 18001/1999 AND SA 8000)

Year	Number of projects financed	Value, euro
2005	76	830472
2006	84	1 457 635
2007	54	1 502 567
2008	43	812 250
2009	10	123 317
2010	8	193 952
Total (2005–2010)	275	4 920 193

Source: the Ministry of Economy, Trade and Business

With regards to the working conditions of employees in the textile and clothing industries in Romania, proceedings have begun for the implementation of the Programme for the Enhancement of Industrial Products' Competitiveness, focusing on the implementation of the OHSAS 18001-1999 (workplace health and safety management) and SA 8000 (social responsibility). Starting with 2005, 275 projects have been financed for the firms in the textile-garments sector, amounting to over 4.9 mil. euros (table 2). The cornerstone of this programme is represented by the concept of decent work perceived as a competitive factor.

What is more, the NGO „AUR – A.N.S.R.U." – the National Association of Human Resources Specialists – is implicated in the project "The impact of the economic crisis on health and occupational safety" alongside its Bulgarian and German counterparts. The objectives and activities of the project are in conformity with the Lisbon Strategy and with the EU 2020 Strategy. Workplace safety is part of the Social European Dialogue and constitutes a priority for the social European partners. The programme aims to monitor employees' health and safety, concentrating on the concept of decent work (occupation, investments, working conditions, salary, new skills required, the guarantee of equal treatment and opportunities within firms for all employee categories – men, women, youths, persons with disabilities etc.). This project sets an example of good practice that facilitates the revival of the textile-garments sector from the point of view of employees' health and working conditions.

Courses of action for encouraging local eco producers and for educating the Romanian consumer in the direction of purchasing eco clothing

Green fashion, a concocted term or a new disease of a planet? Or perhaps just another widely spread fashion theme? Or perchance only an efficient marketing strategy? To these questions that preoccupy researchers, producers and retailers, one can add "Green fashion – a new lifestyle for Romanians?"

The research performed shows the acutely small number of Romanian producers (to which an entirely foreign capital firm operating in Romania can be added) that manufacture ecological clothing products and an even smaller number of those addressing to the internal market. On the other hand, the study reveals a relatively large number of importers of eco garments and of stores distributing such products. Moreover, the research emphasises Romanian consumers' lack of information on the benefits of eco clothing, in terms of health, environmental protection, decent working conditions in the textile and clothing industries.

In this context, I propose the following incentive actions for Romanian producers to orient themselves towards the manufacturing of eco products:

– the increase of agricultural subsidies for eco flax and hemp cultivators;
– the creation of an eco flax-hemp holding;
– the granting of tax incentives to firms fabricating ecological products.

In order to educate Romanian consumers in the direction of purchasing eco clothing, actions should be performed for:

– the promotion of eco clothing sales;
– the briefing of consumers on the advantages of using eco products.

Although Romania has a long lasting tradition in the cultivation of flax and hemp, supported by its special climatic and agricultural potential, the flax and hemp fibre production has considerably reduced since 1989 (the surface cultivated with flax for fibre was of 75 000 ha, and the surface with hemp for fibre counted 48 000 ha), resulting in the effective abandonment of these crops. The agricultural subsidies per hectare granted in 2010 for the year 2009 in several EU Member States, including Romania, are presented in table 3.

Table 3

AGRICULTURAL SUBSIDIES/HA GRANTED IN 2010 FOR 2009, IN EU MEMBER STATES

Country	Agricultural subsidy/ha, in €	Country	Agricultural subsidy/ha, in €
Greece	603	Germany	324
Netherlands	425	Italy	319
Belgium	417	Ireland	307
Denmark	367	France	289
Romania	38		

Source: Ministry of Agriculture and Rural Development

The significant difference between the subsidy granted in Romania and those granted in the rest of the countries practically makes Romanian agriculture unattractive. On the other hand, in order to be ecological, the lands on which flax and hemp are to be cultivated require a conversion period of two years, period during which pesticides cannot be used. The increase of agricultural subsidies/ha for the Romanian flax and hemp crops would lead to much lower raw material costs, and hence to a reduction in the import of such fibres. The revival of flax and hemp crops, and also the assimilation of advanced technology in the manufacturing of fabrics by the users of these raw materials are feasible by attracting European funding.

In order to produce ecological wares, I propose the creation of a holding which would integrate a smelting house for eco flax and hemp and a treatment plant, a spinning mill for processing the flax and hemp fibres, a weaving mill with textile finishing which would process the eco threads, and a firm which would manufacture garments from eco flax and hemp alone or in combination with other natural threads (organic cotton, for instance) – figure 1.

Given the global trends, manifested through a demand of eco fabric clothing and a superior degree of exploitation for flax assortments, this holding can manage processing 960 t/year of flax stems. The difference of 240 t/year is the processable quantity of hemp stems, considering the extensive exploitation possibilities in other industrial branches as well.

For the eco flax and hemp stem processing, an investment of approximately 3 mil. euros is necessary (the

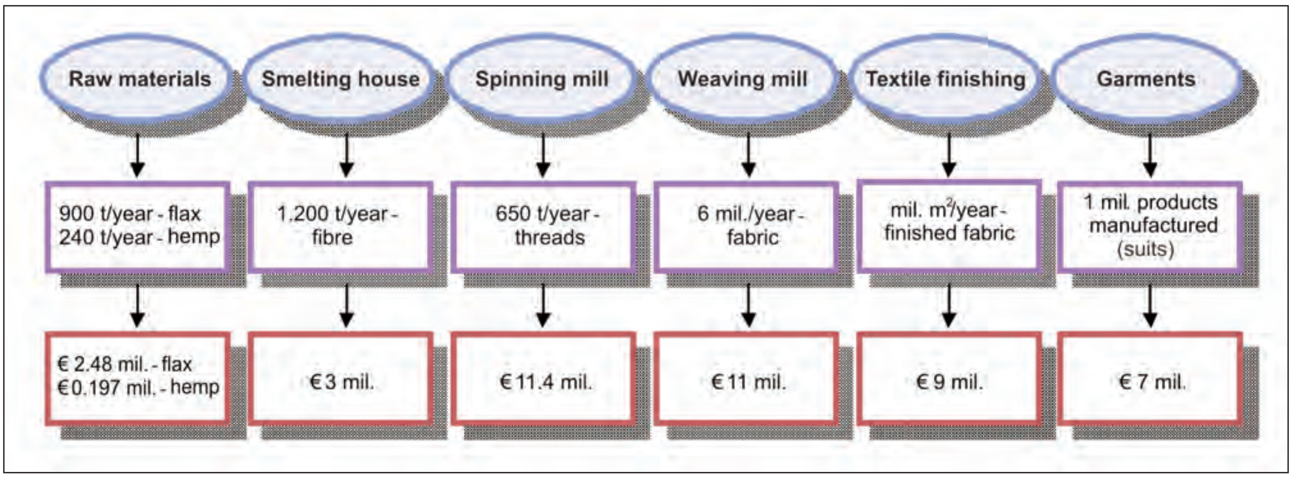

Fig. 1. Holding for eco flax-hemp fabrics

countervalue of the crushing and scutching equipment, of the dust removal systems and of the treatment systems needed for the smelting house). From the technological processing of the flax and hemp stems in the smelting house, roughly the same quantity of fibre could be obtained.

From an investment of around 11.4 mil. euros, required for the purchase of equipment specific to a spinning mill (bundle line, preparation, spinning and winding machinery) and for the procurement of materials and auxiliary products specific to eco production, approx. 650 t/year of threads could result, after excluding losses made during the technological process.

These threads are processed within a weaving mill. The necessary investment for creating one is around 11 mil. euros, destined to purchase machinery for naturally dying threads, for warping, gluing, weaving. About 6 mil. m^2/year would be obtained from the processing of the 650 t of threads (92 000 m^2 of fabric are obtained from a ton of threads).

A textile finishing of the fabric obtained is necessary, by means of an investment of approx. 9 mil. euros (the countervalue of naturally dying and starching – drying machinery).

From these fabrics, approx. 1.1 mil. products can be manufactured – I considered suits of high complexity, as these assortments are frequently demanded on the market. For these the average consumption is of approx. 5.25 m^2/piece. To create the garments section which would produce suits made of eco flax and hemp fabrics, an investment of at least 7 mil. euros is necessary, for the acquisition of machinery specialised in tailoring, manufacturing and finishing. I took into account manufacturing machinery in value of approx. 6 500 euros/piece of equipment, leading to physical productivity levels of around 4.1 suits/person in 8 hours.

The holding can be realised in two alternatives:

- Entirely novel (the creation of a smelting house, of a spinning mill, of a weaving mill, of a textile finishing and of a garment manufacturing section);
- The modernisation of existing smelting houses, spinning and weaving mills, textile finishing machines which are in conservation or not functioning at full capacity and the realisation of a new manufacturing capacity, for which roughly the same level of financial effort is required. The necessary financing can be ensured by attracting European funds.

I suggest that this holding, in the form of the first alternative, be created in the south of the country, due to the fact that this area is suitable for flax and hemp crops (they will initially be imported). Following the second option, the holding can be created in the western development area, in Timiş county, where a preoccupation for these crops exists on account of the agricultural research station Lovrin.

The hemp garments will initially be destined for export (the production dispatched internally will gradually increase, as public information on the benefits of eco clothing gains effects), given the high competitiveness of the products. The level of competitiveness is generated by the superior quality of the products and by the low prices which could be practiced based on lower costs. Within the holding, high quality products could be obtained due to the equipping with advanced machinery both in the primary sector (smelting, spinning, weaving, finishing) and in the final sector (garments). The high competitiveness of the products made in the holding allows the achievement of a return similar to the ones in developed countries (15% compared to 2 – 5%, the level reached in previous years).

Hemp garments will be destined for the internal market, in a wide variety of assortments interpreting folk tradition in a modern manner.

The creation of the eco flax-hemp holding is advantageous, contributing both to the revitalisation of the primary flax and hemp industrial sector, the most degraded segment within the textile industry, and to the consumers' education towards an ecological behaviour.

The General Electric/McKinsey matrix must be applied separately for flax and hemp (fig. 2):

- for the flax assortments, the high attractiveness of the market and the medium competition result in the option for investment/growth.
- for the hemp assortments, the attractiveness of the market and the competition being of medium level, the result is the option of selective investment.

I expect that on the external market the competition for flax garments is of medium level, seeing that on the EU market such assortments are produced and sold in countries like Poland, Hungary, Bulgaria, Slovakia, and so on, but their products present a lower level of competitiveness than Romanian products. The attractiveness of the market is high.

On the internal market the competition for hemp articles of clothing is medium because, in addition to the small number of producers of such assortments, there are also rather numerous importers, and the attractiveness of the market is of medium level.

The conclusion is that it is opportune to invest in the eco flax-hemp fabrics holding destined for the manufacture of garments.

The costs within the holding are reduced due to the exclusion of expenses with procurement, transportation, sale, VAT, remuneration of management and other personnel specific to autonomous units (distinct smelting houses, spinning and weaving mills, textile finishing works). A good price/quality ratio would therefore be ensured for the resulting finished goods, which would lead to an increase in the volume of sales for such products.

Moreover, the granting of tax incentives to firms fabricating ecological products (deductions from tax on profit and so on) would lead to an increase in production and even to donations for instance to charitable organisations and/or poor areas of the country that do not have access to running water and sewerage, policies already practiced by global mass-market firms such as H & M, Marks & Spencer etc.

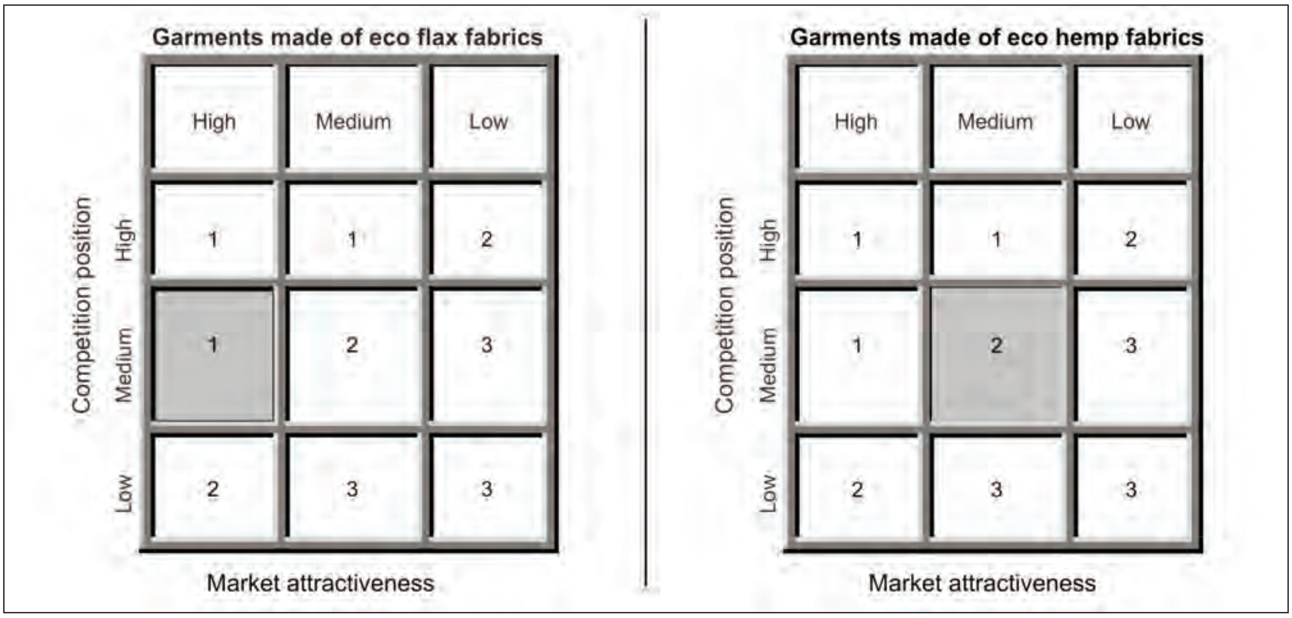

Fig. 2. Garments made of eco flax fabrics:
1 – investment/growth; *2* – selective investment; *3* – decrease/disinvestment

As a general approach, sales promotion includes, for example, the communication of information on: the company, the brand, the product's composition, collective advertising, various demonstrations, exhibitions, sponsorships.

A distributor-oriented approach is often highly diversified, involving: the supply of advertising material and promotion at point of sale, competitions, gifts, bonuses distribution, financial contributions to distributors' various individual or collective actions.

A customer-oriented approach especially includes occupying the front space of stores, price discounts, games and contests, distribution of samples and any other promotional initiatives at the point of sale which do not involve only distributors, but also manufacturers, importers and wholesalers.

As far as the consumer's education is concerned with regards to the use of eco clothing, besides the promotional and informative activities on the benefits of eco clothing, such as those organised by the firm PIF SRL or by the brand Pifou, the firms could distribute samples free of charge for 6 months to a panel of consumers and to a panel of stores. In the case of eco wares for newborns, for example, the consumer panel would be comprised of future mothers, and free samples would be distributed in the first 6 months to maternities. For a correct grasp of consumption and consumers' education, the free distribution of samples in the first six months must be accompanied by studies on the implications of eco consumption on consumers, studies performed every six months.

CONCLUSIONS

The eco current in fashion incorporates several concepts, namely: organic, fair trade, sustainable, recycled. The number of Romanian firms that fabricate eco clothing articles is small, and the eco production of these firms is low in terms of turnover and would not be possible without the continuous support received from the base activity, that of manufacturing clothing from other fabrics. On the other hand, the number of eco clothing importers is relatively large.

In order for green fashion to represent a new lifestyle for Romanians, actions should be performed in the direction of encouraging Romanian producers of such goods and in the direction of informing the consumers on the benefits of using eco clothing and educating them towards the consumption of such products.

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DOCUMENTARE

Noi tehnologii

UN NOU MATERIAL DESTINAT DOMENIULUI CONSTRUCŢIILOR

Pentru ca arhitectura oraşelor să fie la fel de simplă ca şi viaţa persoanelor ce locuiesc acolo, au fost create componente de construcţii uşoare, cu pereţi subţiri, cu o singură curbură sau cu curbură dublă, folosind materiale anorganice, nemetalice, de înaltă performanţă, cum ar fi un material hibrid organic din beton armat cu materiale textile şi un material plastic armat cu fibre de sticlă (GFP).

Noul material compozit, care combină rezistenţa ridicată şi durabilitatea cu un strat foarte subţire de beton, poate avea diverse utilizări în proiectarea componentelor pentru construcţii.

În cazul betonului armat cu materiale textile, stadiul actual al tehnologiei permite o rezistenţă la tracţiune de aproximativ 45 Mpa, în cazul unei grosimi a materialului de aproximativ 20 mm sau mai mult. Dacă materialul de construcţie trebuie să aibă o greutate mai mică, atunci este nevoie de sisteme de consolidare suplimentare, cu structuri mai fine, mai subţiri. În acest sens, plasticul ranforsat cu fibră de sticlă, cu valori ridicate de rezistenţă specifică, posedă un mare potenţial pentru domeniul construcţiilor.

Dezvoltarea unui nou material hibrid, de înaltă performanţă, prin combinarea selectivă a betonului armat cu materiale textile şi GFP, a reprezentat obiectul unui proiect comun de cercetare, sponsorizat de *AiF* – Federaţia Asociaţiilor de Cercetare din Industrie. În acest studiu sunt implicate câteva companii şi institute de cercetare – *Grupul FiberTech, Hentschke Bau GmbH, Panadur GmbH Metallbau Hausmann GmbH, TU Chemnitz* şi *Institutul de Cercetare a textilelor din Saxonia*. Scopul creării unui nou material compozit destinat sectorului construcţiilor a fost acela de a combina avantajele privitoare la rezistenţa şi durabilitatea celor două materiale de ranforsare cu o mai mare libertate de proiectare.

Combinarea betonului ranforsat cu material textil cu un material plastic armat cu fibre de sticlă nu este o acţiune foarte uşoară, deoarece cele două componente au unele caracteristici foarte diferite. Totuşi, prin adaptarea parametrilor materialelor – ceea ce a implicat o apropiere a caracteristicilor lor fizice şi mecanice, şi a etapelor de prelucrare a acestora, a putut fi dezvoltat un nou material hibrid, adecvat sectorului de construcţii. Cel mai bun beton armat cu material textil, pentru asamblare, este obţinut dintr-o compoziţie fină de beton şi un material textil biaxial tricotat din urzeală. Armarea cu materiale textile tricotate din urzeală a fost realizată din fibre de sticlă alcalino-rezistente, cu o fineţe de 2 400 tex, preimpregnate. Combinaţia optimă s-a dovedit a fi cea dintre un material plastic armat cu fibre de sticlă, constând dintr-o ţesătură biaxială, structurată în patru straturi, şi o răşină de poliester, în calitate de matrice.

S-a constatat că un produs laminat de 4 mm grosime, cu un volum fibros de aproximativ 50%, produs din beton consolidat cu materiale textile şi un material plastic armat cu fibre de sticlă, garantează o rezistenţă ridicată la deformarea elastică.

Deoarece componentele materialului hibrid posedă un anumit grad de adaptabilitate, a fost aplicat un strat intermediar, având rolul de a separa cele două materiale în funcţie de caracteristicile lor mecanice, chimice şi termice. Stratul intermediar dezvoltat în acest scop a fost realizat dintr-o răşină epoxidică şi un văl tip fagure, din poliester. Acest strat suplimentar garantează un ansamblu ferm şi durabil de GFP şi beton consolidat cu materiale textile, care asigură separarea necesară evitării fisurilor din beton, cauzate de factori termici şi/sau mecanici. De asemenea, forţele de forfecare sunt transferate între GFP şi beton prin stratul intermediar, care îmbunătăţeşte proprietăţile mecanice ale ansamblului.

Materialul hibrid elaborat, cu o densitate relativ scăzută – de aproximativ 1,65 g/m^3, are o rezistenţă la tracţiune de aproximativ 165 Mpa. Noul ansamblu,

format din materiale inovatoare, oferă dezvoltatorilor un plus de flexibilitate în proiectare, lărgind gama de aplicații a acestuia. Fiind un material fin, uşor şi rezistent este adecvat utilizărilor arhitecturale.
În prezent, noul material hibrid format din GFP şi beton armat cu material textil este supus unor teste de lungă durată, în cadrul pavilionului de cercetare CoFigloo, de la TU Chemnitz.

Kettenwirk Praxis, 2012, nr. 4, p. 18

MĂTASE DE PĂIANJEN CU PROPRIETĂȚI DE CAPTARE A LUMINII

În ultima vreme, oamenii de ştiință au încercat să creeze un material care să imite rezistența incredibil de mare a mătăsii de păianjen.
În prezent, fizicienii investighează capacitatea mătăsii de păianjen de a capta, în mod eficient, lumina. S-a constatat că mătasea naturală ar putea fi o alternativă prietenoasă mediului datorită capacității de transmitere a luminii, prin metode clasice, de exemplu prin sticlă sau prin cabluri din plastic cu fibră optică.
Posibilele aplicații ale mătăsii de păianjen au fost studiate de două echipe, care au lucrat independent şi au prezentat ultimele realizări, cu ocazia reuniunii anuale a Societății OSA, *Frontiers in Optics (FiO),* care a avut loc pe 15 octombrie 2012, în Rochester – New York.
Una dintre echipe, condusă de biologul Fiorenzo Omenetto, de la Universitatea Tufts – din Boston, Massachusetts, studiază proprietățile optice ale proteinei din mătase, utilizabile pentru senzori implantabili şi alte interfețe biologice.
Cea de-a doua echipă, condusă de fizicianul Nolwenn Huby, de la Institutul de Fizică CNRS – din Rennes, Franța, studiază utilizarea mătăsii de păianjen pure, naturale, în ghidarea luminii prin cipuri fotonice, o tehnologie care ar putea da naştere la biosenzori pe bază de mătase şi dispozitive medicale imagistice utilizabile în interiorul corpului uman.
Ambele grupuri speră că activitatea lor privitoare la utilizarea proprietăților optice ale mătăsii va aduce progrese în medicină.
Draglina, proteina folosită de păianjeni pentru a forma structura pânzei lor, este mai puternică decât oțelul, ceea ce face ca fibrele de mătase să fie extrem de rezistente, biocompatibile şi biodegradabile. Produsă în mod natural de către păianjeni şi viermi de mătase, mătasea este o resursă regenerabilă. Pe lângă aceste beneficii, aşa cum arată cele mai recente descoperiri, mătasea este un bun transmițător al luminii, aceasta putându-se deplasa prin mătase aproape la fel de uşor ca şi prin fibrele de sticlă.
În eforturile lor de a exploata beneficiile proprietăților optice ale mătăsii, echipa condusă de Omenetto este în curs de a dezvolta un material din mătase, care are aspectul unui plastic, dar care păstrează proprietățile optice ale mătăsii pure. Unul dintre avantajele acestui material este acela că se poate degrada şi resorbi de organism. Astfel, un senzor sau o etichetă din proteine de mătase ar putea fi implantate într-un os fracturat, pentru a monitoriza vindecarea, urmând ca, în timp, acestea să se dizolve pur şi simplu şi să fie resorbite de organism, fără niciun fel de pericol.
În prezent, echipa condusă de Omenetto investighează o serie de probleme – de la cele fundamentale până la cele comerciale, care depăşesc domeniul opticii implantabile. Recent, Fundația Națională de Ştiință i-a oferit un grant pentru a crea componente electronice compostabile. Această echipă a dezvoltat şi a testat un laser albastru, obținut din materiale pe bază de fibre de mătase, care este biodegradabil şi care foloseşte mai puțină energie decât materialele acrilice, utilizate în mod obişnuit. Sunt studiate, de asemenea, posibilitățile de utilizare a mătăsii pentru a integra o componentă tehnologică într-un țesut viu.
Echipa condusă de Nolwenn Huby studiază capacitatea mătăsii de păianjen pure de a conduce lumina în interiorul cipurilor fotonice, aceasta fiind considerată o modalitate relativ ieftină şi ecologică.
Ca ghid al luminii, mătasea funcționează asemenea microfibrelor de sticlă, frecvent utilizate pentru a transporta lumina într-un cip. Avantajul constă în faptul că lumina iese din mătasea de păianjen gata de utilizare, în timp ce microfibrele de sticlă trebuie să fie încălzite la niveluri ridicate şi atent sculptate, având un cost ridicat. Mătasea este colectată de către un grup de experți în spectroscopia moleculară, conduşi de Michel Pézolet – de la Universitatea Laval, din Quebec, şi predată în laboratorul echipei de la Rennes, în vederea exploatării proprietăților optice ale acesteia.
Prin analiza pânzei de păianjen într-un microcip, cercetătorii au descoperit că mătasea nu numai că propagă lumina, dar poate direcționa sau „cupla" lumina către anumite porțiuni ale cipului. Se speră ca acest lucru să poate fi folosit pentru a crea biosenzori care să detecteze prezența unei molecule sau activitatea unei proteine. De exemplu, pe măsură ce undele de lumină trec printr-o probă de sânge, moleculele îşi schimbă proprietățile undei de lumină într-un mod observabil.
Următoarele cercetări au în vedere necesitățile biologilor şi cadrelor medicale de a crea dispozitive utilizabile în acest domeniu. În afară de dezvoltarea biosenzorilor, pânza de păianjen ar putea constitui o sursă de lumină pentru a fotografia interiorul corpului. Mătasea naturală are un diametru de numai cinci microni, mai puțin de o zecime din grosimea unui fir de păr uman. Fiind foarte subțire şi puternică, fibra din mătase de păianjen pură ar putea transporta lumina în corp printr-o deschidere foarte mică, oferind modalități mai puțin invazive de a face diagnoze imagistice sau chiar chimice, cu ajutorul spectroscopiei, pe baza interacțiunii acesteia cu lumina.
Reunind peste 180 000 de profesionişti, din 175 de țări, Societatea optică OSA găzduieşte comunitatea globală a opticii, prin intermediul programelor şi inițiativelor sale de promovare a intereselor comune, asigurând resurse ştiințifice pentru oamenii de ştiință, inginerii şi oamenii de afaceri care lucrează în domeniu, prin promovarea ştiinței luminii şi a tehnologiilor avansate realizate cu ajutorul opticii şi fotonicii.

***Smart**textiles and nanotechnology, decembrie 2012, p. 3*

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