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Sumar

Contents

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Airflow characteristics of different groove type during rotor spinning process

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REZUMAT – ABSTRACT

Caracteristicile fluxului de aer al diferitelor tipuri de fantă în timpul procesului de filare cu rotor

Tipul de fantă este esențial pentru compactitatea inelului fibros în canelura și coeziunea dintre fibre. A fost investigat efectul tipului de canelură la viteza ridicată a aerului în timpul procesului de filare cu rotor. Viteza fluxului de aer și presiunea statică a canelurilor G, T, U și S ale rotorului cu diametrul de 36 mm au fost studiate cu software-ul Fluent. Rezultatele au arătat că, în aceleași condiții, vitezele celor patru dimensiuni G > T > U > S s-au situat în intervalul de canelură de la 0° la 360°. La pozițiile 0° și 360°, presiunile statice au fost G > S > U > T, în timp ce pentru restul poziției unghiului, presiunile statice au fost S > U > T > G. Luând ca exemplu canalul T, presiunile statice ale rotoarelor au fost între –7330 Pa și –13719 Pa. Fluxurile de aer de mare viteză au fost împărțite în două fluxuri când au intrat în peretele interior al rotorului (punctul 0°), unul în sens orar și unul în sens invers, care s-au unit la punctul de 180°. Acest fenomen permite înțelegerea întinderii fasciculelor de fibre și torsiunea firelor în rotor, care pot fi utilizate pentru a optimiza parametrii în timpul procesului de filare şi pentru a proiecta un nou tip de rotor.

Cuvinte-cheie: fantă, simulare numerică, câmp al fluxului de aer, viteză, presiune

Air flow characteristics of different groove type during rotor spinning process

Groove type is critical to the compactness of fibrous ring in groove and cohesion between fibers. The effect of groove type to high speed airflow during rotor spun yarn spinning process was investigated. Airflow speed and static pressure of G, T, U and S grooves of the 36 mm diameter rotor were studied by Fluent Softwarerespectively. The results showed that under the same conditions, speeds in four slotted size were G > T > U > S within the range from 0° to 360° in groove. At 0° and 360° positions, the static pressures were G > S > U > T, while for the rest of angle position, the static pressures were S > U > T > G. Taking T slot as example, static pressures of the rotors were between –7330 Pa and –13719 Pa. High speed airflows were divided into two streams as soon as they enter into the inner wall of rotor (0° point), one clockwise and one reverse direction, which joined together at point of 180°. This phenomenon gives light to understandfiber strands stretch and twisting as yarn in rotor which can be used to optimize spinning parameters during spinning and design new rotor type.

Keywords: groove; numerical simulation; airflow field; speed; pressure

INTRODUCTION

Rotor spinning is well known for its high output with wide raw materials [1–3]. During rotor spinning process, under the action of the centrifugal force of rotor rotation, fibers slip into the groove after they enter the slipped wall of the rotor by the high negative pressure, then the fibers gathered and twisted to form rotor spun yarn [4]. Coruh et al studied the effect of the nozzle type as one of the most important parts of the open-end rotor spinning system on yarn quality and found that the nozzle type mostly affects yarn quality and yarn tenacity [5]. Roudbari et al investigated effect of an increase in opening roller width on yarn quality including tenacity, strain at peak, work of rupture, evenness, imperfections, hairiness and fibre extent within the yarn structure and reported that an increase in fibre opening in lower level improves yarn quality [6]. Esfahani et al investigated the influence of the navel and rotor type on the tenacity, elongation at break, mass irregularity, total number of imperfections, hairiness, and twist difference values of viscose rotor spun yarns, and found that samples showed a lower value of twist difference produced by a G-type rotor than a T-type rotor [7]. Groove type is critical to the compactness of fibrous ring in groove and cohesion between fibers [8]. There are mainly G, T, U and S types of groove.

In this paper, effects of groove types on airflow speed and pressure during rotor spinning process will be discussed and simulated by 3D model with ANSYS Software which may favor to understand the fiber strands stretch and twisting as yarn in rotor.

MODELS AND EXPERIMENTS

The airflow during rotor spinning process obeys mass conservation and momentum conservation in view of fluid mechanics [9].

Mass conservation equation:

$$\frac{\partial(\rho u_k)}{\partial x_k} = 0 \qquad (1)$$

Where u_k is the air velocity of x_k direction, and ρ is air density.

Momentum conservation equation

$$\frac{\partial(\rho u_i u_k)}{\partial x_k} = -\frac{\partial p}{\partial x_i} + \frac{1}{\mathrm{Re}}\frac{\partial \tau_{ij}}{\partial x_j} \qquad (2)$$

Where ρ is air density, u_k is the air velocity of x_k direction, p is air pressure, Re is Reynolds number, and τ_{ij} is tensor of Newton fluid viscous stress.

$$\tau_{ij} = \mu\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) - \frac{2}{3}\mu\frac{\partial u_k}{\partial x_k}\delta_{ij} \qquad (3)$$

Where μ is coefficient of dynamic viscosity, and δ_{ij} is the function of Komecker delta.

Standard k-ε turbulent model is applied to simulate the motion of air flow in rotor.

$$\frac{\partial(\rho k)}{\partial k} + \frac{\partial(\rho k u_i)}{\partial x_i} = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_t}\right)\frac{\partial k}{\partial x_j}\right] + + G_k + G_h - \rho\varepsilon - Y_M + S_k \qquad (4)$$

$$\frac{\partial(\rho \varepsilon)}{\partial k} + \frac{\partial(\rho \varepsilon u_i)}{\partial x_i} = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right] + + C_{1\varepsilon}\frac{\varepsilon}{k}(G_k + C_{3\varepsilon}G_b) - C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} + S_\varepsilon \qquad (5)$$

Where G_k is the item caused by turbulent kinetic energy k which is generated by the average velocity gradient, G_b is the item caused by turbulent kinetic energy b which is generated by buoyancy, Y_M is on the behalf of pulsation expansion in the compressible turbulent flow, $C_{1\varepsilon}$, $C_{2\varepsilon}$ and $C_{3\varepsilon}$ are experimental constants, σ_k and σ_ε are Prandtl numbers according to turbulent energy k and dissipative energy ε separately, S_k and S_ε are source terms defined by users.

According to the recommended value by Launder et al. [9] and experimental verification, in this paper, model constants are determined as $C_{1\varepsilon} = 1.42$, $C_{2\varepsilon} = 1.68$, $C_{3\varepsilon} = 0.09$, $\sigma_k = 1.0$, $\sigma_\varepsilon = 1.3$.

It is supposed that the airflow speed of inlet is 0.0054 m^3/s and the pressure of outlet is –8000 Pa according to experiments while rotor wall is set as rotational moving wall with the speed of 120000 r/min (diameter 36 mm with G, T, U and S respectively). Angles of groove slot are 35°, 45°, 80° and 85° for G, T, U and S respectively. SIMPLE algorithm (Semi-Implicit Method for Pressure-Linked Equations) is used to solve the pressure and velocity coupled.

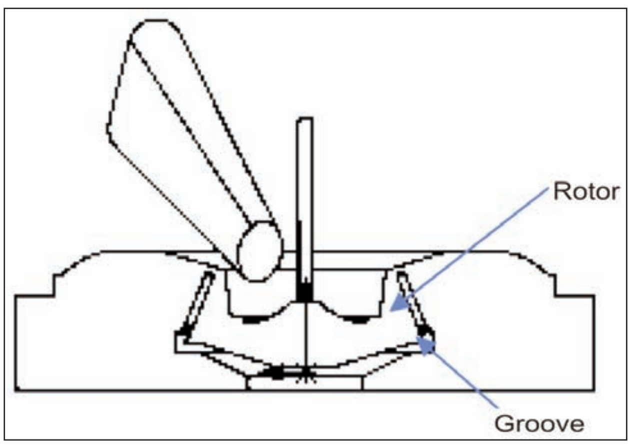

Fig. 1. Geometric model of rotor spinning unit

Standard k-turbulent model is applied as the method of turbulent numerical simulation. As the development of turbulences is not sufficient, wall function method is used here. No slip boundary conditions are used in the wall. Geometric model of spin box was shown by figure 1.

Rotor spinning process was recorded by olymbus i-speed3 in RF30C. Spinning unit is modified by clear plastic.

RESULTS AND DISCUSSION

Table 1

Groove	Levelof static pressure (Pa)	Speed (m/s)
G	–10704	296
T	–7330	261.8
U	–6557	261.2
S	–6255	253

Table 1 is the mean values of pressures and speeds in different groove rotors. For detail information of airflow in groove, speed and pressure of the cross section are showed by figure 2 and 3 respectively.

Angle orders of four grooves type are G < T < U < S (35°, 45°, 80° and 85° respectively). Table 1 and figures 2–3 demonstrate that speed of airflow in different groove are (S) SG > ST > SU > SS, negative pressure (P) PG < PT < PU < PS, hence the absolute value of negative pressure, PG > PT > PU > PS. It can be concluded that for grooves with small angle, airflow speeds achieve higher value and negative pressure are stronger. As experiments demonstrated that yarns showed better quality when produced by small angle grooves, it can be said that higher airflow speed and stronger negative pressure can improve yarn quality [4].

On the other side, short fibers are easier to combine and twist in groove with larger angle which is essential to yarn forming as actual production taking place. For fibers which are soft and long, such as cotton, polyester, viscose yarns can be produced by G and T groove rotors which have smaller angles, while for fibers which are short and have high flexural rigidity such as hemp, tough silk and wool, yarns can be produced by U and S groove rotors which have larger angles as experiment results have shown [4]. And also thinner yarn can be produced by G and T which contents fewer fibers in cross section, while thicker yarn can be produced by U and S which contents more fibers in cross section.

The cross point of groove and the extension of fiber transport channel is set as 0° (also as 360°), following clockwise as showed by figure 3. High speed airflows were divided into two streams as soon as they enter into the inner wall of rotor (0° point), one

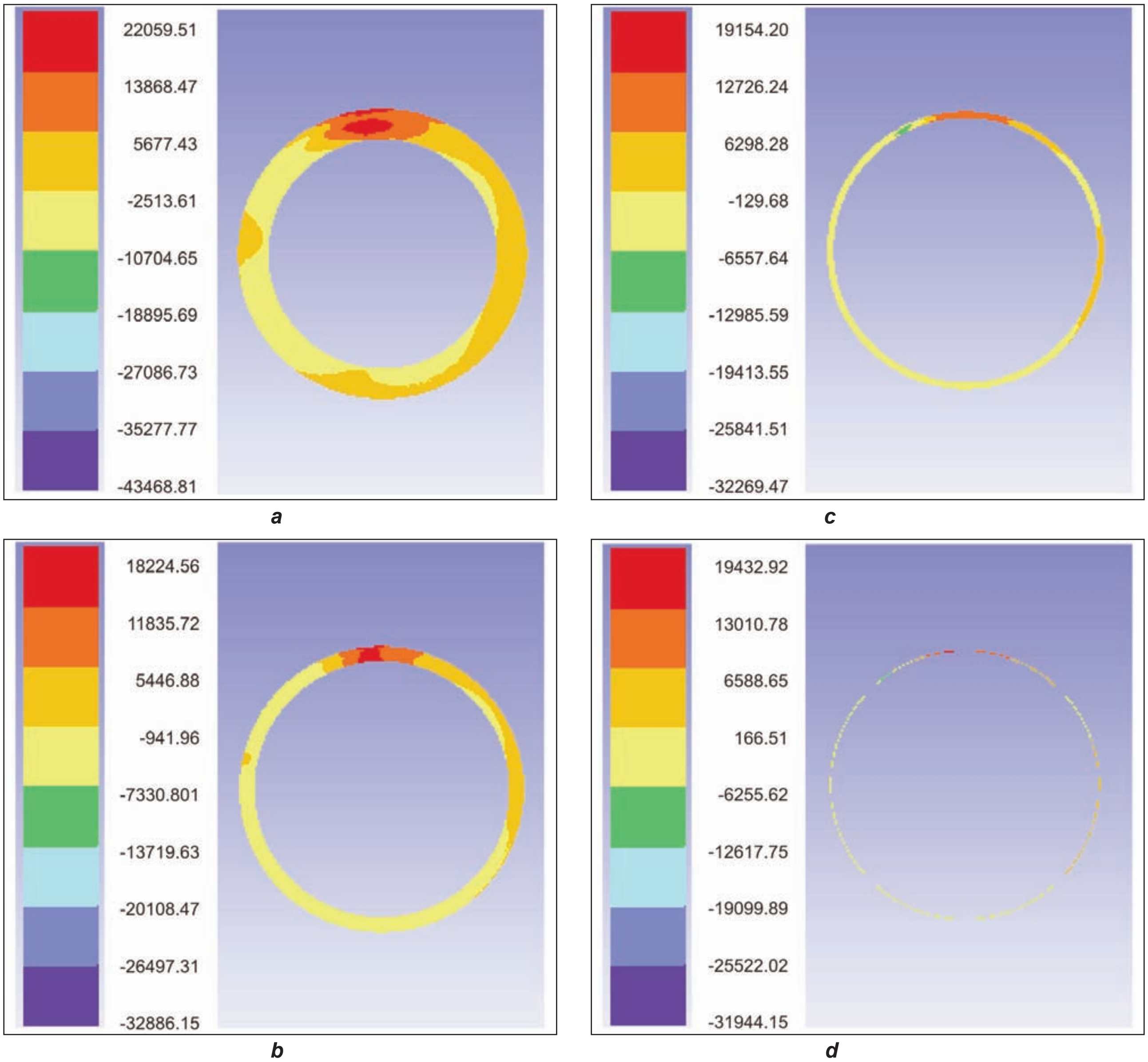

Fig. 2. Static pressure (Pa) distribution of groove wall: *a* – G; *b* – T; *c* – U; *d* – S

clockwise and another reverse direction, which joined together at point of 180°, as demonstrated by figure 3. During rotor spinning process, the fibers enter the incline wall which is called the slipped wall of the rotor and are circulated and piled up into rings like laminated layers, called ‘fibrous ring’ or ‘yarn ring tail’, which exerts a big doubling effect. When the piecing yarn enters the rotor, it will be thrown into the collecting groove and joined with the ‘fibrous ring’. Then the delivery rollers deliver the yarn out and at the same time the rotor rotation twists the yarn tail. Twists were delivered from yarn tail to fibrous ring as figured out by figure 4–5 from 90° to 0°. Compared with the reverse direction, speeds of clockwise airflow are faster and pressures are stronger, which can help fiber strands stretching and twisting as yarn which also be clarified by figure 3.

CONCLUSION

Airflow characteristics in 36 mm diameter rotors with G, T, U and S grooves were simulated and analyzed during rotor spinning process respectively. There are mainly two interesting and useful points. First, airflow speed (S) shows the order of SG > ST > SU > SS, pressure (P) PG < PT < PU < PS (hence the absolute value of negative pressure, PG > PT > PU > PS). It can be concluded that, airflow speeds achieve higher value and negative pressures are stronger in grooves with small angle, which can enhance yarn quality especially thinner yarn. Second, high speed airflow were divided into two streams as soon as they enter into the inner wall of rotor which place is set as 0°, one clockwise and another one reverse direction, which joined together at point of 180°. This phenomenon gives light to understand fiber strands stretch and twisting as yarn in rotor which can be

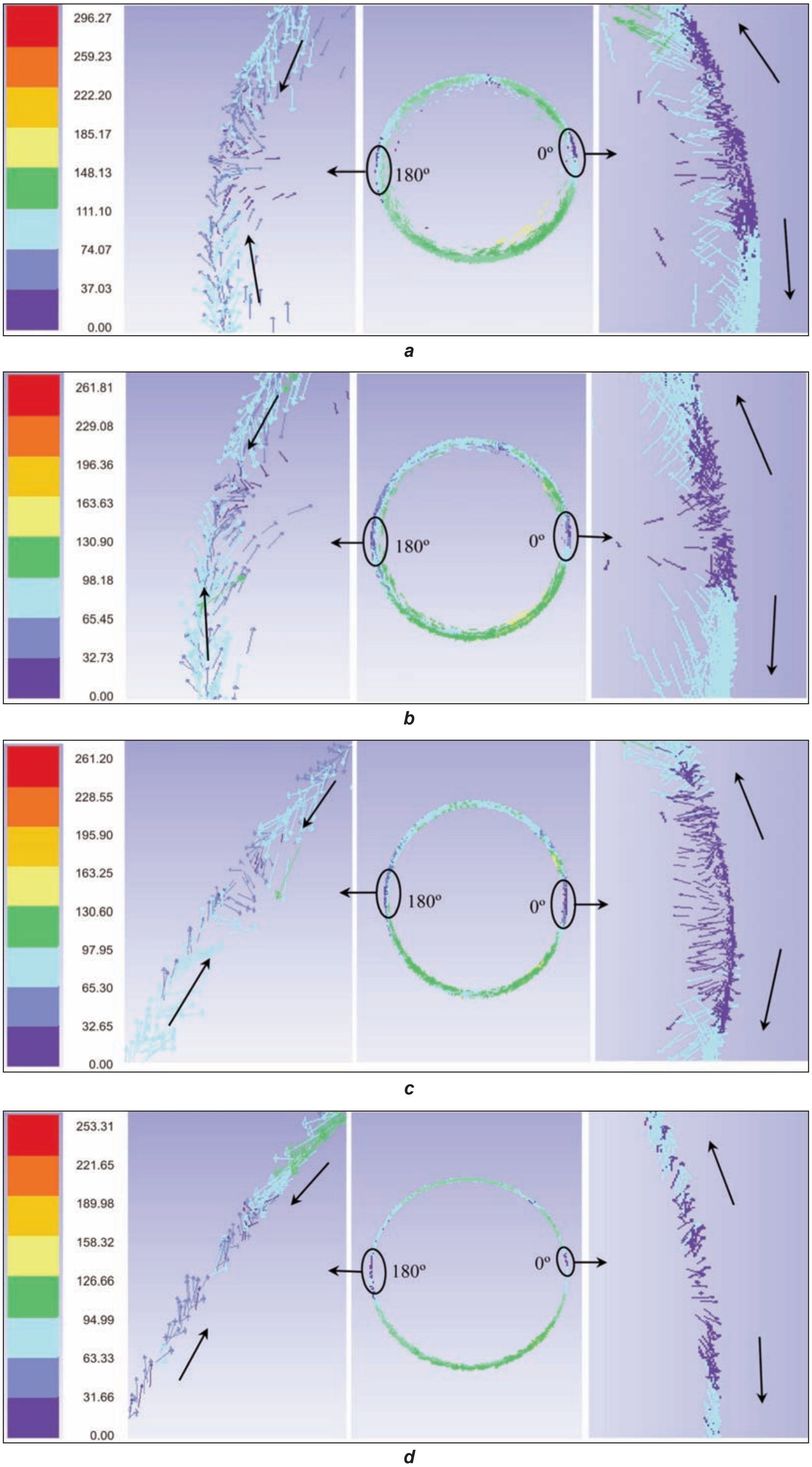

Fig. 3. Airflow speed (m^3/s) of groove wall: *a* – G; *b* – T; c – U; *d* – S

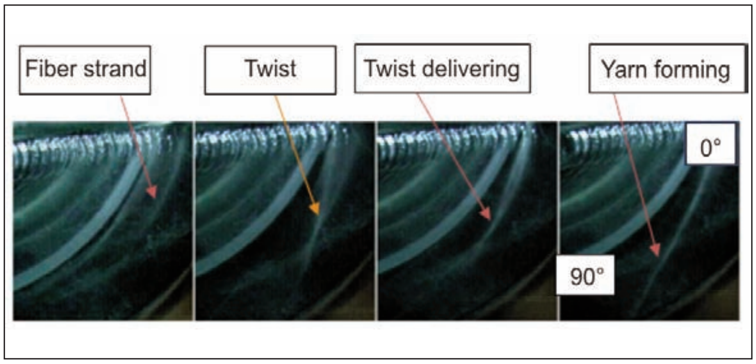

Fig. 4. Twisting process of rotor spun yarn

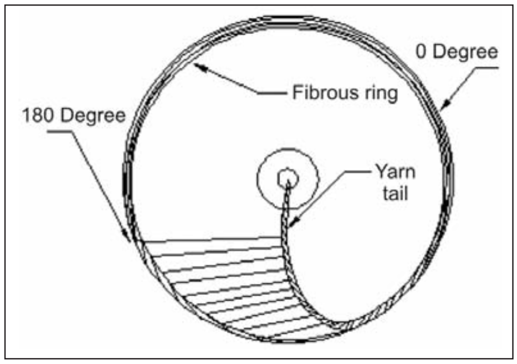

Fig. 5. Fibrous rings and bridge fibers in rotor

used to optimize spinning parameters during spinning and design new rotor type.

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A research on tensile properties of vortex yarns

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REZUMAT – ABSTRACT

Studiu privind proprietățile de rezistență la tracțiune ale firelor Vortex

Filarea este o rafinare a sistemului de filare cu jet, care are proprietăți distinctive, cum ar fi capacitatea de filare a firelor de 100% bumbac cardat și producerea unei structuri de fire inelare chiar și la viteze mari cu costuri reduse. Comparația structurii firelor Vortex cu firele produse prin alte metode de filare, precum și principalii factori de producție (viteza de debitare, laminajul, tipul fusului etc.) care influențează structura firelor au fost principalele subiecte din literatura de specialitate recentă. Cu toate acestea, la fel ca în toate sistemele de filare, posibilitatea de a obține fire fine vortex și comportamentul la rezistență la tracțiune în funcție de finețea firelor reprezintă o preocupare principală pentru producătorii de fire. În acest studiu, după ce au fost produse fire vortex cu finețe diferită (Ne 20, Ne 30, Ne 40) din aceeași materie primă pe o maşină MVS 810, proprietățile de rezistență la tracțiune (tenacitatea, alungirea la rupere, rezistența la rupere, forța de rupere) ale fiecărui fir au fost măsurate cu ajutorul echipamentului de testare Uster Tensojet. Conform rezultatelor testelor analizelor statistice, prin utilizarea valorilor experimentale obținute din teste, s-a stabilit că proprietățile de rezistență la tracțiune ale firelor Vortex au fost direct influențate de finețea firelor.

Cuvinte-cheie: filarea firelor Vortex, finețea firului, proprietăți de rezistență la tracțiune

A research on tensile properties of vortex yarns

Spinning is a refinement of jet spinning system which has distinctive features such as the capability of spinning %100 carded cotton yarn and producing ring-like yarn structure even at high speeds with low cost. Comparison of vortex yarn structure with yarns produced by other spinning methods and also the main production factors (delivery speed, drawing rate, spindle type etc.) influencing the yarn structure have been the main subjects in the literature lately. However as in all spinning systems, the possibility of obtaining finer vortex yarns and the tensile behavior according to yarn count is still a main concern for the yarn producers. In this study, after the vortex yarns at different yarn counts (Ne 20, Ne 30, Ne 40) were produced on MVS 810 machine from the same raw material, the tensile properties (tenacity, breaking elongation, work to break, breaking force) of each yarn were measured with Uster Tensojet test equipment. According to test results of the statistical analyses by using the experimental values obtained from the tests, we determined that tensile properties of vortex yarns were directly influenced by the yarn count.

Keywords: vortex spinning, yarn count, tensile properties

INTRODUCTION

There are many spinning systems which are in commercial use although some of them are still in experimental and some of them have been withdrawn from the yarn markets. Among the spinning systems, ring and compact spinning systems are still the widely most used spinning systems. Open-End Rotor spinning is another most commonly accepted short-staple yarn spinning technology. Lately airflow has been increasingly used as a way of fascinated yarn production [1–3]. There were many attempts for the air-jet spinning innovations such as: Rotofil, Dupont, Toyoda, Toray which had little commercial success. But Murata Air Jet system (MJS) which is equipped with two air-jet nozzles that create air vortices rotating in opposite directions had a renaissance effect on the air jet spinning systems innovation. Instead of two nozzles a modified single air nozzle was developed for Murata Vortex Spinning system (MVS).

This system is claimed to be capable of producing 100% carded cotton yarns which have a ring spun-like appearance and higher tenacity due to higher number of wrapping fibers when compared with the previous air-jet spinning systems. Vortex, a functional yarn produced by MVS, is a registered trademark of Murata Machinery [4]. Vortex yarn has high functionality which can be applied to many industrial fields besides being appropriate for everyday goods. Murata Company has developed MVS 810, MVS 81T, MVS 851, MVS 861 and lastly the MVS 870 model spinning machines. Murata MVS 810 was the first vortex spinning machine exhibited at Osaka International Textile Machinery Show in 1997 (OTEMAS '97). The machine had a delivery speed of up to 400 m/min [3]. In MVS system a drawn sliver is fed to a four-line drafting system. After coming out of the front rollers, the fibers move to the air-jet nozzle where the high-speed whirled air current arises. The preceding part of the fibers reaching the vortex chamber become the core fibers which will be wrapped by trailing ends called wrapping fibers inside the spindle which has a hole in the center. The vortex yarn formation occurs at the spindle outlet and the yarn defects are removed before the winding process [4–5].

As the literature was reviewed, it can be seen that there are several studies related to the investigations of vortex yarn and the parameters influencing the vortex yarn tenacity values. Pei and Yu made a research about the numerical study on the effect of nozzle pressure and yarn delivery speed on the fiber motion in the nozzle of Murata vortex spinning. A two-dimensional FSI model combined with the fiber–wall contact was applied for simulating a single fiber moving in the airflow inside the MVS nozzle. The nozzle pressure and yarn delivery speed – on the fiber motion and in turn, the yarn tenacity was analyzed [6]. Pei and Yu made another research about the numerical and experimental research on the influence of parameters on the tensile properties of Murata vortex yarn (MVS). Four parameters; nozzle pressure, jet orifice angle, twisting surface angle and the distance between the nozzle inlet and the spindle were the main parameters for evaluating their influence on yarn tensile parameters [7]. Ortlek et al. made a study about the spindle diameter and working periods on the properties of %100 viscose MVS yarns. Larger spindle diameter resulted in high hairiness as well as low unevenness and tenacity values [8]. Kuthalam and Senthilkumar investigated the effects of fiber fineness and spinning speed on polyester vortex spun yarn properties. They selected 5 different production speed (320, 340, 360, 380 and 400 m/min) with 4 different fiber fineness (0.9, 1.1, 1.3 and 1.5 dtex). By using a linear regression method they concluded that fiber fineness and the production speed did not influence the yarn tenacity [9]. Tyagi et al. investigated the effects of fiber type, blend ratio and the yarn type on the yarn characteristics. According to the results of investigation, tenacity, work of rupture and breaking extension values were significantly affected by the process parameters [10]. Erdumlu and Oxenham investigated the tenacity and breaking elongation of plied vortex spun yarns. The researchers concluded that plying process led to tenacity increment up to 20% whereas they observed a decrement in breaking elongation [11].

Although there were some investigations concerning some process parameters' influence on vortex yarns in the early studies, there is still a gap in the literature related to influence of yarn count on tensile properties of vortex yarns. Vortex yarn production in finer counts lead to decrement of the core fiber ratio in the yarn structure. This may cause deterioration in yarn properties in terms of yarn evenness and yarn tenacity. The expected target from this study is to analyse the effect of yarn count on vortex yarns in terms of tensile properties such as tenacity (cN/tex), breaking elongation (%), work to break (N.cm) and breaking force (cN). The study also aims to contribute to literature by comparison of tensile results of vortex yarns produced at the acceptable yarn count range.

EXPERIMENTAL WORK

The vortex yarns were produced on MVS 810 Model Murata Vortex yarn machine. Three (3) different yarn counts (Ne 20, Ne 30, Ne 40) were selected with the same raw material of cotton fiber at a constant delivery speed of 200m/min and constant nozzle pressure of 5 kgf/cm^2. The Diyarbakır cotton type with the maturity of 0.94 was used as a raw material which had the following properties: 4.57 micronaire reading, 29.25 mm Upper Half Mean Length (UHML), Uniformity index (UI) of 85, 5.2 % breaking elongation and 34/4 grams/tex strength (table1).

Cotton fibers were opened, carded and cleaned at the same blow room equipment. Rieter C50 type carding machine was used during the process. For the combed sliver preparation, three passages of drawing (breaking, second and finisher draw) were applied by utilizing RIETER RSB 951 type draw machines. Rieter E62 combing machine was used for the combing process for a better fiber alignment and sliver evenness. After three passages of drawing, the combed slivers with a linear density of approximately Ne 0,20 were transferred to vortex spinning machine of MVS 810. The sliver count was same for the three yarn counts (Ne 20, Ne 30, Ne 40). The yarn samples were produced with the nozzle holder of 2p 130d L7 (9,3) type and the spindle with 1.2 mm inner diameter on MVS 810 vortex yarn spinning machine (figure 1). Delivery speed of the slivers was remained the same as 200 m/min for the three different yarn counts. The list of yarn samples and corresponding test conditions are presented in table 2.

Table 1

PROPERTIES OF COTTON FIBER USED FOR VORTEX YARN PRODUCTION

Upper Half Mean Length (UHML)	Micronaire	Short Fiber Index (SFI)	Tenacity (g/tex)	Breaking elongation (%)	Maturity
29,25	4,57	5	34/4	5.2	0,94

Table 2

NOMINAL YARNS AND PROCESS PARAMETERS

Yarn count	Nozzle pressure	Delivery speed (m/min)	Spindle (mm)	Total Draft Ratio of MVS 810 (TDR)	Main Draft Ratio of MVS 810 (MDR)
Ne 20	5 kgf/cm^2	200	1.2 mm	90	25
Ne30	5 kgf/cm^2	200	1.2 mm	136	37
Ne 40	5 kgf/cm^2	200	1.2 mm	200	33

Fig. 1. Production of vortex yarns on MVS 810 spinning machine

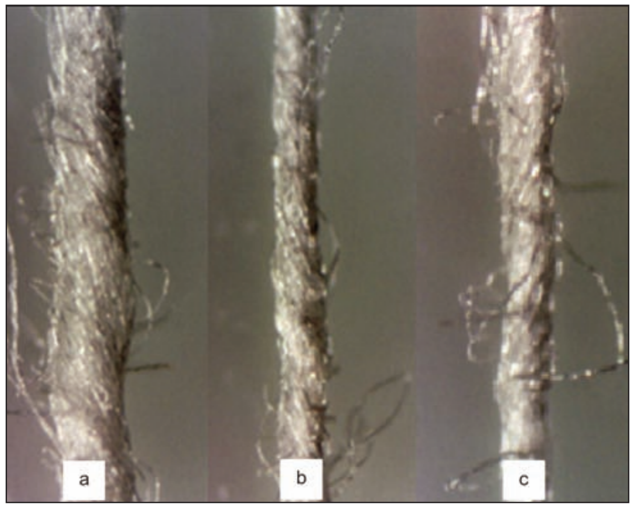

Fig. 2. SEM images of vortex yarns:
a – Ne 20; *b* – Ne 30; *c* – Ne 30 vortex yarn

Table 3

YARN CODES FOR THE EXPERIMENTAL WORK	
Yarn Count	**Yarn Code**
Ne 20	2050
Ne 30	3050
Ne 40	4050

The produced vortex yarns were coded as 2050, 3050, 4050 for the yarn counts of Ne 20, Ne 30 and Ne 40 respectively in order to be used in the graphs and the statistical analyses in our study (table 3)
In the scope of our work, the vortex yarn samples produced in three different yarn count (Ne 20, Ne 30, Ne 40) were detailly observed by using Scanning electron microscope (SEM) in Erciyes University's Textile Engineering Laboratory. Our structural analyze also confirmed the information of vortex yarn consisting of two fiber groups; wrapping and core fibers. Vortex yarn samples were also compared in terms of tenacity (cN/tex), breaking elongation (%), breaking force (cN) and work to break values (N.cm) by using measurement data of Uster Tensojet yarn testing device present in BEYTEKS (Beyşehir, Turkey) yarn testing laboratory. 10 bobbins were chosen for the efficient assessment of each yarn sample and ten different yarn pieces were taken from each bobbin according to Uster test standard. All the measurements were conducted under the standard test conditions, 65 ± 2% relative humidity and 20 ± 2°C. All statistical procedures were conducted using the SPSS 15.0 Statistical software package. In the study completely randomized one-factor analysis of variance (ANOVA) was used for the determination of the statistical significance of the yarn count on tensile properties of vortex yarns. The means were compared by TUKEY HSD tests. The value of significance level (α) selected for all statistical tests in the study is 0.05. The treatment levels were marked in accordance with the mean values, and any levels marked by different letter (a, b, c) showed that they were significantly different.

RESULTS AND DISCUSSION

Yarn structure

Optical images of 3 different vortex yarn samples spun in various counts (Ne 20, Ne 30, Ne 40) were displayed in figure 2.
According to our visual analysis; the parallel fiber groups called "core fibers" were wrapped with the wrapping fibers in the same appearance as described by the previous authors. They gave detailed information about the vortex yarn structure where they also mentioned about the wild fibers protruding randomly along the yarn axis [3, 5, 12]. Tyagi et al. made a research about structural properties of vortex yarns where they classified the structure into three main categories as core fibers, wrapper fibers and wild fibers. Core fibers were defined as the straight parallel fiber groups around which were wrapped by wrapping fibers. The same researchers also emphasized the wild fibers which protrude from the yarn strand randomly [12]. Erdumlu et al. concluded in their study that wrapping fiber ratio increases as the vortex yarn gets finer [2]. Our images displayed in figure 2 also revealed that more wrapping fibers were observed as the vortex yarn gets finer. With the scope of early studies; this result was attributed to the lower inter-fiber cohesion which leads to higher fiber separation with more wrapping fiber ratio because of the swirling air current in finer vortex yarns.

Tensile properties

Tenacity (cN/tex), breaking elongation (%), breaking force (cN) and breaking work values (N.cm) of vortex yarns with different yarn counts (Ne 20, Ne 30, Ne 40) were evaluated with the graphs and the one-factor analysis of variance with Tukey HSD test.

Tenacity results (cN/tex) of vortex yarns

Figure 3 displays the tenacity results of vortex yarns at three different yarn count (Ne 20, Ne 30, Ne 40). According to figure 3, the highest tenacity was obtained from the Ne 4050 coded yarn groups.

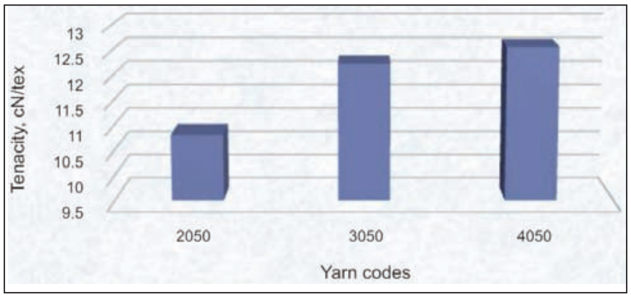

Fig. 3. Tenacity results of vortex yarns

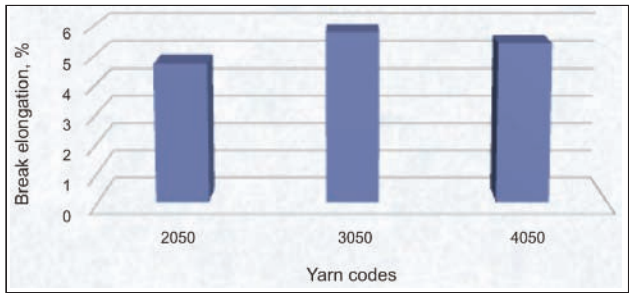

Fig. 4. The breaking elongation (%) results of the vortex yarns

And the minimum yarn tenacity was obtained from the Ne 2050 coded yarn groups. It was easily observed that there is an increment trend for the tenacity values of vortex yarns as they get finer.

The Anova results for yarn tenacity results indicated that there were statistically significant (5% significance level) differences between the tenacity values of the vortex yarns having different yarn counts. The TUKEY HSD test results given in table 4 revealed that, the vortex yarns having different yarn counts possessed statistically different tenacity values. The rank for the yarn tenacity from the lowest to the highest value was as follows: Ne 20, Ne 30, Ne 40. Murata company's catalog also confirms our result with the information that the more the yarn gets finer the more increases the vortex yarn tenacity [13]. Supporting our result Oxenham also concluded in his work that as the vortex yarns got finer, the tenacity values increased. The author explained this result with the wrapping fibers' wrapping length increment which make tighter wrappings leading to higher tenacity. He also emphasized that the ratio of the wrapping fibers to the core fibers is a very important variable for tenacity determination [14]. Kuppers et al.'s investigation results also support our findings which claim that the best proper tenacity values can be obtained between the yarn count of Ne 24 and Ne 38 vortex yarns. They concluded that there is a decrease in yarn tenacity in finer and coarser yarns [15]. However the tenacity results remained same as the yarn became finer in Erdumlu's study [2]. The tenacity results of finer vortex yarns were generally higher also in Yılmaz and Kayabası's study which was an investigation about the effect of fiber type and yarn fineness on vortex yarn properties [16].

Table 4

TUKEY HSD TEST FOR VORTEX YARN TENACITY		
Parameter		**Yarn tenacity (cN/tex)**
Yarn count (Ne)	4050	12,5960a
	3050	12,2460b
	2050	10,8330c

NOTE: The different letters next to the counts indicate that they are significantly different from each other at a significance level of 5 %.

Breaking elongation (%) results of vortex yarns

Figure 4 displays the braking elongation (%) values of the vortex yarns. The maximum breaking elongation (%) values were obtained from the 3050 coded yarns. The minimum breaking elongation (%) values were obtained from the 2050 coded yarns. There was not a trend for the rank of the breaking elongation values for the yarn count. The lower breaking elongation (%) values obtained for coarser yarns (Ne 20) might be the result of the high number of core fibers in vortex yarns which increases the forces acting on the yarn leading minimum fiber slippage. In some of the studies in the literature, related to breaking elongation (%) values of vortex yarns, it was found to be higher than conventional ring, compact and open-end rotor spun yarns although it was expected to be lower due to the presence of wrapper fibers [17, 18]. In Leitner's investigation, vortex spun yarns had similar breaking elongation values with the ring spun yarn [19].

The Anova results for breaking elongation (%) values indicated that there were statistically significant (5% significance level) differences between breaking elongation of the vortex yarns having different yarn counts. The Tukey HSD test results given in table 5 revealed that, the vortex yarns having different yarn counts possessed statistically different breaking elongation values. The breaking elongation value was obtained as 4.76 (%) from the 2050 coded yarns, as 5.81 (%) from the 3050 coded yarns and as 5.44 (%) from the 4050 coded yarns.

Table 5

TUKEY HSD TEST FOR VORTEX YARNS' BREAKING ELONGATION (%) VALUE		
Parameter		**Breaking elongation (%)**
Yarn count (Ne)	3050	5,81a
	4050	5,44b
	2050	4,76c

NOTE: The different letters next to the counts indicate that they are significantly different from each other at a significance level of 5 %.

Breaking force (cN) results of Vortex yarns

Figure 5 displays the braking force (cN) values of the vortex yarns. The maximum breaking force (cN) values were obtained from the 2050 coded yarns. The minimum breaking force (cN) values were obtained from the 4050 coded yarns.

The Anova results for breaking force values (cN) indicated that there were statistically significant (5% significance level) differences between breaking force values of the vortex yarns having different yarn

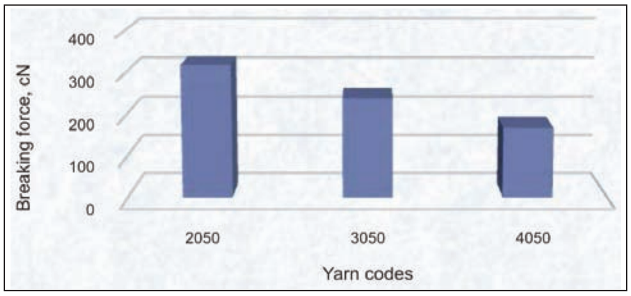

Fig. 5. Breaking force (cN) values of the vortex yarns

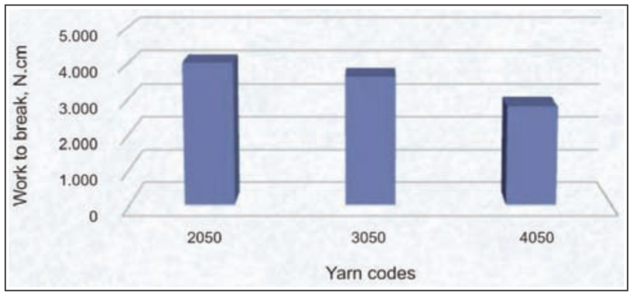

Fig. 6. Work to break (N.cm) results of vortex yarns

Table 6

TUKEY HSD TEST FOR BREAKING FORCE VALUES (cN)		
Parameter		**Breaking force (cN)**
Yarn count (Ne)	2050	319,9 a
	3050	241,1 b
	4050	169 c

NOTE: The different letters next to the counts indicate that they are significantly different from each other at a significance level of 5 %.

Table 7

TUKEY HSD TEST FOR VORTEX YARNS' WORK TO BREAK VALUES (N.cm)		
Parameter		**Work to break (N.cm)**
Yarn count (Ne)	2050	4.072a
	3050	3.672b
	4050	2.823c

NOTE: The different letters next to the counts indicate that they are significantly different from each other at a significance level of 5 %.

counts. The Tukey HSD test results given in table 6 revealed that the vortex yarns having different yarn counts possessed statistically different breaking force values (cN). The breaking force (cN) value was obtained as 319,9 from the 2050 coded yarns, as 241,1 from the 3050 coded yarns and as 169 from the 4050 coded yarns.

Work to break (N.cm) values

Figure 6 displays the work to break (N.cm) results of the vortex yarns at 3 different yarn count (Ne 20, Ne 30, Ne 40).The maximum breaking work (N.cm) value was obtained from the 2050 coded vortex yarns. This may be attributed to the higher inter fiber cohesion of fibers in coarser yarns which have higher proportion of core yarns comparing to fine yarns but lower wrapping fiber ratio because of minimum separation of trailing ends. On the other hand the minimum breaking work was obtained from the 4050 coded vortex yarns. The similar result was obtained in Gunaydin et al.'s investigation where the effect of nozzle pressure and yarn count on vortex yarns' work to-break values was also mentioned [20].

The Anova results for work to break values (cN.cm) indicated that there were statistically significant (5% significance level) differences between breaking work values of the vortex yarns having different yarn counts. The TUKEY HSD test results given in table 7 revealed that the vortex yarns having different yarn counts possessed statistically different breaking work values (N.cm). The breaking work (N.cm) value was obtained as 4,072 from the 2050 coded yarns, as 3.67 from the 3050 coded yarns and as 2.82 from the 4050 coded yarns.

CONCLUSIONS

Vortex yarns boast many outstanding characteristics, such as less hairiness, better resistance to pilling, better moisture absorption and wash resistance [1, 3]. However there is still restriction about the vortex yarn spinnability in finer yarn counts. The ratio of the wrapper fibers to core fibers should be concerned as a vital parameter for finer vortex yarns production with minimum deterioration. Murata Machine producers claimed that the range of yarn count spinnable on vortex system is between Ne 20 and Ne 70 in the latest model of MVS 870 [21]. As we mentioned in the introduction part, there are many process parameters influencing the vortex yarn structure and yarn quality such as the delivery speed, nozzle pressure, spindle type, drawing ratio, etc. Additionally according to literature findings and our study results, yarn count is a very important factor regarding the vortex yarns' tensile properties. As result of the experimental work that has been carried out in the frame of the paper below listed conclusions can be drawn out.

Produced vortex spun yarn samples has three basic parts of a typical vortex yarn, core fibers, wrapper fibers and wild fibers. Experienced visual analysis proved that amount of wrapper fibers increased as the vortex yarns got finer. On the other hand, the amount of wrapper fibers decreased in coarser yarns. Our measured results and statistical analysis work proved that yarn count is an important parameter which influence the vortex yarn tensile properties. The highest tenacity was obtained from the Ne 40 yarns. However it is suggested for the producers to be careful when the yarn becomes too much finer or too much coarser since the early studies' experimental results revealed that tenacity values follow a decreasing trend as the yarn becomes too much finer or too much coarser. When it comes to breaking elongation (%), the maximum breaking elongation values were obtained from the 3050 coded yarns, the minimum breaking elongation (%) values were obtained from the 2050 coded yarns. There was not a trend for the rank of the breaking elongation (%) values for the yarn count. It can be expressed that similar trend was observed for breaking force and work-to break values of vortex yarn samples. Measured results of breaking force and work-to break values and statistical analysis revealed that as the vortex spun yarn becomes coarser, breaking force and work-to break values rise up.

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Cyclic deformation properties of knitted sportswear fabrics by different test methods

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VİLDAN SÜLAR AYŞE OKUR EZGİ ÖZÇELIK

REZUMAT – ABSTRACT

Determinarea proprietăţilor de deformare ciclică a materialelor tricotate pentru îmbrăcăminte sport prin utilizarea a diferite metode de testare

Materialele din fibre de elastan sunt considerate la modă și funcționale de mult timp, mai ales deoarece se aşează pe corp într-un mod confortabil. Acest studiu investighează proprietățile de deformare ale materialelor tricotate pentru îmbrăcămintea sport. Au fost utilizate trei metode diferite de testare pentru a compara capacitatea de întindere a materialelor supuse testării. Au fost produse 12 materiale tricotate în conformitate cu cerințele clienților prin utilizarea a două densități liniare diferite ale firelor de bază (viscoză Ne28, viscoză Ne36), două setări diferite (normal, strâns) și trei tipuri diferite de finețe ale firului buclat din poliamidă/poliester (70/20, 70/40, 70/70)". Ca rezultat, s-a efectuat o analiză comparativă între aceste trei metode și a fost analizat efectul parametrilor structurali, cum ar fi densitatea liniară a firelor din elastan buclat și structura materialului. S-a observat că materialele din fire de viscoză Ne28 au în general valori de deformare mai mici în comparație cu cele din fire de viscoză Ne36. S-a observat că efectele parametrilor structurali, cum ar fi densitatea liniară a firelor buclate și dispunerea, au avut valori semnificative din punct de vedere statistic, la un nivel de încredere de 95% pentru multe dintre materialele care au fost supuse testării. În plus, s-a constatat că nu există o tendință sistematică la tipurile de materiale pentru diferitele metode de testare.

Cuvinte-cheie: îmbrăcăminte sport, elastan, deformare, material tricotat, structura tricotului, densitatea liniară a firului

Cyclic deformatin properties of knitted sportwear fabrics by different test methods

Fabric having elastane fiber is accepted as fashionable and functional for a long time, especially for the fabrics fit the body in a comfortable way. This study examines the deformation properties of knitted sportswear fabric. Three different test methods were used to compare the stretching abilities of the test fabrics. 12 knitted fabrics were produced according to the customer demands by using two different base yarn linear density (Ne28 viscose, Ne36 viscose), two different settings (normal, tight) and three different poliamid/elastane gimped yarn denier (70/20, 70/40, 70/70)". As a result, comparative analysis has been carried out between these three methods and the effect of structural parameters such as linear density of gimped elastane yarn and fabric setting was analyzed. It was observed that fabrics having Ne28 viscose yarn have generally less deformation values in comparison to the fabrics having Ne36 viscose yarn for the results of different test methods. The effects of structural parameters such as linear density of gimped yarn and setting were found statistically significant at 95%confidence level for many of the test fabrics. Besides, it was found out that there is no systematic tendency observed among the fabric types for the different test methods.

Keywords: sportswear, elastane, deformation, knitted fabric, fabric setting, yarn linear density

INTRODUCTION

During daily activities or sport, fabrics permitting physical activity in a comfortable way are desired, for example tights, swimwear and etc. Repetitive body movements and different extension abilities between skin and a garment restrict the movements of the wearer during usage. A physical problem or an undesired appearance occurs on the garment and this difference becomes an esthetical problem. Fabric bagging which is a fabric deterioration that generally occurs on elbows, knees, hips and heels and a partially or totally permanent three dimensional deformation appears. In order to improve stretching properties of the fabrics and clinging the fabric on the body, yarns containing elastane fiber have been used in many areas. To use elastane yarn with a ratio of 2–3 % in fabrics is sufficient to provide the appropriate stretch properties[1]. Besides desired stretchability of a fabric or easier movement with this elastic fabric and recovery properties after deformation become interesting for everybody.

Many researchers studied on bagging deformation, recovery and stretch properties of fabrics by examining the problem from different views [1, 2–17]. In these researches, the problem was examined theoretically and experimentally. In the experimental studies, researchers generally used a tensile tester or an apparatus. The deformation properties were examined during and after loading and unloading cycles. For the studies conducted especially on fabric bagging, the researchers utilized a circular apparatus adaptable to a tensile tester to simulate fabric bagging [3–8, 11, 16]. In these bagging measurement methods, generally a predetermined bagging height was used and load values were recorded for five deformation cycles simultaneously with the test. On the other hand, subjective perception and fabric appearance were examined in some of these studies. Grunewald and Zoll [8], Özdil [10], Bilen and

Kurumer [13] used a test device similar to an arm as described in DIN 53860 [2] and they examined fabric bagging occurring on the elbow of an arm in static conditions. Some researcher investigated the bagging deformation different from these methods [9–10, 12–13, 15]. Abghari et al. [9] examined the relation of in-plane fabric tensile properties by developing a new test method and measuring woven fabric tensile deformations along warp and weft directions. Baghaei et al. [12] investigated the tensile fatigue cyclic loads by designing an apparatus adaptable to a tensile tester and after applying cyclic loads they examined fabric bagging by using Zhang's method. Sülar [15] developed a new testing instrument inspiring from DIN 53860 [2] to create fabric bagging under dynamic conditions. The main difference from the mentioned standard is to study under dynamic conditions and to simulate up and down motion of an arm having elbow joint. The researcher produced an artificial arm to deform fabrics and several woven fabrics were also investigated in that study.

In recent years, the numbers of the researches conducted on elastic fabrics and examining the topic from different views are getting higher with increasing usage of elastane yarn in many different applications. In some applications which require more extensibility and fitting to body such as sportswear, knitted fabrics are generally preferable because of their more elastic structure. For that reason, determination of the deformation and recovery properties of these fabrics become interesting and an important issue. Thus, a set of systematically produced knitted fabrics were used to examine the deformation properties in this study. Besides that, the effect of different structural parameters on deformation properties was investigated by using three different test methods, one of which is common amongst clothing companies and the other two methods are generally used by researchers. The benefits of the current research is being a comparative study by using different test methods and using systematically produced fabrics to examine the effects and interactions of fabric properties separately for different test methods.

EXPERIMENTAL WORK

Materials and method

Twelve types of knitted fabrics suitable for tights as sportswear, having two different linear densities of viscose yarn (Ne 28 and Ne 36, open-end rotor spun), three different linear densities of polyamide/elastane gimped yarn (70/20, 70/40 and 70/70 denier) and two different tightness levels (normal and tight), were produced in this study. All fabrics were produced on Mayer & Cie circular knitting machine in 18 gauges in 36-inch diameter. After knitting and pad-batch dying, washing, neutralization, drying and sanforization processes were applied respectively. Consequently, all the fabrics were treated with the same dyeing and finishing routine.

The test fabrics were conditioned at 20 ± 2°C and 65 ± 2% relative humidity at least 24 hours according to ASTM D1776. The physical parameters of the produced fabrics are listed in table 1.

Methods

The details of three test methods and the measured/calculated parameters are presented in table 2. The effects of structural parameters were evaluated and the fabrics were compared with these methods. M&S P15 A test method was chosen as the first test method because of its being very common method amongst many clothing companies. As the second test method, a pneumatic bursting tester was used to obtain a spherical deformation on fabrics to simulate

Table 1

BASIC STRUCTURAL PROPERTIES OF THE TEST FABRICS

Fabric code	Viscose yarn	Gimped yarn (denier) (PA/EL)	Setting level	Setting (cm^{-1})		Raw material content * (%)	Mass per unit area (g/m^2)
				wale	course		
A1	Ne 28(21.1tex)	70/40	Normal	28	28	72/20/8	343.9
A2	Ne 28(21.1tex)	70/40	Tight	28	34	73/20/7	382.5
A3	Ne 28(21.1tex)	70/70	Normal	28	29	67/24/9	362.0
A4	Ne 28(21.1tex)	70/70	Tight	28	34	69/22/9	430.0
A5	Ne 36(16.4tex)	70/40	Normal	29	28	70/24/6	324.0
A6	Ne 36(16.4tex)	70/40	Tight	28	34	69/25/6	350.0
A7	Ne 36(16.4tex)	70/70	Normal	28	28	62/26/12	354.8
A8	Ne 36(16.4tex)	70/70	Tight	28	36	64/28/8	375.4
A9	Ne 28(21.1tex)	70/20	Normal	28	26	68/24/8	313.7
A10	Ne 28(21.1tex)	70/20	Tight	28	32	66/25/9	331.2
A11	Ne 36(16.4tex)	70/20	Normal	28	28	62/30/8	287.6
A12	Ne 36(16.4tex)	70/20	Tight	28	36	60/31/9	294.8

* CV, PA and EL denotes Viscose, Polyamide and Elastane, respectively.

Table 2

TEST METHODS AND PARAMETERS USED IN THE EXPERIMENTAL STUDY				
	Test instrument/test method	**Test direction**	**Parameters**	**Abbreviation of the measured/calculated parameter**
1	Universal tensile tester (M&S P15 A)	wale and course	Extension at 1500 cN (mm) Residual extension (%) Modulus(Load at 40% extension, cN)	Ewale, Ecourse REwale, Ecourse Mwale, Mcourse
2	Pneumatic bursting tester	spherical	Distension at 1, 3 and 5 cycles (mm)	Distension 1 cycle Distension 3 cycle Distension 5 cycle
			Distension difference between 1-3 cycles (%) Distension difference between 1-5 cycles (%)	Distension 1-3 cycle Distension 1-5 cycle
3	Artificial arm by human elbow	spherical	Bagging resistance (cN) Bagging height (mm)	BR H

the deformation occurs especially on knees of the tights. As the third method, artificial arm by human elbow was used to evaluate the deformation properties of knitted fabrics by making a number of bagging cycles.

Cyclic tests with M&S P15 A method

Test samples having rectangular shape (150 × 50 mm) both in wale and course directions were prepared for M&S P15 A test method. A universal tensile tester was used by a computer control. Test samples were extended to a fixed load (1.5 kgf ≈ 1500 cN) and 500 mm/min test speed was used according to the test procedure (figure 1,*a*). During two deformation cycles, maximum extension values were simultaneously recorded by the computer and after completing the test, residual extension values (%) were obtained by using the tested sample waiting for two minutes on a plane platform (eq. 1).

$$RE(\%) = ((F_{length} - I_{length}) / I_{length}) \times 100 \quad (1)$$

In equation 1, *RE* is residual extension (%), F_{length} is final length (mm) and I_{length} is initial length (mm). Final length is the measured length after two minutes completing the test and initial length is always 80 mm. Three repetitions were conducted for every test direction.

Cyclic tests with pneumatic bursting tester

In the second method, a pneumatic bursting tester was used to deform the fabric samples. Before cyclic tests with bursting tester, bursting strength values of the test fabrics were checked and 100 kPa pressure was selected as a common value that causes a spherical deformation but lower than the bursting strength of all fabric types. Extension&Recovery (cyclic) programme of the instrument was utilized for fabric deformation and test area having 50 cm^2 was selected for this purpose (figure 1,*b*). The test sample was inflated till the pressure reaches 100 kPa and the distension on the sample during test was recorded for every bagging cycle. The distension values were used as a measure of bagging deformation on fabrics. In the origin of this method, only the distension

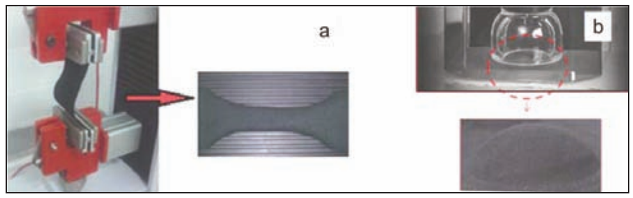

Fig. 1. Test process and deformed fabric samples by two different deformation methods: *a* – M&S P15 A method; *b* – pneumatic bursting tester

values after 5 cycles are given. In this research, different simple parameters were also calculated by using the measured values. The distension values after 1, 3 and 5 cycles and the differences in percentage (%) between cycles were calculated to examine the deformation behaviour.

Cyclic tests with artificial human elbow

The entire test procedure was repeated according to the details given in a previous study for this method [16]. According to the procedure of this test method, tubular test samples were prepared by sewing. Test samples were deformed by the help of a pneumatic piston of the artificial arm under dynamic conditions for 400 cycles. After test, samples were waited on the measuring tube for two minutes as M&S P15 A test method. Before and after deformation, height of the fabric sample on the measuring tube was taken by using the shadow of the samples on a point paper to handle bagging height values. Bagging height was calculated from the equation given below (eq. 2).

$$H \text{ (mm)} = h_2 - h_1 \quad (2)$$

where, *H* indicates bagging height, h_1 indicates height of fabric sample measured from its own shadow before bagging test and h_2 is assigned to height of fabric sample measured from its own shadow after bagging test. Figure 2 shows test process, deformed fabric and schematic measuring principle. As another parameter, load values which were simultaneously recorded by a load cell during the bagging cycles were used. The average of these load values was taken as bagging resistance.

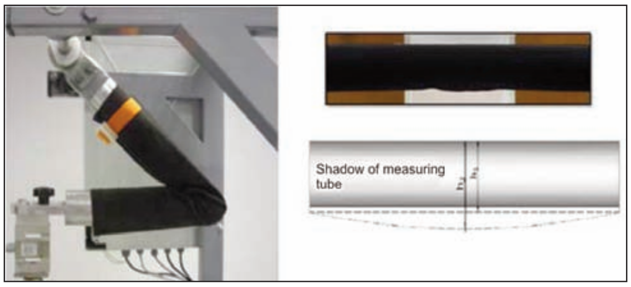

Fig. 2. Test process, deformed fabric sample by artificial human elbow and measurement of bagging deformation on a measuring tube

RESULTS

In this part, the results were given and examined respectively according to different deformation test methods. All the test results given in table 3, 6 and 9 were statistically evaluated in terms of variance analyses by using SPSS 19.0 for Windows. Post-hoc test procedure (Student Newman Keuls, SNK) was also used to compare the groups for the linear density of gimped yarn and setting. Besides correlation analysis was conducted to examine the relationships between the parameters of three test methods. For all statistical analyses, 95% confidence level ($p < 0.05$) was considered to be significant.

Cyclic tests results by M&S P15 A test method

The test results obtained by using this test method are tabulated in table 3 and shown in figure 3 and 4. When table 3 was examined, it can be said that all the fabrics have extension values higher than 50 mm by 1500 cN extension load. The load values necessary to extend the fabrics till 40 % extension in course direction are higher than the ones in wale direction. When figure 3 is examined, it is obvious that especially tight fabrics produced by Ne 28 yarns can be less extended. When yarn linear densities are compared, it can be said that to extend the test fabrics produced by Ne 28 yarns are harder than the test fabrics made of Ne 36 yarn. Lower residual extension values were obtained for Ne 28 fabrics both in two test directions and this situation is very distinct for all the test fabrics.

Considering the setting level, generally lower extension values were obtained for tight fabrics in wale and course directions. When residual extension values are examined, it is seen that there is a good agreement with the extension values. The variance analysis result is seen in table 4. When the effects of structural parameters were examined, it was determined that linear density of gimped yarn, setting and the interactions are statistically significant ($p < 0.05$) at 95% confidence level for all test fabrics.

For the fabrics made of Ne 36 yarns, course setting has no statistically significant effect on extension and residual extension results in wale direction. The results of SNK post hoc test show that test results were generally divided into three groups as 70/20, 70/40 and 70/70 denier gimped yarn beginning from the lowest to highest deformation respectively

Table 3

EXTENSION AND RECOVERY PROPERTIES OF TEST FABRICS DEFORMED BY M&S P15 A TEST METHOD

Fabric code	Extension at 1500 cN (mm)		Residual extension (%)		Modulus (Load at 40 % extension, cN)	
	wale	course	wale	course	wale	course
A1	64.9	59.4	3.8	2.5	386.7	500.0
A2	60.7	37.9	3.8	0.6	463.3	1490.0
A3	67.9	48.5	4.2	1.3	470.0	950.0
A4	65.1	38.7	4.8	0.6	456.7	1540.0
A5	88.5	81.9	9.6	7.5	230.0	290.0
A6	92.0	60.0	9.4	3.3	223.3	543.3
A7	104.1	71.6	12.3	4.8	236.7	483.3
A8	98.0	53.6	10.9	2.5	250.0	793.3
A9	58.3	75.2	2.5	5.4	476.7	270.0
A10	62.6	38.5	4.0	1.3	463.3	1550.0
A11	85.0	86.4	6.3	7.1	210.0	213.3
A12	86.1	51.8	8.6	2.7	233.3	686.7

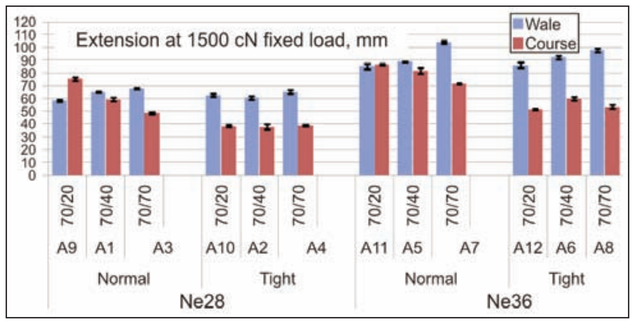

Fig. 3. Extension behaviour of the test fabrics deformed by M&S P15 A test method

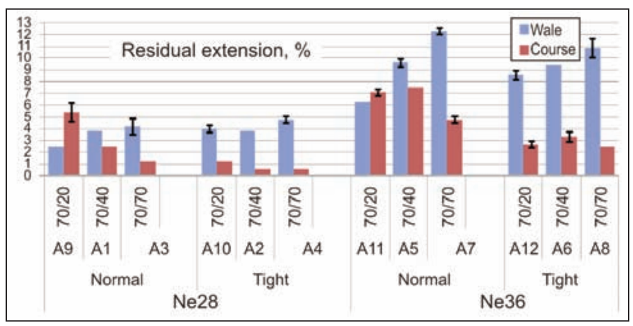

Fig. 4. Residual extension behaviour of the test fabrics deformed by M&S P15A test method

(table 5). The extension and residual extension values in course direction were separated into three groups between 70/70 (lowest) and 70/20, (highest) denier gimped yarn. In this method, whether the results were evaluated separately according to viscose yarn count or setting level, in every situation 70/40 denier gimped yarn took place in the second group amongst other gimped yarns.

Cyclic test results by pneumatic bursting tester

The cyclic test results of the test fabrics by pneumatic tester are presented in table 6 and figure 5 and 6.

Table 4

VARIANCE ANALYSIS FOR THE EFFECTS OF STRUCTURAL PARAMETERS ON M&S P15 A TEST RESULTS					
		Viscose yarn_count = Ne28		**Viscose yarn_count = Ne36**	
Source	**Dependent variable**	**F**	**Sig.**	**F**	**Sig.**
linear density of gimped yarn	Ewale (mm)	33.513	0.000	191.811	0.000
	Ecourse (mm)	193.813	0.000	74.189	0.000
	Mwale (cN)	8.608	0.005	11.583	0.002
	Mcourse (cN)	779.786	0.000	140.264	0.000
	REwale (%)	19.625	0.000	160.348	0.000
	REcourse (%)	101.189	0.000	56.758	0.000
setting	Ewale (mm)	2.202	0.164	0.547	0.474
	Ecourse (mm)	1.683E3	0.000	1.788E3	0.000
	Mwale (cN)	3.041	0.107	6.750	0.023
	Mcourse (cN)	1.753E4	0.000	879.282	0.000
	REwale (%)	18.375	0.001	1.245	0.286
	REcourse (%)	241.444	0.000	676.917	0.000
linear density of gimped yarn *setting	Ewale (mm)	18.216	0.000	18.835	0.000
	Ecourse (mm)	199.252	0.000	72.256	0.000
	Mwale (cN)	9.851	0.003	5.250	0.023
	Mcourse (cN)	771.643	0.000	32.027	0.000
	REwale (%)	7.125	0.009	33.045	0.000
	REcourse (%)	48.503	0.000	22.783	0.000

Values given in gray colour shows significant values at 95% confidence level.

Table 5

STUDENT-NEWMAN-KEULS (SNK) TEST RESULTS SHOWING THE EFFECT OF PA/ELASTANE GIMPED YARN COUNT ON THE EXTENSION PROPERTIES OF TEST FABRICS								
Main effects			**Subsets for the parameters**					
Viscose yarn	**Setting level**	**Gimped yarn denier**	**Ewale** (mm)	**Ecourse** (mm)	**Mwale** (cN)	**Mcourse** (cN)	**REwale** (%)	**REcourse** (%)
Ne 28	Normal	70/20	a	c	b	a	a	c
		70/40	b	b	a	b	b	b
		70/70	c	a	b	c	b	a
	Tight	70/20	a, b	a	a	a	a	b
		70/40	a	a	a	a	b	a
		70/70	b	a	a	b	a	a
Ne 36	Normal	70/20	a	c	a	a	a	b
		70/40	b	b	b	b	b	b
		70/70	c	a	b	c	c	a
	Tight	70/20	a	a	a, b	b	a	a
		70/40	b	b	a	a	a	b
		70/70	c	a	b	c	b	a

The average values are arranged such that the letter 'a' shows the **lowest** value and the letter 'c' shows the **highest** value **for every parameter in each subset**. Any two values not sharing a letter in common mean that they are significantly different from each other at 95% confidence level.

It can be easily seen that the distension values of all the fabrics are increasing with the increasing number of the distension cycles. Thus, the distension values between cycles were calculated in percentage and these calculated values were also compared. The lower distension values were determined for the fabrics made of Ne 28 yarn. This result is similar with the first cyclic test method M&S P15 A. Especially the effect of fabric structural parameters is more distinct when distension difference values were examined.

When figure 5 is examined, it can be said that the interaction between the factors are similar for different cycles. The fabrics produced by Ne 28 viscose yarns have lower distension values in comparison to

Table 6

DISTENSION PROPERTIES OF THE TEST FABRICS DEFORMED BY PNEUMATIC BURSTING TESTER					
Fabric code	Distension at 100 kPa pressure (mm)			Distension differences between cycles (%)	
	1 cycle	3 cycle	5 cycle	1-3 cycle	1-5 cycle
A1	47.50	49.85	50.38	4.95	6.05
A2	44.35	46.28	46.78	4.34	5.46
A3	46.25	48.58	49.08	5.02	6.10
A4	46.15	47.98	48.55	3.95	5.20
A5	54.58	57.88	58.63	6.03	7.41
A6	52.28	54.80	55.40	4.82	5.97
A7	58.05	61.05	61.85	5.16	6.54
A8	53.83	56.43	57.08	4.82	6.03
A9	44.35	46.15	46.43	4.06	4.68
A10	41.50	42.93	43.28	3.44	4.28
A11	50.75	53.53	54.03	5.46	6.45
A12	45.45	47.40	47.75	4.29	5.06

the ones produced by Ne 36 viscose yarn. The tight fabrics have lower deformation values and this situation is clearer for the fabrics having finer yarn. When linear density of gimped yarn is examined, the lowest and the highest distension values are noticed for 70/20 denier and 70/70 denier yarns respectively.
When the differences between distension cycles are considered (figure 6), it can be said that the fabrics produced by finer viscose yarn have higher values. In that case, it may be thought that these fabrics can be inflated more easily while applying the same pressure for different cycles. Firstly, more extensibility may be thought as it is an expected situation for good stretching properties. Secondly, being easily inflatable can be also thought the fabrics can be deformed easily and some of the dome-shaped deformation may be permanent. Besides, it is not possible to say something about the residual deformation in this method. For that reason, it will be necessary to pay more attention about the recovery properties while using this test method.
When variance and SNK results given in table 7 and 8 were examined for all test fabrics, it is seen that setting and linear density of gimped yarn are statistically significant factors affecting the distension values. Only the effect of course setting is not statistically significant on distension difference between 1–5 cycles. In this method, test results took place into two groups such as 70/20 (first, the lowest), 70/40 and 70/70 (second) for the fabrics produced by Ne 28 viscose yarn.
For the fabrics made of Ne 36 viscose yarn, the test results were divided into three subsets in accordance with the linear density of gimped yarn (the lowest: 70/20; the highest: 70/70). This means that the differences between these three groups are statistically significant. According to the distension difference results, the test fabrics were divided into two main groups such as 70/20 gimped yarn in the first group,

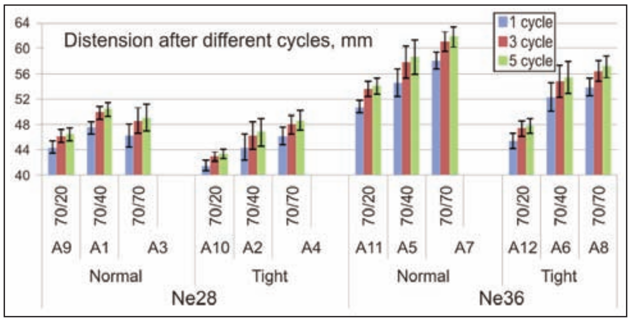

Fig. 5. Distension values for the test fabrics deformed by pneumatic bursting tester

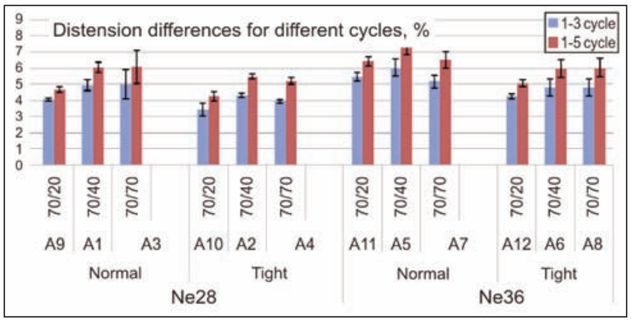

Fig. 6. Distension difference values for the test fabrics deformed by pneumatic bursting tester

70/40 and 70/70 gimped yarn took place in the same group since there was no statistical difference between these two groups.

Cyclic test results by artificial human elbow

The cyclic test results are given in table 9 and illustrated in figure 7 and 8. When bagging resistance values are examined, it can be said that even lower load values can cause bagging deformation. Besides, it is seen that bagging deformation values are changing between 2–4 mm. In general, a bagging deformation under 5mm is accepted by the customer. In that situation, it can be said that although bagging deformation was observed for the test fabrics, it may not be a problem for the customers.
It is noticeable that the highest bagging height values were determined for the fabrics having 70/20 polyamide/elastane yarn (A9-A12) while the lowest bagging height values were obtained generally for the fabrics having 70/70 gimped yarn. When the test fabrics coded as A9-A12 are examined, it is found out that these fabrics have the lowest mass per unit area and the finest gimped yarn amongst the other fabric samples.
The variance and SNK results were given in table 10 and 11. The effect of linear density of gimped yarn and setting on the bagging parameters were found statistically significant for the fabrics made of Ne 28 and Ne 36 viscose yarn (*p*<0.05). The effect of setting level was statistically significant onlyfor the fabrics made of Ne 28 viscose yarn. When fabric subsets were examined by using SNK procedure (table 11), it is seen that the bagging resistance results were separated into two subgroups such as 70/20

Table 7

VARIANCE ANALYSIS FOR THE EFFECTS OF STRUCTURAL PARAMETERS ON CYCLIC TEST RESULTS BY PNEUMATIC BURSTING TESTER					
		Viscose yarn_count = Ne28		Viscose yarn_count = Ne36	
Source	**Dependent variable**	**F**	**Sig.**	**F**	**Sig.**
linear density of gimped yarn	Distension 1 cycle	13.186	0.000	47.836	0.000
	Distension 2 cycle	15.602	0.000	41.030	0.000
	Distension 3 cycle	16.220	0.000	42.626	0.000
	Distension 1-3 cycle (%)	6.671	0.007	3.843	0.041
	Distension 1-5 cycle (%)	9.302	0.002	8.132	0.003
setting	Distension 1 cycle	12.390	0.002	34.804	0.000
	Distension 2 cycle	16.157	0.001	36.055	0.000
	Distension 3 cycle	14.484	0.001	37.105	0.000
	Distension 1-3 cycle (%)	8.708	0.009	28.146	0.000
	Distension 1-5 cycle (%)	3.006	0.100	34.543	0.000
linear density of gimped yarn *setting	Distension 1 cycle	2.823	0.086	1.725	0.206
	Distension 2 cycle	2.340	0.125	1.316	0.293
	Distension 3 cycle	2.264	0.133	1.271	0.305
	Distension 1-3 cycle (%)	0.188	0.831	2.732	0.092
	Distension 1-5 cycle (%)	0.417	0.665	2.513	0.109

Values given in gray colour shows significant values at 95% confidence level.

Table 8

STUDENT-NEWMAN-KEULS (SNK) TEST RESULTS SHOWING THE EFFECT OF PA/ELASTANE GIMPED YARN COUNT ON THE DISTENSION PROPERTIES OF TEST FABRICS							
Main effects			**Subsets for the parameters**				
Viscose yarn	**Setting level**	**Gimped yarn denier**	**1 cycle** (mm)	**3 cycle** (mm)	**5 cycle** (mm)	**1-3 cycle** (%)	**1-5 cycle** (%)
Ne 28	Normal	70/20	a	a	a	a	a
		70/40	a, b	b	b	a	b
		70/70	b	b	b	a	b
	Tight	70/20	a	a	a	a	a
		70/40	b	b	b	a	a
		70/70	b	b	b	a	a
Ne 36	Normal	70/20	a	a	a	a	a
		70/40	b	b	b	a, b	b
		70/70	c	c	c	b	a
	Tight	70/20	a	a	a	a	a
		70/40	b	b	b	a	b
		70/70	b	b	b	a	b

The average values are arranged such that the letter ‘a’ shows the **lowest** value and the letter ‘c’ shows the **highest** value **for every parameter in each subset**. Any two values not sharing a letter in common mean that they are significantly different from each other at 95% confidence level.

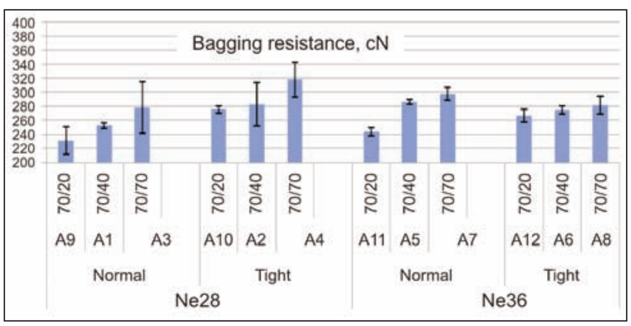

Fig. 7. Bagging resistance of the test fabrics deformed by artificial human elbow

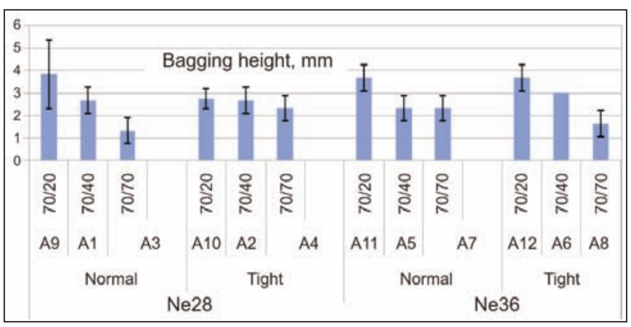

Fig. 8. Bagging height of the test fabrics deformed by artificial human elbow

Table 9

BAGGING PROPERTIES OF THE TEST FABRICS DEFORMED BY ARTIFICIAL HUMAN ELBOW		
Fabric code	**Bagging resistance (cN)**	**Bagging height (mm)**
A1	252.3	2.7
A2	282.7	2.7
A3	278.3	1.3
A4	318.0	2.3
A5	286.0	2.3
A6	274.3	3.0
A7	297.3	2.3
A8	281.7	1.7
A9	230.8	3.8
A10	275.3	2.8
A11	243.8	3.7
A12	266.9	3.7

denier gimped yarn (first subgroup, lowest) while the other two gimped yarns were in the second group. Besides, bagging height values were divided into two subsets and 70/70 denier gimped yarn has the lowest values while 70/20 and 70/70 denier gimped yarns were in the same group.

Relationship between three cyclic deformation methods

To examine the relationship between three cyclic deformation methods, correlation analyses were conducted for all test parameters used in the study. Only the significant correlation coefficients were given in table 12. It was observed that the deformation tendency is generally similar for the factors such as the yarn linear density of viscose and gimped yarn and also setting level. When table 12 were examined, it can be seen that there are positive and negative correlations between the different cyclic test methods. There are statistically significant and high correlations

Table 10

VARIANCE ANALYSIS FOR THE EFFECTS OF STRUCTURAL PARAMETERS ON BAGGING TEST RESULTS					
		Viscose yarn_count = Ne28		**Viscose yarn_count = Ne36**	
Source	**Dependent variable**	**F**	**Sig.**	**F**	**Sig.**
linear density of gimped yarn	BR (cN)	5.704	0.018	27.959	0.000
	H (mm)	5.000	0.026	15.200	0.001
setting	BR (cN)	11.730	0.005	0.130	0.725
	H (mm)	0.005	0.943	0.000	1.000
linear density of gimped yarn *setting	BR (cN)	0.139	0.872	10.225	0.003
	H (mm)	2.535	0.121	2.400	0.133

Values given in gray colour shows significant values at 95% confidence level.

Table 11

STUDENT-NEWMAN-KEULS (SNK) TEST RESULTS SHOWING THE EFFECT OF PA/ELASTANE GIMPED YARN COUNT ON THE BAGGING PROPERTIES OF TEST FABRICS				
Main effects			**Subsets for the parameters**	
Viscose yarn	**Setting level**	**Gimped yarn denier**	**Bagging resistance** (cN)	**Bagging height** (mm)
Ne 28	Normal	70/20	a	b
		70/40	a, b	a, b
		70/70	b	a
	Tight	70/20	a	b
		70/40	a, b	b
		70/70	b	a
Ne 36	Normal	70/20	a	b
		70/40	a, b	a, b
		70/70	b	a
	Tight	70/20	a	b
		70/40	a, b	b
		70/70	b	a

The average values are arranged such that the letter 'a' shows the **lowest** value and the letter 'c' shows the **highest** value **for every parameter in each subset**. Any two values not sharing a letter in common mean that they are significantly different from each other at 95% confidence level.

Table 12

CORRELATION COEFFICIENTS BETWEEN THE PARAMETERS OF THE TEST METHODS					
Parameters	Distension 1 cycle (mm)	Distension 3 cycle (mm)	Distension 5 cycle (mm)	Difference 1-3 cycle (%)	Bagging resistance (cN)
Ewale (mm)	0.877	0.878	0.871		
Ecourse (mm)		0.610	0.602	0.720	
Mwale (cN)	–0.762	–0.775	–0.774		0.573
Mcourse (cN)		–0.590	–0.579	–0.669	
REwale (%)	0.856	0.849	0.839		
REcourse (%)				0.709	

Values given in gray colour shows significant correlations at the 0.01 level (2-tailed).
Values given in white colour shows significant correlations at the 0.05 level (2-tailed).

between the parameters of vertical cyclic deformation methods (M&S P15A) and spherical cyclic deformation method (pneumatic bursting tester). It is an interesting result because although the deformation style is very different from each other, significant correlations were found. The number of the cycles is low for these two methods; this may be one of reasons. Apart from these, the results handled from artificial human elbow were quite different. It is possible to say that making different number of cycles under dynamic conditions and measurement of the deformation values of these fabrics may be more realistic instead of two or five deformation cycles at any direction. Besides as seen in figure 2, it is possible to see the simulated appearance by artificial human elbow method.

CONCLUSION

In the present study, three different test methods were used to compare the deformation properties of sportswear fabrics. Thus, 12 knitted fabrics were produced according to the customer demands by using two different base yarn linear density (Ne 28 viscose, Ne 36 viscose), two different settings (normal, tight) and three different polyamide/elastane gimped yarn denier (70/20, 70/40, 70/70). Three different test methods were used and comparisons were made.

Generally, it was found out that the test fabrics having Ne 28 viscose yarn have less deformation values in comparison to the fabrics having Ne 36 viscose yarn. Also the setting level examined in the present study was found out statistically significant and tight fabrics especially produced by Ne 28 yarns have generally shown less extension and residual extension. Generally, it can be said that the effects of structural parameters such as linear density of gimped yarn and setting were found statistically significant at 95% confidence level for many of the test fabrics. When the results of correlation analysis were reviewed, it is seen that there are positive and negative correlations between the parameters of different test methods.

Consequently, there are some similarities and differences between the results obtained by using different test methods. For any kind of test methods, it can be said that it may be preferable to use 70/40 denier gimped yarn because of its consistent test results amongst the other gimped yarns. Generally the fabrics having 70/40 denier gimped yarn were taken in the middle subgroup when the test results were examined according to deformation values. Besides, Ne 28 viscose yarn and tight setting may also be preferable for the production of these kinds of fabrics when all the test results have been reviewed.

To produce a suitable fabric or a garment according to customer demands is very important thus to predict the performance of textile products is crucial. When the clothing fabric is the topic, examination of deformation or shape retention is one of the major properties. Researches examining the effect of structural parameters on deformation characteristics by comparing the results of different test methods may provide a better reliable solution to evaluate fabric properties. Besides, by making these kinds of researches, it will be possible to find out the willing stretching and recovery properties of sports fabrics. From this point of view, the current research may be useful to choose the test method which is more suitable with the customers' demands.

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Flax, hemp and cotton plants in Romania – a study for reconsideration of the textile industry

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REZUMAT – ABSTRACT

Inul, cânepa şi bumbacul în România – studiu pentru reconsiderarea industriei textile

În ultimul timp, se manifestă fenomene climatice intense care, pentru agricultură, înseamnă recurgerea la schimbări în structura culturilor. Un asemenea demers presupune selecția culturilor după criteriul condițiilor naturale, acesta fiind primul din mulțimea factorilor care influențează deciziile în utilizarea terenurilor agricole. Procesul este însă de mare amploare, ceea ce denotă participarea şi a altor criterii la luarea deciziilor. Printre acestea regăsim criteriul economic, adică măsura în care produsele rezultate din culturi sunt cerute pe piață, fie pentru consum alimentar sau pentru industria de procesare, prețurile practicate, pentru a asigura un anumit nivel al eficienței economice pentru producători, dar şi elemente care țin de pârghiile financiare de susținere a unor culturi, tradiție şi competențe distinctive, posibilități de achizitionare a factorilor de producție. Lucrarea promovează reconsiderarea inului, cânepei şi bumbacului, datorită relevanței lor pentru industria textilă, pe de o parte, şi pentru punerea în valoare a zonelor de favorabilitate şi consolidarea bazei genetice a speciilor în institute de cercetare, pe de altă parte. Obiectivul fundamental al studiului îl constituie elaborarea celor mai bune combinări ale plantelor textile în raport cu alte culturi şi determinarea nivelului de eficiență economică.

Cuvinte-cheie: plante textile, rotația culturilor, analize, eficiență economică

Flax, hemp and cotton plants in Romania – a study for reconsideration of the textile industry

Lately, intense agricultural climate events are manifested, which means changes in crop structure. Such an approach involves crop selection depending on natural conditions; this is the first of the set of factors that influence decisions in agricultural land use. The process is, however, large-scale, denoting participation of other criteria when making decisions. Among them we find the economic criterion, i.e. the extent to which the products of crops are required in the market, either for food consumption or the processing industry, the prices, to ensure a certain level of economic efficiency for manufacturers, but also elements of financial leverage supportive of culture, tradition and competent distinctive possibilities of purchasing inputs. The paper promotes reconsidering of flax, hemp and cotton, due to their relevance for the textile industry, on the one hand, and for valuing the favorability areas and strengthening the genetic basis of species in research institutes, on the other hand. The fundamental objective of the study is the development of the best combinations of textile plants in relation to other crops and determining the level of economic efficiency.

Keywords: textile plants, crops rotation, analysis, economic efficiency

INTRODUCTION

Romania has a great agropedoclimatic potential to grow plants from cereals to fodder and textiles. The advantages of the Romanian agriculture are that resources are available to develop these crops and provide the necessary products for processing industries in order to increase the added value nationwide. In this context the flax, hemp and cotton textile plants are known to be suitable for these environmental resources, found in the geographical center of Romania, in the Eastern, Northern and from the Southern limit. Seeds of these plants are rich and are used in food consumption and processing industry where oils are obtained with multiple destinations. Also, textile fibers resulted from processing represent raw material base of the textile industry. In the period 1957–2006 (INCDA Fundulea (vol. LXXV, 2007)), there were included 16 varieties for flax, 4 varieties of hemp and 1 variety for cotton. So, the total of varieties is 21. The flax is used for oil and fiber. Fiber shows strength and durability, including high humidity, which means that it has resistance to rotting, has silky luster and fine, is conductive of heat and also hygroscopic. These characteristics make that flax to contribute to durable and pleasant textile products. Lately, natural and synthetic textile fibers were used. Synthetic fibers are improper because they are flammable and favor perspiration. Strain is used entirely in order to obtain short textile fibers – tow and waste. Also, from flax seeds oil is obtained to be used in industry, and residues which are used in animal feed or for papermaking [1].

The hemp is used in the textile industry as fiber for technical products. Hemp products are biodegradable 100%, also recyclable and reusable. The hemp seed contributes to oils for cosmetics and active ingredients from leaf are used in the pharmaceutical industry. The hemp is an agricultural product which is characterized by great rapidity of growth, which creates benefits of primary resources for the final

Table 1

ECONOMIC IMPORTANCE OF TEXTILE PLANTS			
Product	**Use**	**Characteristics**	**Observation**
Fiber	Textile industry	Flax fiber: resistance to tearing and rotting; silky luster; good heat conductivity	Fiber derived from: – strain: flax and hemp – seed: cotton
Tow	Flax: paper for cigarette; rough fabrics; phonic and thermal insulation materials		
	Hemp: insulating material (acoustic and thermal automotive industry and housing), boards for furniture, bedding for animals (absorbs smell of urine)		
Waste	Flax: fodder		
	Hemp: mushrooms fertilizer		Waste hemp is more important than manure (3-4 time)
Leaf	Hemp: fodder, pharmaceutical industry, tea		
	Cotton: organics acids		
Seed	Oil (comestible and industrial), fodder and pharmaceutical industry		

Table 2

TECHNICAL CHARACTERISTICS OF NATURAL FIBERS [1]								
Fiber	**Count** (Nm)	**Density** (g/cm^3)	**Length** (mm)		**Thickness** (mm)		**Tenacity** (cN/tex)	**Breaking elongation** (%)
			Medium	**Maximum**	**Medium**	**Maximum**		
Flax	3500–8000	1,50	17–20	125–130	7–20	40	54	3,0
Hemp	3000–5000	1,48	15–25	65	14–22	50	47	2,2
Cotton	3000–9000	1,52–1,54	25–35	60	18–20	25	45–19	6,8

product. Also, research shows usefulness of hemp for obtaining paper and positively impact on the environment. It is estimated that on an area of 0.4 ha hemp is obtained the same quantity of paper as the 1.6 ha of forest. It also can be recycled cotton paper by 7 or 8 times, while the wood obtained from 3 times [2].

The cotton has a smooth and elastic fiber and is suitable to coloring, and enters in competition with artificial or synthetic fibers. Cotton fiber is one of the most important raw materials that are processed in the textile industry. All mentioned reflect the relevance of flax, hemp and cotton in the economic circuit (table 1).

Textile fibers from flax, hemp and cotton have characteristics related to smoothness, density, thickness, toughness and elongation. All these have been identified and measured by researchers (table 2).

Technical features of natural fibers show that each indicator is representative in terms of industrial usefulness. Also, the values of indicators for each of plants studied show technology of processing.

MATERIAL AND METHOD

Flax, hemp and cotton plants were traditional plants in Romania. Lately these plants were becoming less and less in production structure of Romania. In terms of territorial areas, flax, hemp and cotton occupied large areas in Romania. As a complex, in terms of productive areas, geographical location, delimitation and characterization are based on knowledge of all economic and natural factors: climate, determined by

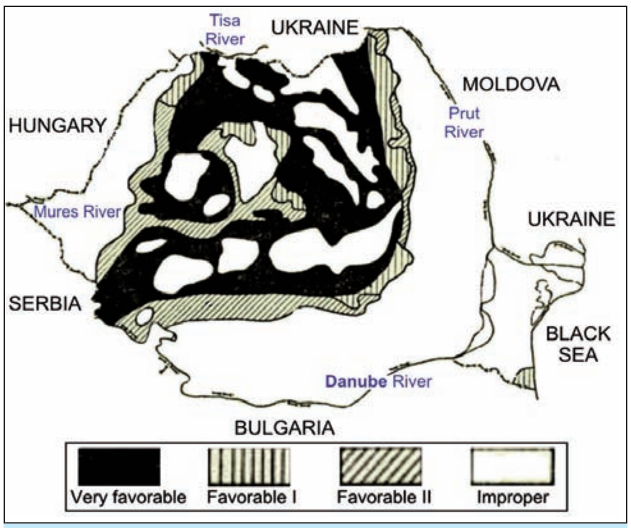
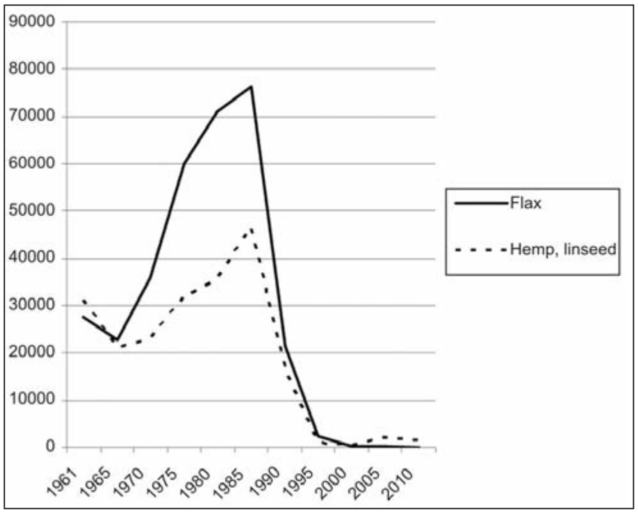


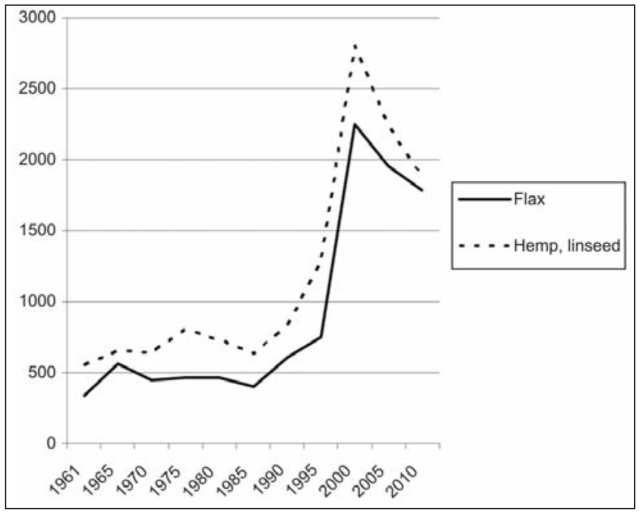
Fig. 1. Flax ecological area in Romania [2]

temperature and precipitation; soil conditions, orography of the land and its fertility, the demand towards the products. Flax was grown with fluctuating results in Harghita, Satu Mare, Suceava, Neamț, Braşov, Covasna, Maramureş, Bihor, Sălaj, Prahova, where this species found favorable condition (figure 1).

Flax fiber has specific water consumption, between 400 and 1000 mm. As shown in figure 2, intra-mountain and extra-mountain depressions are favorable for flax fiber, where there is a rate of 220–250 mm rainfall during the growing season and temperature not exceeding 17°C.



a



b

Fig. 2. Statistics of flax, hemp and cotton in Romania: *a* – area cultivated, ha; *b* – average production, kg/ha

Muntean et al. [3], shows favorability of specific area on the ground by removing the mountain range, while decreasing it in terms of climate. Hemp has favorable conditions in Timiş, Mureş, Transilvania (Someş, Mureş and Târnave) and Moldova (Siret Plain and the River Moldova) and brown soils of Plateau Getic and Romanian Plain North. Cotton can be placed along the Danube (20–40 km) from Mehedinți up in Ialomița and the South-West of Constanța. In terms of area, flax, hemp and cotton had significant agricultural land in the world, in Europe and Romania. Statistics show, for example that in 1977 [4], 1514 million hectares were cultivated of which 98% in Europe. Regarding the production of fiber, ranged from 345 kg/ha in 1961–1965 to 430 kg/ha during 1972–1976 and 459 kg/ha in 1977. In 1977, in Romanian agriculture, flax plant for fiber was cultivated on 65000 ha, and average production was of 462 kg of fiber/ha (less than global average, but above the European average with 8 kg).

In Romanian agriculture, the flax area and strains production greatly were reduced with the 100 ha and 100 t/ha in 2007 (National Institute of Statistics). As regards cotton, this plant no longer grows since 2000. The highest production was recorded in 1985 with 1260 tons and the lowest in 1962 with 4 tons, in 1999 with 6 tons and in 1995 with 7 tons. According to FAOSTAT, textile plants were analyzed starting 1961.

In terms of crop rotation, the three textile plants are influenced by various factors. For this reason, flax, hemp and cotton do not come in rotation with each other. It is important to know the phenomenon of "fatigue of soil" determined by flax. In this condition, flax is cultivated on the same soil after a period of 6 years (table 3). Hemp and cotton should follow best preceding species. Maize was failed, because of conventional technique (the use of herbicides).

Romanian research has led not only to the appropriate area for textile plants, but also to create varieties that find favorable conditions. Muntean et al. lists 25 varieties of flax that can be cultivated in Romania and recommends combining favorable conditions with the appropriate technology for an average productions between 4500 and 8000 kg/ha, respectively production of flax fibers between 1480 and 4256 kg/ha (table 4) [3, 7].

As a result of Romanian research, hemp and cotton produce an important quantity of fiber (table 5 and table 6). Hemp has the largest capacity for processing and production of fiber represents 55% of the total quantity of dried strains.

Romanian hemp is important for industry, which stimulated research in this field. Since 2007 new varieties of hemp were approved. Important Institutes for Research and Development such as S.C.D.A. Lovrin, S.C.D.A. Secuieni [5–6] created varieties of hemp which have been obtained high production per hectare, some varieties being tested by the Institute for Testing and Registration. S.C.D.A. created Lovrin 110 dioica variety of hemp and hemp dioica new variety approved in 2007, Silvana, plus new line of hemp

Table 3

CROP ROTATION OF TEXTILE PLANTS		
Before ←	**Species**	**→ After**
Autumn wheat, vegetables, mash	flax	all species except potato and sugar beet
Clover, alfalfa, potatoes, sugar beet, legumes	hemp	all species except sunflower and tobacco plant
Sugar beet, sunflower, tobacco plant, cereals, legumes	cotton	all spring crops

Table 4

FLAX PRODUCTION, kg/ha						
Production (kg/ha)	by which					
	70% dried strains				10% seeds	20% waste
	Dried strains (kg)	of which				
		fibers	flax	tow		
		14–27%	47–76%	60–24%		
4500	3150	441–850	1480–2394	1890–756	450	900
8000	5600	784–1512	2632–4256	3360–1344	800	1600

Table 5

HEMP PRODUCTION, kg/ha						
Production (kg/ha)	by which					
	60–65% dried strains				10–12% seeds	25–30% waste
	Dried strains (kg)	of which				
		55% fiber	of which			
			hemp	tow		
			60%	40%		
10000	6000–6500	3300–3575	1980–2145	1320–1430	1000	2500
12000	7200–7800	3960–4290	2376–2574	1584–1716	1440	3600

Table 6

HEMP VARIETIES APPROVED AT S.C.D.A. SECUIENI – NEAMȚ [5]			
Species	**Productivity**		
	Strains (tones/ha)	**Fiber**	**Seed** (kg/ha)
Secuieni Jubileu	5,2–7,2	26–29%	900–1200
Zenit	8–9	25–26%	900–1200
Diana	829	2,611 t/ha	773
SF-200	9,475	3,04 t/ha	1043

Table 7

FINANCIAL SUPPORT FOR HEMP				
Year	**Proposal**	**Direct payment to the surface**	**Transitional National Support**	**Total financial support**
	euro/ha			
2016	204	136	17	357
2017	214	139	16	369
2018	224	141	15	380
2019	234	143	13	390
2020	240	143	13	396

dioica Lovrin 202. In the period 2008–2009, experimental productions of hemp strains ranged from 5 tones/ha created by Secuieni to 14 tones/ha to varieties Hungary 139 and Zakarpatie 127 (14722 kg/ha). The species Silvana and Lovrin 110 had productions ranging from 11667 kg/ha and 13333 kg/ha, respectively 12500 kg/ha to 15000 kg/ha.

Table 8

COTTON FIBER [7]				
Variety	**Average production** (kg/ha)	**Weight** (g)	**Fiber**	
			%	kg/ha
Chirpan-539	2274	26,3	39,6	900,5
Dorina	2126	28,1	41,0	871,66

Starting from the utility and economic benefits that hemp offers it is needed to reconsider this sector. For this, there are proposals for financial support in the period 2016–2020 and legislation (Ministry of Agriculture, Forests and Rural Development). The increase of hemp will be done under the law and under the approval of the Department for Agriculture and Rural Development (table 7). Also, the utility and economic benefits and demand are found in flax processing. It is estimated that for the period 2020–2030 the number of processing units will increase compared to 2012 (from 2 units in year 2012 to 3 units in year 2020 and 5 processing units in year 2030).

Regarding cotton production (table 8), the average production is between 2126 kg and 2274 kg. Cotton fiber represents 41% of total production.

Analysis of the flax, hemp and cotton shows differences at the level production and content of fiber. The flax production is between 4500–8000 kg/ha, to hemp production is between 10000–12000 kg/ha and cotton is about 2,300 kg/ha. Also, the quantity of fiber is different from 27% for flax to 55% for hemp and 41% for cotton. Flax, hemp and cotton differ because

Table 9

TECHNOLOGICAL DIAGRAM				
Activity	**Specification**	**Species**		
		Flax	**Hemp**	**Cotton**
Work soil	Time/period	Autumn	Autumn	Autumn
		Spring	Spring	Spring
Fertilization	N:P:K	1:2:3	1:03:0.5	1:0.5:1
Sowing	Spring, T°C	2–3	8–9	12
	Rows spacing	unploughed	unploughed	ploughed
	Density	2400 seeds/m^2	450 seeds/m^2	240 thousands plants/ha
	Seed quantity, kg/ha	85–100 (MMB = 4,1–8,7 g)	85–95 (MMB = 15–25 g)	25–30 (MMB = 60–170 g)
Crop care work	Combating weeds	herbicides	herbicides	herbicides/hoeing
	Combating disease	fungicides	fungicides	fungicides
	Combating pests	insecticides	insecticides	insecticides
	Irrigation	Yes	Yes	Yes
	Other	No	No	Transected
Harvest	Mechanized/ manual	Yes	Yes	Yes
	Time	July/ August	The last decade of August	The last decade of September
Expenditures, Euro/ha		500–600	500–600	1000–1200

of production system, namely in terms of subsystems technological and economic (table 9).

RESULTS AND DISCUSSIONS

The analysis of data and increasing of requirement for textile plants make the reconsideration of agricultural field necessary. Starting from these, this section presents a case study about rotation of flax, hemp and cotton plants in correlation with other crops and a case study about textile plants economic efficiency. The first proposition is developed on three matrixes, taking into consideration the technological and economic correlation between crops.

The flax matrix contents crops such as maize, barley, wheat and mash (table 10). The crops rotation is for eight years and seven plot of land. It can observe that flax is cultivated before maize and barley, also after wheat.

The hemp crop rotation is constituted for a period of six years and six plots (table 11). Crop rotation includes hemp, wheat, peas, sugar beet, potatoes and alfalfa. In the first year the crops rotation contents hemp, sugar beet, wheat and potatoes. Hemp is grown on the same plot in the 5th year.

It is visible that crop rotation includes 6 years and 5 plots (table 12). The cotton can be combined with sunflower, wheat, peas, alfalfa and spring barley. The cotton may be grown after sunflower. Also, after cotton may be cultivated spring barley and alfalfa.

Elaboration of the three matrixes was made for the knowledge of the connection between crops and their sequence on the plot. In this way, the best ratio between the basic crops and preceding ones is ensured (table 13).

Table 10

FLAX MATRIX							
Plot Year	I	II	III	IV	V	VI	VII
I	**Flax**	Wheat	Barley	Maize	Maize	Mash	Maize
II	Maize	**Flax**	Wheat	Maize	Mash	Barley	Maize
III	Mash	Maize	**Flax**	Wheat	Maize	Maize	Barley
IV	Barley	Mash	Maize	**Flax**	Wheat	Maize	Wheat
V	Maize	Maize	Mash	Barley	**Flax**	Wheat	Maize
VI	Maize	Barley	Maize	Maize	Maize	**Flax**	Mash
VII	Wheat	Maize	Maize	Mash	Barley	Maize	**Flax**
VIII	**Flax**	Wheat	Barley	Maize	Maize	Mash	Maize

Table 11

HEMP MATRIX						
Plot Year	I	II	III	IV	V	VI
I	**Hemp**	Alfalfa	Sugar beet	Wheat	Potatoes	Wheat
II	Wheat	Alfalfa	**Hemp**	Sugar beet	Wheat	Potatoes
III	Pease	Alfalfa	Alfalfa	**Hemp**	Sugar beet	**Hemp**
IV	Sugar beet	Alfalfa	Alfalfa	Wheat	**Hemp**	Pease
V	**Hemp**	Sugar beet	Alfalfa	Pease	Wheat	Sugar beet
VI	Wheat	**Hemp**	Alfalfa	Potatoes	Pease	**Hemp**

Table 12

HEMP MATRIX					
Plot Year	I	II	III	IV	V
I	Sunflower	Wheat	Pease	Wheat	**Cotton**
II	**Cotton**	Sunflower	Wheat	Pease	Alfalfa
III	Spring barley	**Cotton**	Sunflower	Wheat	Alfalfa
IV	Pease	Spring barley	**Cotton**	Sunflower	Alfalfa
V	Wheat	Pease	Spring barley	**Cotton**	Alfalfa
VI	Wheat	Wheat	Wheat	Spring barley	Sunflower

Table 13

<table>
<tr><th colspan="11">COMPARATIVE ECONOMIC ANALISYS OF THE TEXTILE PLANTS</th></tr>
<tr><th rowspan="2">Species</th><th colspan="10">Indicators</th></tr>
<tr><th colspan="2">Average production (kg/ha)</th><th colspan="4">Fibers production (kg/ha)</th><th>Expenditure (Euro/ha)</th><th>Incomes (Euro/ha)</th><th>Profit (Euro/ha)</th><th>Rate of profit (%)</th></tr>
<tr><td rowspan="3">Flax</td><td>Min.</td><td>Max.</td><td colspan="2">4500</td><td colspan="2">8000</td><td rowspan="3">600</td><td rowspan="3">750</td><td rowspan="3">150</td><td rowspan="3">25,0</td></tr>
<tr><td rowspan="2">4500</td><td rowspan="2">8000</td><td>Min.</td><td>Max.</td><td>Min.</td><td>Max.</td></tr>
<tr><td>441</td><td>850</td><td>784</td><td>1512</td></tr>
<tr><td rowspan="3">Hemp</td><td>Min.</td><td>Max.</td><td colspan="2">10000</td><td colspan="2">12000</td><td rowspan="3">600</td><td rowspan="3">800</td><td rowspan="3">200</td><td rowspan="3">33,3</td></tr>
<tr><td rowspan="2">10000</td><td rowspan="2">12000</td><td>Min.</td><td>Max.</td><td>Min.</td><td>Max.</td></tr>
<tr><td>3300</td><td>3575</td><td>3960</td><td>4290</td></tr>
<tr><td>Cotton</td><td>Min.</td><td>Max.</td><td colspan="2">2126</td><td colspan="2">2274</td><td>1200</td><td>1400</td><td>200</td><td>16,6</td></tr>
</table>

The rate of profit is an indicator that expresses the economic efficiency of the three plants. The rate of profit is influenced by the size of the total production costs and, in particular, by those variables costs that increase in proportion to the respective activity. Variable costs have impact mainly through some costs, such as seed, labor and mechanical works. To determine the profit rate total expenditure, total incomes and profit were taken into account. The maximum expenditures per hectare to flax are 600 euros, 600 euros from hemp and 1200 from cotton. The incomes from the three plants are different. The incomes from flax are 750 euros per hectare, 800 euros from hemp, and 1400 euros from cotton. The minimum selling price per kilogram is 0.16 euro from flax, 0.08 euro hemp and 0.65 euro from cotton. Considering these data, profit per hectare is 150 euros from flax, 450 from hemp and 200 euro from cotton. The profit rate was calculated as the ratio between profit and expenditures. The rate of profit from flax is 25.0% and from hemp and cotton is 33.3%, respective 16.6%.

CONCLUSIONS

The paper has considered studying textile plants, flax, hemp and cotton in order to reintroduce them in the Romanian agriculture. It was found that Romania has an average level of competitiveness because of disadvantages of availabilities of raw materials from own production. The need for these crops is for their importance to the textile industry. For this purpose, data and information on the ecological area of these plants, technology practiced, average production, total expenditure and total incomes were used. It was found that ecological conditions in Romania allow the cultivation of flax, hemp and cotton. In terms of average production per hectare were found differences. The average production of flax is between 4500–8000 kg/ha, hemp production is between 10000–12000 kg/ha, and the average cotton production is between 2126–2274 kg/ha. Also, differences are found in the amount of fiber. The largest amount of fiber is obtained from the hemp (55%). The amount of fiber flax is 27% of average production and the cotton fiber is 41%. It was resulted from the case studies that flax is associated in rotation with maize, barley, wheat and mash. The hemp is associated with wheat, peas, sugar beet, potatoes and alfalfa. Regarding cotton, crop rotation includes sunflower, wheat, peas, alfalfa and spring barley. The economic analysis of flax, hemp and cotton showed that the highest efficiency was recorded at hemp (33.3%), then at flax (25.0%). As regards cotton, it was found that the profit rate is 16.6%, which means the lowest value of textile plants analyzed.

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Improved properties of wool on sheepskins by low pressure plasma treatment

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REZUMAT – ABSTRACT

Îmbunătățirea proprietăților blănurilor de ovine prin tratarea cu plasmă la presiune joasă

Lucrarea prezintă experimentările privind tratarea blănurilor de ovine cu plasmă la presiune joasă în atmosferă de hexafluoropropan şi îmbunatățirea proprietăților de hidrofilie ale cheratinei şi colagenului. Pre-tratarea pieilor de ovine cu plasmă la presiune joasă permite obținerea blănurilor cu capacitate îmbunătățită de absorbție a apei, vopsire în culori mai vii şi obținerea unui grad de moliciune mai mare. Rezultatele sugerează posibilitatea reducerii consumului de materiale pentru denaturarea, vopsirea sau ungerea cheratinei, cu efecte de mediu semnificative. Identificarea unei cantități mai mici de sulf în stratul superficial de lână confirmă efectul de denaturare datorită tratamentului cu plasmă la presiune joasă. Prezența atmosferei de hexafluoropropan în mediu de tratare nu a modificat proprietățile hidrofile ale blănurilor de ovine, denaturarea prin oxidare a lânii a constituit cel mai important efect pentru îmbunătățirea capacității de absorbție a apei.

Cuvinte-cheie: plasmă de joasă presiune, blănuri ovine, cheratină, absorbție de apă

Improved properties of wool on sheepskins by low pressure plasma treatment

The paper presents the experimental treatment of wool on sheepskins with plasma at low pressure in hexafluoropropane atmosphere and the improvement of keratin and collagen hydrophilic properties. Pre-treatment of sheepskins with low pressure plasma treatment allows obtaining sheepskins with a higher water absorption capacity, dyed in more vivid colors and with greater softness. The results suggest the possibility of reducing material consumption for keratin denaturation, dyeing and fatliquoring, with significant environmental effects. Identification of smaller amounts of sulphur in the surface layers of treated wool confirms the denaturation effect using low pressure plasma treatment. The presence of hexafluoropropane atmosphere in experimental conditions does not change the hydrophilic properties of sheepskins, and erosion by oxidation of wool is more important, with effects on increasing water absorption capacity.

Keywords: low pressure plasma, sheepskins, keratin, water absorption

INTRODUCTION

In recent years low pressure plasma technology has been improved to achieve polymerization of monomers on materials, depositing real nanocoatings on the surface, and adding new and permanent functionalities to the material. Atmospheric-pressure dielectric barrier discharge (DBD) cold plasma was employed to prepare catalysts [1]. In-package cold plasma processing is highly desirable in the food and biomedical industries as it allows for efficient sterilization and prevents against post-packaging contamination [2–3]. Cold plasma seemed to be a promising and convenient strategy of preventing the early adherence of *Candida albicans* on acrylic resins, which would greatly benefit potential dental applications [4]. Physical mechanisms of the interaction of cold plasmas with organic surfaces are very much discussed in literature [5]. Surface preparation and modification has gained an enormous interest in the last decennia and new applications have been discovered [6–7]. It is a completely different approach to modify only the surface properties without changing the bulk properties. This delivers new materials with new possibilities, which opens perspectives to resolve production or design problems or even develop completely new applications.

The low pressure plasma technology is such an alternative where the surface is modified at the microscopic level in a dry, environmentally friendly and cost-efficient way, without manual operations or the use of chemical products.

Moreover, low pressure plasma technology has been improved to achieve increased reactivity in flame resistance treatment of wood or reduced shrinkage of dyed and finished wool [8–11]. Other applications for leather dyeing showed that in argon atmosphere the acid dyeing can be performed with better dry and wet rubbing resistance and suggest the possibility of reducing dying auxiliaries [12]. The application of cold plasma for wool on sheepskins was reported also for improving pigment based dyeing or for wool bleaching [13–14].

The paper presents the treatment of wool on sheepskins with low pressure plasma, and the influence on dyeing, softness and water absorption properties.

EXPERIMENTAL WORK

Methods of investigation

Sheepskins tanned with basic chromium salts with an area of 21 cm × 70 cm were treated in hexafluoropropane atmosphere, at low pressure, for 3 minutes using a gas plasma installation CD400 manufactured by EUROPLASMA Belgium (figure 1).

Sheepskins treated with plasma at low pressure were analyzed in terms of their resistance to water drop (ISO 15700:998), water absorption ability (EN ISO 5403:2003) and softness (EN 17235:2002). These properties are related to the ability of sheepskin surface (wool cover-keratin cuticle and the dermal layer–collagen structure) to be reactivated under low pressure plasma. In order to understand the mechanism of activation of keratin surface a series of treated and untreated sheepskins were analyzed by SEM-EDX technique (FEI Quanta 200).

Fig. 1. Gas plasma CD400 Roll-to-roll installation

Reactivation of keratin was assessed through dyeing tests in 2 different concentrations of acid dye, with 0.2 g/L and 0.5 g/L Sell acid blue PF, according to the technology described below. The color modification of wool was assessed by using DATA Color Check Plus II portable device assisted by CIELab color management software.

Technology for wool on sheepskins dyeing

Wool on sheepskins pre-treated with low pressure plasma (P_H) and untreated (M-Control samples) were dyed using the technology presented in table 1.

RESULTS AND DISCUSSIONS

Analysis of the absorption capacity of water on the surface and inside the dermis of sheepskins tanned with basic chromium salts and treated with plasma at low pressure in hexafluoropropane atmosphere indicated an increase in surface hydrophilicity (figure 2), and the water droplet penetration time was 30 seconds compared to 50 seconds for untreated sheepskins. After 2 hours of water immersion, absorption ability of treated sheepskins increases by 168% compared to the untreated ones (figure 3).

Analysis of water absorption ability of sheepskins treated with plasma at low pressure indicates that treatment induces a reactivation of the hydrophilic groups of keratin, which suggests the possibility of reducing both surfactants used in rewetting, and dyes or fat liquoring agents.

Analysis of sheepskins dyed with two dye concentrations and pre-treated with plasma in hexafluoropropane atmosphere indicates differences in lightness between samples and controls in favor of the samples (figure 4) comparable to other similar tests

Table 1

Process in Faloppi drum	**Quantity** (g/L)	**Chemical product**	**Temperature** (°C)	**Time** (min) **pH**
Wetting	2000	water	40	
	0.5	**Borron SE**		60
Drain				
Wool denaturation	2000	water	40	
	1.5	Na_2CO_3		
	1	**Borron SE**		60
Drain and wash		water	65	10
Wool dye	2000	water	65	
	1	**Invaderm AL**		
	0.5	**INVADERM P**		10
	0.5	Formic acid (1:10)		20
Control				pH = 3.6
	0.2/0.5	**Sellacid blue PF**		60
Fixing	1	Formic acid (1:10)		30
Drain and wash			25	10
Rest for 24 hours. Free drying. Sawdust milling and degreasing. Staking. Wool ironing.				

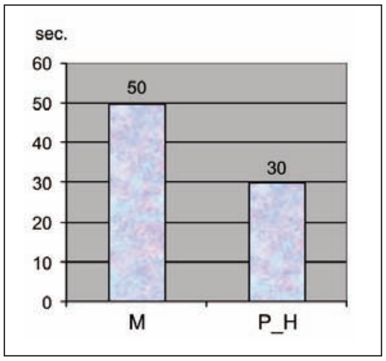

Fig. 2. Time of water penetration for dermis of chromium tanned wool on sheepskin

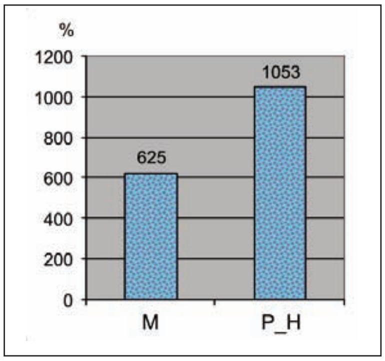

Fig. 3. Water absorption after 2h of immersion of chromium tanned wool on sheepskin

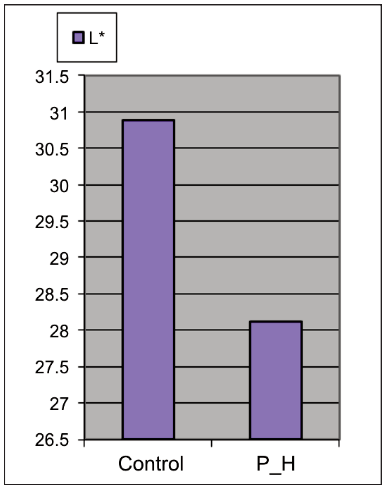

Fig. 4. Lightness of wool dyed and pre-treated with low pressure plasma

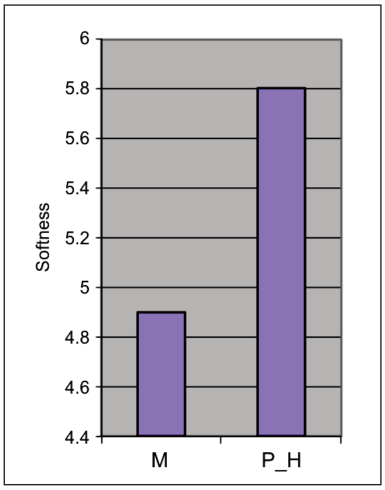

Fig. 5. Softness of sheepskins pre-treated with low pressure plasma

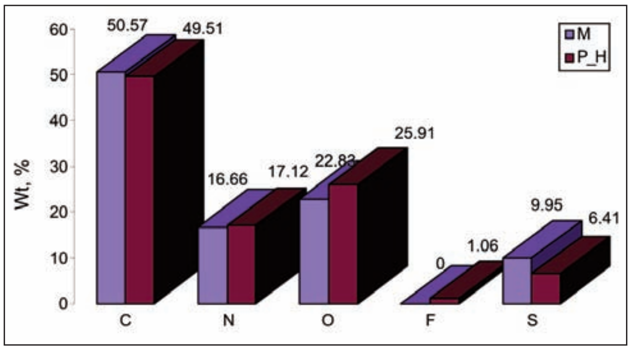

Fig. 6. Surface elemental analysis of the wool yarn treated and untreated with plasma at low pressure

performed on leathers [5]. The softness of sheepskin dermis improved considerably, from the value of 4.9 to 5.8, as figure 5 shows.

The mechanism of activation of the keratin surface by low pressure plasma treatment was identified by SEM-EDX structural analysis (table 2).

This analysis allowed the identification of a shallow structure with many asperities, more eroded compared with untreated wool, a concentration less than S, of 64.4% in comparison with untreated control (figure 6). The presence of oxygen in a higher amount by 3% in the pre-treated sample suggests a number of oxidative effects that occur as a result of plasma action. The presence of 1% F in keratin did not lead to a change in the hydrophobicity of wool, oxidative and corrosive processes seem more important, with an effect in increasing the absorption capacity of water and affinity for dye.

CONCLUSION

Pre-treatment of sheepskins with low pressure plasma allows obtaining sheepskins with a higher water absorption capacity (168% compared to the untreated ones), dyed in more vivid colors and with greater softness (from 4.9 to 5.8). The results suggest the possibility of reducing material consumption for keratin denaturation, dyeing and fat liquoring, with significant environmental effects. Identification of smaller amounts of sulphur by 64.4% in the surface layers of treated wool confirms the denaturation effect using low pressure plasma. The presence of hexafluoropropane atmosphere in experimental conditions does not change the hydrophilic properties of sheepskins, and erosion by oxidation of wool (3% more oxygen in the composition of pre-treated wool) was more important, with effects on increasing water absorption capacity.

Acknowledgements

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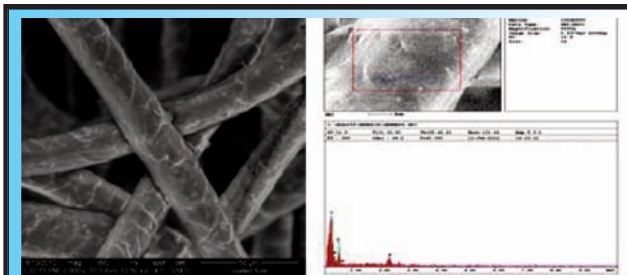
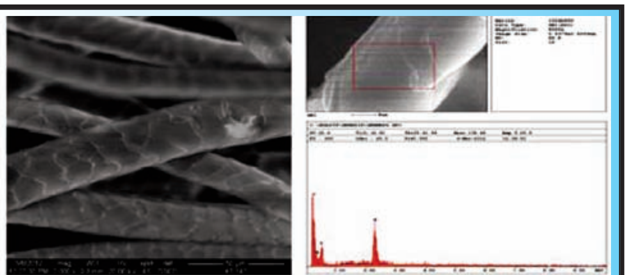
Table 2



Wool treated with low pressure plasma



Untreated wool

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Effects of spinning technology on denim fabric performance

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REZUMAT – ABSTRACT

Efectele tehnologiei de filare asupra performanței țesăturilor denim

Scopul acestui studiu este de a investiga efectele tehnologiei de filare a firelor asupra performanței țesăturilor denim. În acest scop, au fost realizate cinci probe diferite de 100% bumbac Ne 16/1 cu tehnologii diferite de filare, și anume: tehnologia de filare cu inele a firelor pieptănate, compacte, tip sirospun, filate pe maşini OE cu rotor si a celor filate vortex. Probele de țesătură denim au fost țesute prin utilizarea acestor mostre de fire numai în direcția bătăturii. Proprietățile de rezistență la rupere, rezistență la sfâșiere, rezistență la abraziune, rigiditate și rezistență la întindere a probelor de țesătură denim au fost testate. Pentru a înțelege importanța statistică a tehnologiei de filare asupra performanței țesăturii denim, s-a efectuat o analiză unică de varianță (ANOVA). S-a observat că firele produse prin tehnologii de filare diferite influențează performanțele țesăturii în mod semnificativ.

Cuvinte-cheie: performanța țesăturii, tehnologia de filare, proprietățile firului, țesătură denim

Effects of spinning technology on denim fabric performance

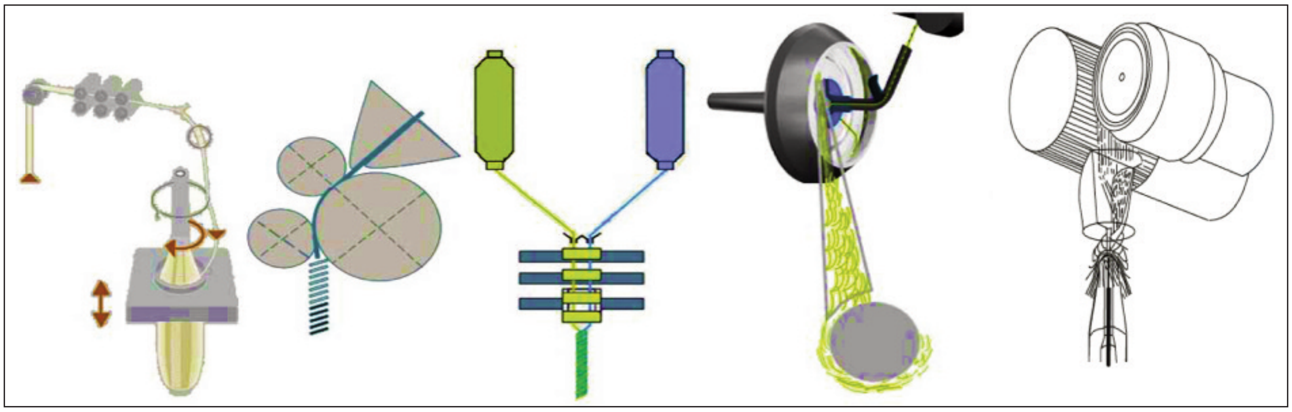
In this study it is intended to investigate the effects of yarn spinning technology on denim fabric performance. For this aim five different 100% Cotton Ne 16/1 yarn samples were produced with different spinning technologies namely; combed ring, compact, sirospun, Open-End (OE) rotor and vortex. Then denim fabric samples were woven by using these samples yarns only in weft direction. Breaking strength, tear strength, abrasion resistance, stiffness and stretch properties of denim fabric samples were tested. In order to understand the statistical importance of the spinning technology on denim fabric performance, one-way analysis of variance (ANOVA) was performed. Consequently, it is seen that yarns produced from different spinning technologies affect the woven fabric performance, significantly.

Keywords: fabric performance, spinning technology, yarn properties, woven denim fabric

INTRODUCTION

Denim fabric is one of the foremost and most widely used woven fabric types in the world. Due to the increased capital investments on denim fabric production, it is necessary to clarify the effective parameters on denim fabric performance. It is a known fact that woven fabric properties are greatly influenced by yarn properties, structural features of fabrics and finishing treatments.

Yarns produced by using different spinning technologies not only differ from one another in respect of their structure but also in their bulk, mechanical and surface properties. The properties of fabrics produced from the yarns produced by different spinning technologies are affected by such yarn properties. All the spinning technologies have their own merits and demerits, which are inherent in the respective systems [1]. With respect to the spinning technology, in the literature the studies are generally focused on the comparison of woven fabric properties produced from ring and compact spun yarns. However, compact spinning is oriented to better fiber utilization and the high quality rather than higher productivity [2]. The compact spun yarn is produced by the same technique as the conventional ring spinning but have an extra compacting zone which is equipped by the suction system. In this zone, maximum free protruding fibers become parallel and condensed [3]. As a result of these studies which deal with the comparison of ring and compact spinning systems, it is concluded that woven fabrics produced from compact spun yarns have higher breaking strength, breaking extension, tear strength, pilling resistance and abrasion resistance [1, 4–6]. In another study, the tensile and thermal comfort properties of woven fabrics produced from ring and compact spun yarns were investigated. 65/35% polyester/cotton yarn samples were produced by using ring and compact spinning systems and woven fabric samples were produced from these yarns. As a result of this study, it is seen that fabric sample produced from ring spun yarn had higher water absorbency, drying rate and thermal absorbency in wet state than compact spun yarn fabric. On the other hand, compact yarn fabric has higher water vapor permeability and higher tensile strength than ring spun yarn fabric [7]. In the literature, there are some other studies on woven fabric performance in order to compare the other spinning technologies. Sawrow and Ahmed studied the effects of ring, compact and siro spinning technologies on strength and abrasion resistance properties of cotton woven fabrics. Better tensile strength and pilling resistance were observed for fabrics produced from compact yarns and also better dye absorbency was detected for fabrics produced from sirospun yarns [3]. Rengasamy et al. presented an experimental study on the tensile properties of woven fabrics produced from ring, OE rotor, air-jet and friction spun yarns. It is stated that the fabrics made from air-jet, OE rotor



a b c d e

Fig. 1. Spinning technologies used in the study (a) ring, (b) compact, (c) sirospun, (d) OE rotor [9] and (e) vortex [10]

and ring yarns had the same fabric breaking strength in spite of low yarn strength values of air-jet and rotor yarns are weaker [8]. In another study, comfort properties of fabrics woven from ring, OE rotor and friction spun yarns were investigated. Consequently, fabric sample produced by friction spun yarn had the highest air permeability whereas the fabric produced by OE rotor spun yarn had the highest water vapor permeability. With respect to the tactile comfort, fabric produced from ring spun yarn was the best. Additionally, the fabric sample woven from friction spun yarn was reported for low bagging resistance. Despite the presence of these previous studies there isstill a lack of information in the literature to highlight the effects of different spinning technologies on denim fabric performance. In this study it is intended to investigate the effects of yarn spinning technology namely, combed ring, compact, sirospun, OE rotor and vortex spinning on woven denim fabric performance.

EXPERIMENTAL WORK

In this study, it is aimed to investigate the effects of spinning technology on denim fabric performance namely, fabric breaking strength, fabric tear strength, abrasion resistance, stiffness and stretch. For this aim, five different yarn samples with 37 Tex yarn linear density were produced from 100% cotton raw material via different spinning systems. The spinning systems used in this study is seen in figure 1.

Table 1

COTTON FIBRE PROPERTIES	
Property	**Value**
Spinning Consistency Index	145
Fineness, µg/inch	4.83
Maturity Index	0.97
Length, mm	29.13
Short Fiber Index, %	8.2
Strength, g/Tex	32.7
Elongation, %	8

Cotton fiber properties were determined by using Uster High Volume Instrument (HVI) and the results are given in table 1.

In the production process of yarn samples, one type of card sliver was produced from cotton and fed to proper machines producing combed ring, compact, sirospun, OE rotor and vortex yarns. In doing so, five yarn samples were produced. Production parameters of sample yarns are given in table 2.

All samples were conditioned at 20 ± 2°C and 65 ± 4% relative humidity according to ISO 139 before the tests [11]. The quality and tenacity parameters of the

Table 2

PRODUCTION PARAMETERS OF SAMPLE YARNS					
	Ring	**Compact**	**Siro**	**OE Rotor**	**Vortex**
Card sliver count, Ne	0.120	0.120	0.120	0.120	0.120
Draw frame sliver count, Ne	0.120	0.120	0.120	0.120	0.120
Roving count, Ne	0.90	0.90	0.90	-	-
Ring diameter, mm	40	38	40	-	-
Spindle speed, rev/min	13000	13000	13000	-	-
Yarn twist, turns/m	710	710	710	710	-
Rotor speed, rev/min	-	-	-	102000	-
Rotor diameter of, mm	-	-	-	36	-
Delivery speed, m/min	-	-	-	-	320
Spindle air pressure, MPa	-	-	-	-	0.55

Table 3

QUALITY PARAMETERS OF SAMPLE YARNS					
Yarn Properties	**Ring**	**Compact**	**Siro**	**OE Rotor**	**Vortex**
U,%	7.36	7.13	7.58	10.27	8.27
CVm, %	9.25	8.98	9.51	12.92	10.41
Thin place, -40%/km	1.3	0.6	1.3	110	4.2
Thick place, +50%/km	0.6	0	0	31.3	0
Neps, +200%/km	3.1	0.6	1.9	48.8	3.3
Hairiness	6.87	4.36	6.45	5.27	4.55
Tenacity, cN/Tex	17.91	17.87	18.02	13.10	12.35
CV,% (Tenacity)	5.00	4.77	4.25	5.44	5.68
Breaking Elongation, %	7.35	8.12	6.53	6.52	6.12
CV,% (Breaking Elongation)	5.35	4.58	7.04	5.71	7.14

Table 4

STRUCTURAL FEATURES OF SAMPLE WOVEN FABRICS					
	Ring	**Compact**	**Siro**	**OE Rotor**	**Vortex**
Fabric mass, g/m^2	259	264	264	267	265
Fabric thickness, mm	0.60	0.60	0.60	0.60	0.60
Warp sett, yarns/cm	31	31	31	31	31
Weft sett, yarns/cm	24	24	24	24	24

sample yarns were tested with Uster Tester 4 and Uster Tensorapid test devices and the results are given in table 3.

Five woven fabric samples were produced by using the sample yarns in weft direction. 3/1 Twill weave type was chosen for woven fabric samples due to being a widely used weave type for denim fabrics. In warp direction, standard dyed 100% cotton denim warp sheet was used. All fabric samples were conditioned according to TS EN ISO 139 before the tests and the tests were performed in the standard atmosphere of 20±2°C and 65±4% relative humidity. Structural features of fabric samples namely, fabric weight, fabric sett and thickness were determined according to ASTM D3776 [12], ASTM D3775 [13] and ASTM D1777 [14] standards, respectively. Structural features of these sample woven fabrics are given in table 4.

In order to investigate the effects of spinning technology on the fabric breaking strength and tear strength, fabric samples were tested according to the standards of ASTM D5034 [15] and ASTM D1424 [16] respectively. Denim garments are usually washed and this washing treatment causes strength deterioration. So, breaking strength and tear strength tests were done after domestic home laundering aiming to determine the original strength properties. Home laundering was performed according to AATCC 135:2012 [17] for three times. Abrasion resistance, stiffnessand stretch properties of fabric samples were tested according to the standards of TS EN ISO 12947-3 [18], ASTM D4032 [19] and ASTM D3107 [20], respectively. These tests were performed on dry relaxed fabrics.In order to understand the statistical importance of spinning technology on denim fabric performance properties, one-way ANOVA was performed. In order to determine which groups belong to the significant differences obtained, Tukey HSD multiple comparison test was applied. For this aim the statistical software package SPSS 21.0 was used to interpret the experimental data. All test results were assessed at 95% confidence interval.

RESULTS AND DISCUSSION

Breaking force

Breaking force results of samples are given in figure 2. The sample yarns which were produced by different spinning technologies were merely used in weft direction of the sample fabrics. This is because the warp direction breaking force results are not considered. With respect to weft direction breaking force, it is seen from figure 2 that, the fabrics produced from ring and compact spun yarns exhibit similar fabric breaking force values. On the other hand, for the rest of the samples the breaking force values decrease

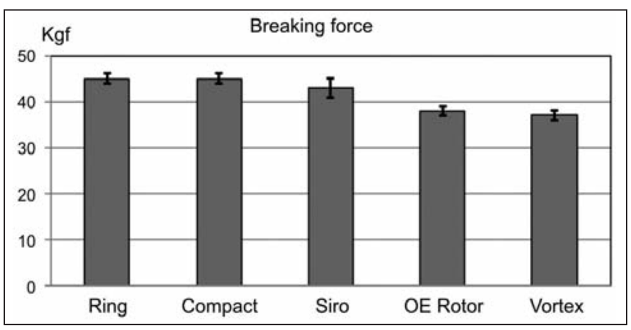


Fig. 2. Weft direction breaking force of samples

Table 5

ANOVA FOR BREAKING FORCE IN WEFT DIRECTION							
		Sum of squares	**df**	**Mean square**	**F**	**Sig.**	**Tukey HSD**
Weft break	**Between groups**	177.600	4	44.400	27.750	0.000	(Rotor-Vortex)* (Siro-Compact-Ring)*
	Within groups	16.000	10	1.600	–	–	
	Total	193.600	14	–	–	–	

* The mean difference is not significant at the 0.05 level.

for fabric samples produced from siro, OE rotor and vortex yarns, respectively. Similar fabric breaking force values of ring and compact samples were expected owing to the similar yarn tenacity values. The fabric breaking force values of the samples produced from rotor and vortex yarns are also reasonable regarding the yarn tenacity values. But fabric sample produced from siro yarn exhibits lower fabric breaking force in spite of having the highest yarn tenacity than all other yarn types. Fabrics produced from OE rotor and vortex yarns suffer from breaking force. This is because ring, compact and siro spinning technologies are preferable for denim fabrics regarding the breaking force.

ANOVA results for weft direction breaking force of samples are given in table 5. According to ANOVA results seen in table 5, the effect of different spinning technologies on weft direction breaking force is found to be significant ($p = 0.000 < 0.05$) at 95% confidence interval.

According to Tukey HSD multiple comparison test, fabrics produced from rotor and vortex yarn have statistically similar breaking force results. Also, fabrics produced from ring, compact and siro yarns exhibit statistically similar breaking force results. On the other hand, these two groups of fabrics have statistically different breaking force results.

Tear Strength

Tear strength results of samples are given in figure 3. The warp direction tear strength results are not considered due to the fact that the sample yarns were only used in weft direction. During tearing the yarns which are perpendicular to tearing direction break individually. So yarn tenacity is the foremost parameter that affects the tear strength. The woven fabric samples which were produced from ring, compact, OE rotor and vortex yarns exhibit the expected tear strength tendency regarding the yarn tenacity values. Otherwise, the fabric sample produced from siro yarn has moderate tear strength in spite of having the highest yarn tenacity value among all samples. A similar phenomenon is obvious for weft direction fabric breaking strength results. Tearing is a more frequent denim fabric failure in comparison to breaking. So it is very important to select the proper spinning technology. The fabrics produced from ring, compact and siro spun yarns are more favorable than other technologies, regarding the tear strength.

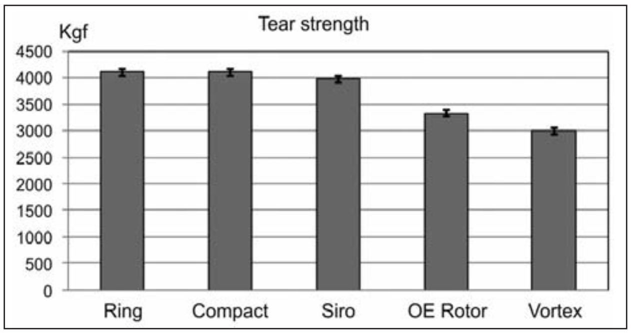


Fig. 3. Weft directiontear strength of samples

ANOVA results for weft direction tear strength of samples are given in table 6. ANOVA results in table 6 indicate the statistically significant ($p = 0.000 < 0.05$) effect of yarns spinning technology on weft direction tear strength at 95% confidence interval.

According to Tukey HSD multiple comparison tests, fabrics produced from ring, compact and siro yarns have statistically similar tear strength results; whereas rotor and vortex fabrics have statistically different tear strength results from this group (ring, compact and siro). Also, rotor and vortex fabrics have statistically different tear strength results from each other.

Stiffness

Stiffness results of samples are given in figure 4. According to figure 4 that exhibits the stiffness of the samples it is seen that there is a considerable difference

Table 6

ANOVA FOR TEAR STRENGTH IN WEFT DIRECTION							
		Sum of squares	**df**	**Mean square**	**F**	**Sig.**	**Tukey HSD**
Weft tear	**Between groups**	3125762.667	4	781440.667	184.386	0.000	(Ring-Compact-Siro)*
	Within groups	42380.667	10	4238.067	–	–	
	Total	3168143.333	14	–	–	–	

* The mean difference is not significant at the 0.05 level.

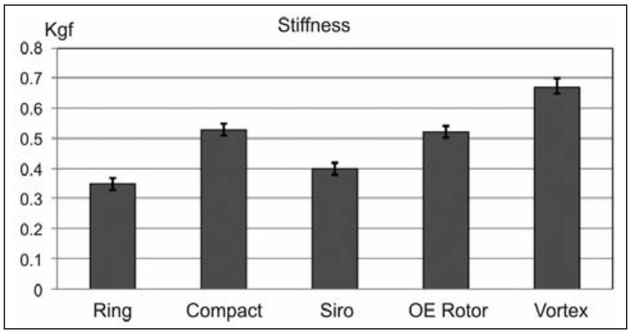


Fig. 4. Stiffness of samples

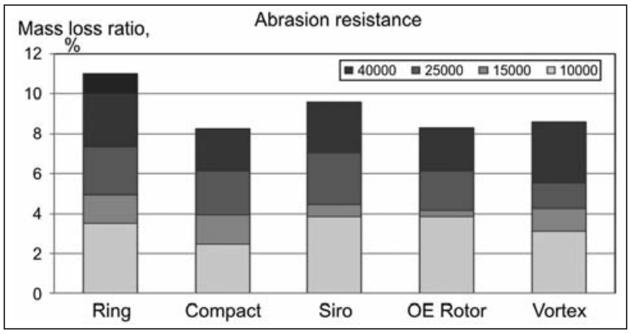


Fig. 5. Abrasion resistanceof samples

among samples. The fabric sample produced from vortex yarn has the highest stiffness value and this sample is followed by the fabric samples produced from compact, OE rotor, siro and ring yarn types, respectively. In other words, fabric sample produced from ring yarn has the best tactile comfort property. In an earlier study, a similar result was indicated for fabric sample produced from ring yarn in comparison to rotor and friction spun yarn [1]. There is no agreed boundary level for stiffness of denim fabrics. But it is known that garments which suffer from tactile comfort will cause discomfort for the wearers. Since the fabric samples produced from ring or siro spun yarn should be proper for denim garment.

ANOVA results for stiffness property of samples are given in table 7.The effect of yarn spininng technology on denim fabric stiffness is found to be statistically significant ($p = 0.000 < 0.05$) at 95%confidence interval. According to Tukey HSD multiple comparison test results fabrics produced from rotor and compact yarns have statistically similar stiffness results. The rest of the samples, have statistically different stiffness values among each other and this group (rotor and compact).

Abrasion resistance

The abrasion resistance of the samples was determined by the mass loss as the difference between the initial mass and mass after the abrasion cycles of 10.000, 15.000, 25.000 and 40.000. These values were then expressed as a percentage of initial mass and given as mass loss ratio %. Abrasion resistance results of samples are given in figure 5.

It is seen from figure 5 that the fabric samples produced from different yarn types have different abrasion levels. Especially ring sample exhibits considerably higher mass loss ratio than other samples. If figure 4 which is related to fabric stiffness is confronted with figure 5, it is observed that for all samples there is an inverse proportion between mass loss ratio and stiffness of the fabrics. In other words, the samples which are stiffer have higher abrasion resistance. This is a probable result of easier movement of softer fabrics due to the rubbing motion. Since the factors that increase the removal of fibers from the fabric structure deteriorates the abrasion resistance. Abrasion resistance is the foremost performance property for denim fabrics. It designates the presence of acceptable quality within the lifespan of the garment. Since the abrasion not only affects the loss of a performance property but also affects the appearance of the fabric. Especially denim fabrics which are dyed in dark colors suffer from low abrasion resistance than fabrics with lighter colors. Therefore abraded and unabraded views of the samples are given in figure 6 to examine this effect in a detailed manner. As seen from figure 6, in spite of different mass loss ratio values of the samples, the fabric views after abrasion denote similar deterioration for all samples.

ANOVA results for abrasion resistance of samples after 40.000 cycles of the test device are given in table 8.The effects of spinning technology on mass loss ratio after 40.000 rubbing cycles is found to be insignificant ($p = 0.150 > 0.05$) at 95% confidence interval.

Stretch

Fabric stretch values were determined according to applying a specified tension principle. For this aim 2.3 kg tension was selected. Three loading cycles were applied to specimen with 2.3 kg which one complete cycle should take approximately 5 seconds and the specimen is under the specified tension for

Table 7

ANOVA FOR STIFFNESS

		Sum of squares	df	Mean square	F	Sig.	Tukey HSD
Stiffness	Between groups	0.318	4	0.079	283.593	0.000	(rotor-compact)*
	Within groups	0.006	20	0.000	–	–	
	Total	0.323	24	–	–	–	

* The mean difference is not significant at the 0.05 level.

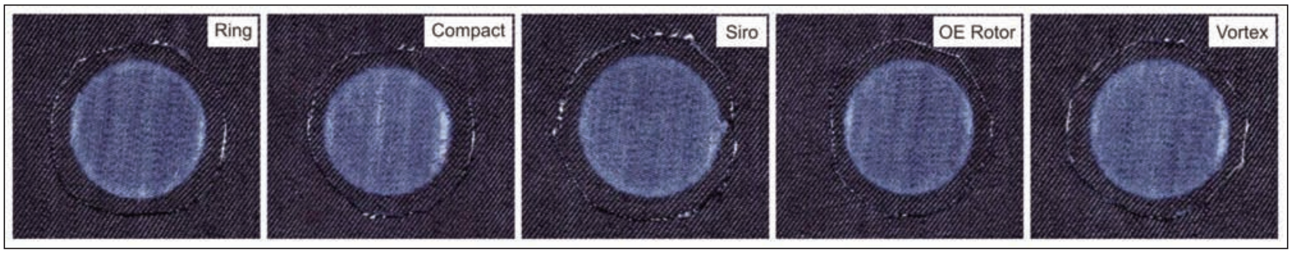


Fig. 6. Abraded and unabraded views of the samples

Table 8

ANOVA FOR ABRASION RESISTANCE

		Sum of squares	df	Mean square	F	Sig.
Abrasion	Between groups	8.115	4	2.029	2.144	0.150
	Within groups	9.460	10	0.946	–	–
	Total	17.575	14	–	–	–

Table 9

ANOVA FOR STRETCH IN WEFT DIRECTION

		Sum of squares	df	Mean square	F	Sig.	Tukey HSD
Stretch	Between groups	197.067	4	49.267	33.591	0.000	(rotor, vortex, siro, compact)*
	Within groups	14.667	10	1.467	–	–	
	Total	211.733	14	–	–	–	

* The mean difference is not significant at the 0.05 level.

approximately 3 seconds. Following the third cycle, a fourth cycle was applied and the stretched length of the specimen is measured immediately after loading. The length difference between the unstretched and stretched specimen is detected. Then these values were expressed as a percentage of initial length and given as stretch %. Elasticity results of samples are given in figure 7.

It is desirable from a garment to have high stretch levels under tension. This means that the fabric can provide a good formability and do not restrict the movement of the body. As it is evident from figure 7, the fabric sample produced from the ring spun yarn has the lowest stretch value among all samples. For the rest of the samples, the fabrics produced from compact and OE rotor yarns have slightly higher stretch values than siro and vortex samples. All the yarn types except ring can be selected for denim fabric keeping the stretch property in mind.

ANOVA results for stretch property of samples are given in table 9. According to ANOVA results obtained from stretch property of samples, the effect of spinning technology is found to be significant ($p = 0.000 < 0.05$) at 95% confidence interval.

According to Tukey HSD multiple comparison tests, fabric produced from ring yarn has statistically different stretch property than other samples. Besides, the rest of the samples have statistically similar stretch property among each other.

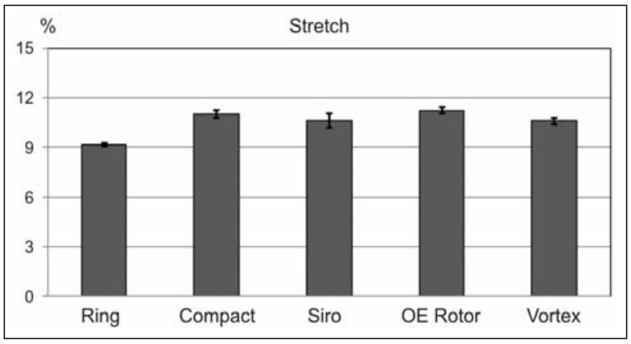


Fig. 7. Stretch of samples

CONCLUSIONS

In this study it is intended to investigate the effects of different spinning technologies namely, ring, compact, siro, OE rotor and vortex on denim fabric performance. Regarding the performance tests results and ANOVA, spinning technology has an important effect on weft direction breaking strength, weft direction tear strength, stiffness, abrasion resistance and stretch properties. According to the experimental results of the study, it is seen that ring and compact spinning systems provide better breaking and tear strength properties as well as good yarn tenacity. According to Tukey HSD multiple comparison test, there are two groups of fabrics that exhibit similar breaking and tear strength results. The first group consists in ring, compact and siro with higher strength values and the second group consistsin rotor and vortex with lower strength values. The difference between these groups is found to be statistically significant, in 95% confidence interval. The fabric sample produced from ring yarn has the worst abrasion resistance (mass loss ratio), but in spite of different mass loss ratio values of the samples, the fabric views after abrasion denote similar deterioration for all samples. On the other hand, fabric samples produced from compact, vortex and OE rotor yarns suffer from high stiffness, but siro and ring fabric samples are preferable for a better touch. Besides, the ring yarn fabric exhibits the lowest stretch property among all samples. According to Tukey HSD multiple comparison tests, fabric produced from ring yarn has statistically different stretch property than other samples whereas, the rest of the samples have statistically similar stretch property among each other. Consequently, the compact yarn sample seems to be advantageous among all samples. For further studies, warp yarns produced with different the yarn spinning technologies should be used for a better understanding of the effects of spinning technology on denim fabric performance.

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A new method for the fibrogram measurement – Image measuring method

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REZUMAT – ABSTRACT

O nouă metodă de măsurare a fibrogramei – Metodă de măsurare a imaginii

Fibrograma este cheia pentru măsurarea lungimii fibrei. Pentru a obține fibrograma rapid și precis, acest studiu prezintă o nouă metodă pentru măsurarea fibrogramei, și anume metoda de măsurare a imaginii care poate obține două fibrograme complete simultan. Această metodă constă în patru etape: prelevarea de probe, obținerea imaginii pe scara de gri, calcularea parametrilor de grosime și extragerea fibrogramei. Se introduce metodologia și se efectuează numeroase experimente pentru a investiga disponibilitatea metodei de măsurare a imaginii. Rezultatele arată că metoda de măsurare a imaginii poate fi utilizată pentru măsurarea fibrogramei.

Cuvinte-cheie: fibrogramă, imagine pe scara de gri, parametri de grosime

A new method for the fibrogram measurement – Image measuring method

The fibrogram is the key to measuring the fiber length. In order to obtain the fibrogram quickly and accurately, this paper presents a new method for the fibrogram measurement, namely Image measuring method which can obtain two entire fibrograms by one time. This method consists of four steps: sampling, obtaining gray image, calculating thickness parameters and extracting the fibrogram. The methodology is introduced and many experiments are performed to investigate availability of Image measuring method. The results show Image measuring method can be used to measure the fibrogram.

Keywords: fibrogram, gray image, thickness parameters

INTRODUCTION

Length is one of the fundamental properties of textile fibers, which affects yarn strength, yarn hairiness, the properties of fabrics and the efficiency of the yarn spinning process [1–3]. Traditional methods for fiber length measurement are Almeter, Roller analyser and Comb sorter method. These methods are slow, tedious, so they cannot meet the needs of modern production and quality control [4–5].

At present, fiber-beard method is an advanced method for fiber length measurement. In this method, fibers are clamped randomly, aligned in the holding line, and combed to form the beard, and then the fibrogram is measured by the instrument [6–7]. The fibrogram is the beard curve that shows the quantity of fibers at each protruding distance from the holding line. High Volume Instrument (HVI) is used to measure fiber length in this method. However some research pointed out that fibers are likely to slip, be lost and be entangled in the sampling process of HVI, and thus fiber distributions of the inner and outer of the comb are asymmetric [8–10]. Therefore, the mathematics relationship between the fibrogram and the fiber length distribution of the original sample is ambiguous. Furthermore, some fibers may be entangled near the root of the clamp and a single fiber may be held at the holding-line many times. Hence, the fibrogram scanning has to begin at a certain distance from the holding line, and the beard cannot be scanned fully.

Therefore, how to obtain the fibrogram quickly and accurately is the key to measuring the fiber length. This paper presents a new measuring method for the fibrogram, namely Image measuring method, which can generate two entire fibrograms synchronously. The methodology was demonstrated and experiments were performed to examine this new method.

METHODOLOGY USED

Image measuring method for the fibrogram measurement consists of four steps: sampling, obtaining gray image, calculating thickness parameters and extracting the fibrogram. Firstly, the dual-beard was produced by sampling. Secondly, the dual-beard was put on a transmission scanner to obtain a digital gray image. Thirdly, the thickness parameter of any pixel in the digital gray image was calculated. Finally, based on the thickness parameter and the digital gray image, the fibrogram was extracted.

Step 1: Sampling

First, a certain weight of the sample was selected randomly from tested fibers, then opened and mixed by hands, and removed trash particles with a pair of tweezers. Second, the sample was drawn three times by a fiber draw-off device to prepare a sliver in which fibers are parallel, straight and uniform nearly. Third, the sliver was clamped randomly along the fiber longitudinal axis by a clamper, and then loose fibers on the open end of the clamper were removed. Lastly, clamp the sliver with another clamper at the holding line of the first clamper, release the first clamper and remove all loose fibers on the open end of the second one. Then, the dual-beard with 5 cm was obtained.

The two sides of the dual-beard are approximately symmetrical and fibers in the beards are well straightened and parallel, which allows two entire fibrograms scans apart from the holding line simultaneously.

Step 2: Obtaining the digital gray image

The dual-beard sample was scanned by a transmission scanner to a digital gray image. A grayscale digital image is an image in which the value of each pixel is a single intensity value, that is, it contains only the luminance information without color information. Often, the grayscale intensity is stored as an 8-bit integer giving 256 (from 0 to 255) possible different shades of gray from black at the weakest intensity to white at the strongest.

The dual-beard was put on the glass tray of the scanner. The parameters of the scanner were set as follows: scan type was gray scale; resolution was 1000 dpi (0.0254 mm per pixel). A beard image, with high 2257 pixels and width 2339 pixels, was shown in figure 1.

Step 3: Calculating thickness parameters

According to Beer-Lambert Law, when a parallel monochromatic light, whose incident intensity is I_0, passes through a light absorbing material with even and non scattering vertically, the theoretical relationship between the absorption coefficient k, the thickness x and the transmission intensity of the material I is:

$$I = I_0 \, e^{-kx} \tag{1}$$

From equation (1), we have:

$$x = \frac{1}{k} \ln (I_0 / I) \tag{2}$$

Although the beard is nonhomogeneous material, the light transmittance is very good and the scattering is limited. Therefore, let us suppose that the beard obey Beer-Lambert Law, and then we will confirm that this assumption is correct through experiments.

I_0 is equal to 255 and I is equal to the gray value of each pixel, so the thickness of the beard at any point is:

$$x = \frac{1}{k} \ln (255 / I) \tag{3}$$

Equation (3) is the formula for calculating the thickness of the material.

According to equation (3), at the i^{th} column and the j^{th} row, the relationship between the thickness of the beard x_{ij} and the transmission intensity I_{ij} can be expressed as:

$$x_{ij} = \frac{1}{k} \ln \left(\frac{255}{I_{ij}}\right) \tag{4}$$

So, at the i^{th} column, the progressive accumulate thickness is:

$$x_i = \frac{1}{k} \sum_{j=1}^{m} \ln \left(\frac{255}{I_{ij}}\right) \tag{5}$$

Because k is constant, the thickness parameter t_i at the i^{th} column can be expressed as:

$$t_i = kx_i = \sum_{j=1}^{m} \ln \left(\frac{255}{I_{ij}}\right) \tag{6}$$

Equation (6) is used to calculate the thickness parameter t_i of the beard.

Step 4: Extracting the fibrogram

The digital gray image of the beard can be seen as gray value matrix with m rows and n columns, and each column is perpendicular to the fiber axis. The origin of the coordinates is set at the location of the holding line where t_0 is set 1. So, at the i^{th} column, the relative quantity of fiber equaled t_i at this column was divided by t_0, and the protruding distance to zero point equaled $i \times 0.0254$ mm. The fibrogram is the beard curve that shows the quantity of fibers at each protruding distance from the holding line, as shown in figure 2. The abscissa and ordinate values are protruding distance and relative quantity of fiber, respectively.

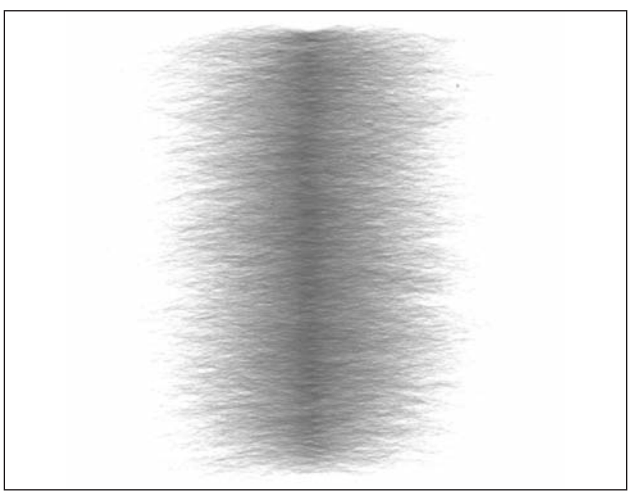

Fig. 1. Digital gray image of the dual-beard

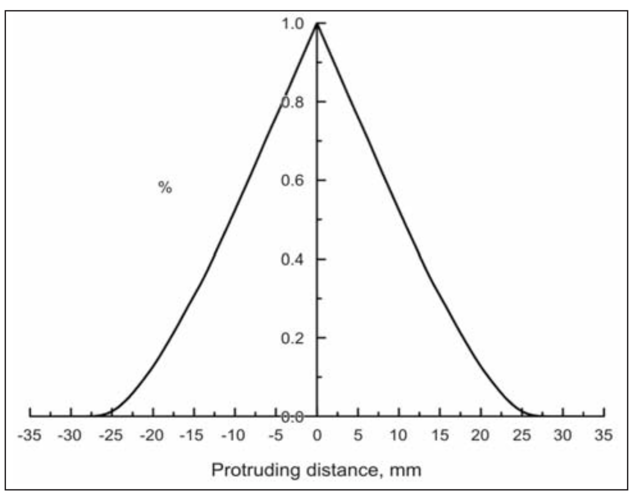

Fig. 2. The fibrograms

EXPERIMENTAL WORK

From the above, it can be known that the key technology of Image measuring method is the calculation of thickness parameters. Therefore, experiments were performed to verify that the method for calculating thickness parameters was correct.

Experiment 1: The relationship between the transmission intensity and the fiber contents

Sample: In order to get the relationship between the transmission intensity and the fiber contents, the gray value of the image with different fiber contents should be tested. So, in this experiment, cotton fibers were used to make the beard with different weights as follows: 16 mg, 19 mg, 24 mg, 28 mg, 33 mg, 36 mg and 40 mg; and kapok fibers were used to make the beard with different weights as follows: 12 mg, 14 mg, 15 mg, 17 mg, and 19 mg.

Test methods: The beards were put on the transmission scanner to obtain digital gray images. In order to get the positive correlation between the gray value and the beard thickness at any point, the digital gray image of the beard should be inverted. The gray value of each pixel in the inverted image was extracted by using the system software.

The origin of the coordinates is set at the location of the holding line; the ordinate values are the progressive accumulate gray values of every column which is vertical with fiber long direction; and the abscissa values are the protruding distance to zero point. Thus, the gray cumulative curve of the beard was obtained as shown in figure 3.

Experiment 2: Trueness of the thickness parameter of the beard

Sample: In order to verify the applicability of the equation (3) for homogeneous and transparent materials, the uniform polyester films were used to simulate the thickness distribution of the beard. 16 pieces of films were cut into 5 cm*10 cm rectangle.

Test methods: 16 pieces of films were spread on the glass tray of the scanner in turn with equal distance 5 mm. Thus, the layer of films were 16 layers, 15 layers ... 1 layer from left to right, and the material thickness was stepped down. The digital gray images of films were obtained by the scanner.

Because of the more layers with the lower light intensity, the gray value of the 16 layers is the minimum, and the 1 layer's is the maximum. In order to get the positive correlation between the gray value and the film thickness, the digital gray image of the films should be inverted, as shown in figure 5.

RESULTS AND DISCUSSION

Results 1: The Relationship between the transmission intensity and the fiber contents

The curve in figure 3, *a* is the gray cumulative curve of cotton fiber whose weight is 16 mg, 19 mg, 24 mg, 28 mg, 33 mg, 36 mg, 40 mg from the bottom to the top, and the curve in figure 3, *b* is the gray cumulative curve of kapok fiber whose weight is 12 mg, 14 mg, 15 mg, 17 mg, 19 mg from the bottom to the top.

From figure 3, it can be seen that the gray cumulative value in every column declines with the decrease of the beard weight, and the decreased amplitude rises gradually with the increase of the weight reduction. This shows there is a significant nonlinear relationship between the fiber weight and its output. Also, it can be seen that with the increase of the beard weight, the gray cumulative curve is gradually changed into an upper convex shape from the concave shape. This shows the relationship between the fiber weight and its transmission intensity is not exactly the same along the fiber's length. So, in order to determine this relationship, from the origin, the gray cumulative values of every curve are made as the ordinate every 2 mm, and the beard weight is made as the abscissa, as shown in figure 4.

As shown in figure 4, for the cotton and kapok fiber, although the change of the gray value caused by the increase of fiber weight is different, the trend is consistent in different positions along the beard's length. It shows that there is a nonlinear relation between the fiber weight and the transmittance on any cross section of the beard, and the thicker the fiber is, the more obvious the nonlinear relationship is. Therefore, in order to get the distribution of the beard's thickness, it is necessary to convert the nonlinear relation into a linear relationship by some means.

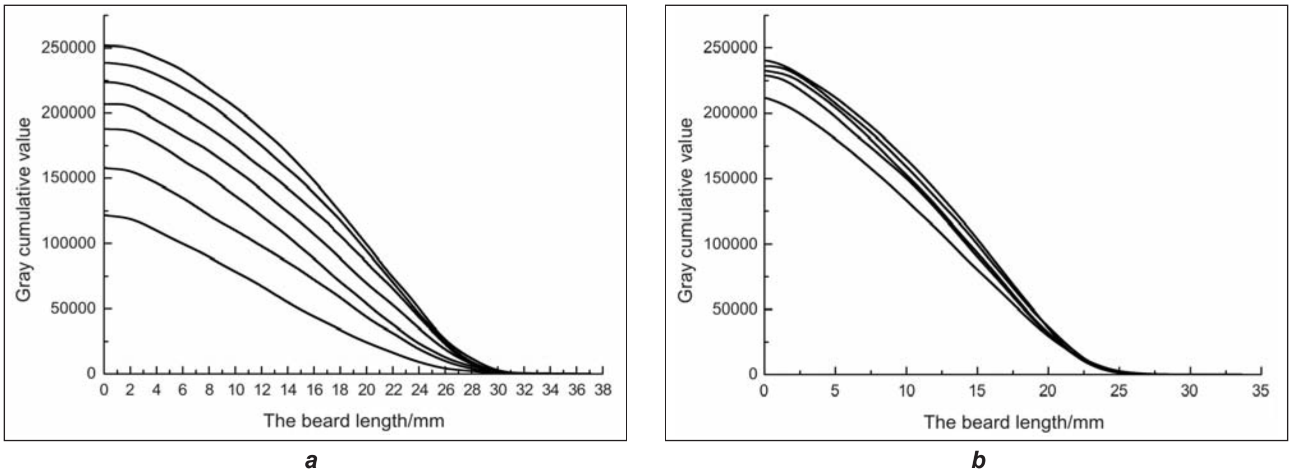

Fig. 3. The gray cumulative curve of the beard with different weights: *a* – cotton fiber; *b* – kapok fiber

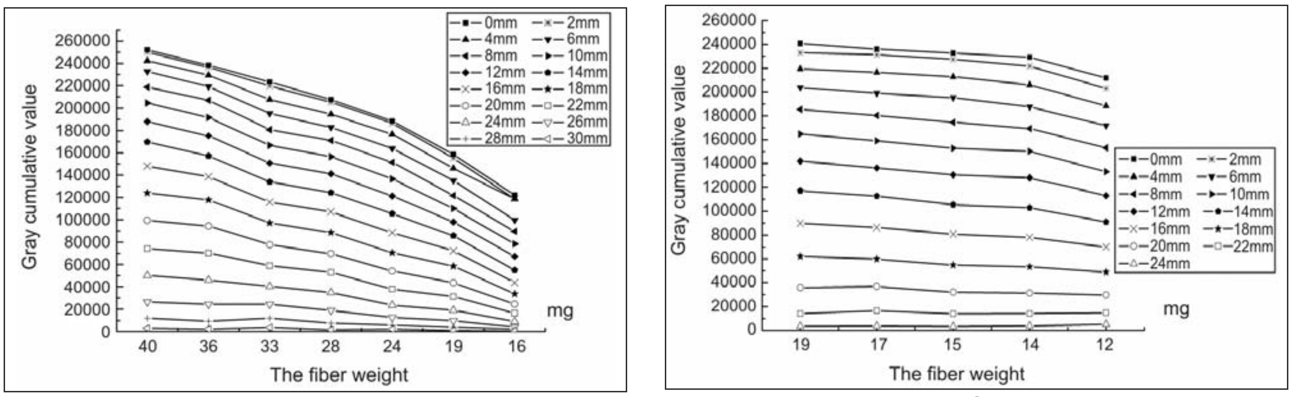

Fig. 4. The relationship between the transmittance and the fiber weight in different positions along the longitudinal direction: *a* – cotton fiber; *b* – kapok fiber

Results 2: Trueness of the thickness parameter of the beard

In figure 5, the progressive accumulate gray values of every column are calculated, and the average gray value of different layers of films are obtained. Then, the gray value of 16 layers of films is set to 1, and the relative gray value of *i* layers of films equals the value that the gray values of *i* layers of films divided by the gray values of 16 layers of films. Gray value varies with the number of layers of films as figure 6. Figure 6 shows there is a non-linear relation between the film thickness and the relative gray value, which can be fitted by using negative exponential curve.

The thickness of films is obtained after logarithmic transformation of the relative gray value of films by equation (3). Then, the thickness of 16 layers of films is set to 1, and the relative thickness of *i* layers of films equals the value that the thickness of *i* layers of films divided by the thickness of 16 layers of films. Then, after logarithmic transformation, the curve is showing in figure 7.

Fig. 5. The inverted digital gray image of the films

As shown in figure 7, the curve is approximate straight line after logarithmic transformation. It shows that the approximate straight line can better reflect the thickness of the polymer layer. It is likely to be due to different transmission properties of different layers, the approximate straight line is still weakly convex. This experiment shows that the formula for calculating the thickness parameter is completely applicable for the beard simulated by homogeneous and transparent materials.

In order to verify the applicability of the equation (3) for fiber materials, figure 8 is obtained from the data in figure 4 after logarithmic transformation by equation (3). As shown in figure 8, the linear regions of the curves have also significantly increased after logarithm transformation. The points at a distance of more than 10mm from the holding line are basically in a straight line. And the points at a distance of lower than 8mm from the holding line have a nonlinear trend, especially the points in the curves of the fiber weight greater than 30 mg. The reason is that the beard is a mixture of fibers and air and is not completely uniform light transmission material. The incident light is reflected and refracted at the interface between the fiber and the air, especially thicker positions of the beard. Therefore, the weight of the beard should be limited to less than 30 mg. In summary, too thick beard will bring great errors, and equation (6) is

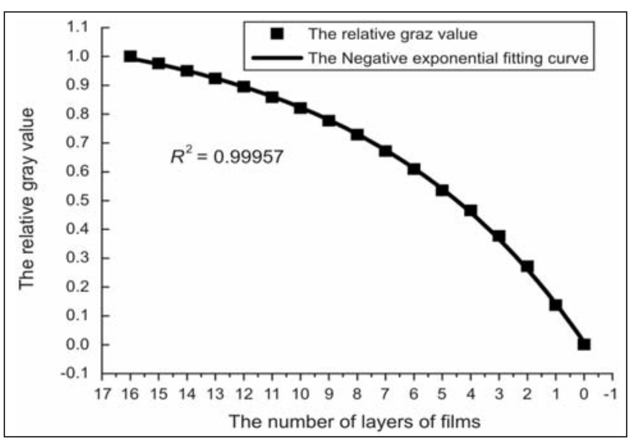

Fig. 6. The negative exponential fitting curve

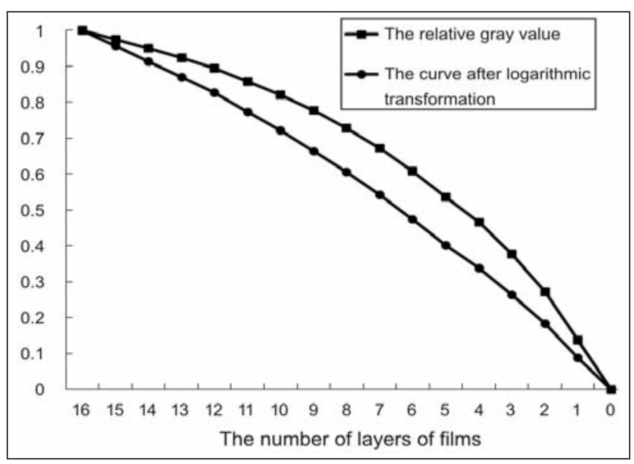

Fig. 7. The curve after logarithmic transformation

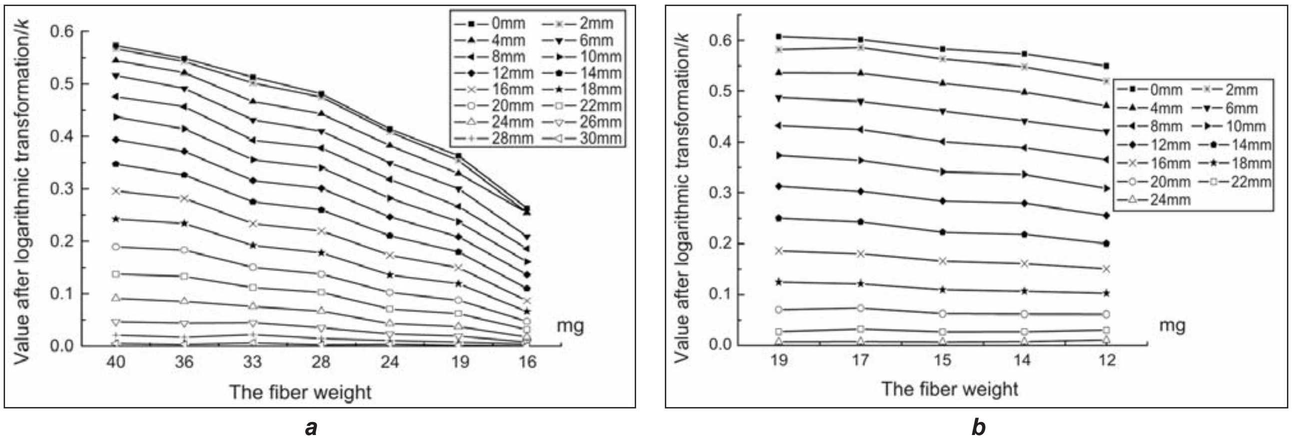

Fig. 8. The relationship between the transmittance and the fiber weight in different positions along the longitudinal direction after logarithmic transformation: *a* – cotton fiber; *b* – kapok fiber

suitable for the fiber material when the weight of the beard is limited to less than 30 mg.

CONCLUSIONS

A new method for the fibrogram measurement was presented, namely Image measuring method which involved sampling, obtaining gray image, calculating thickness parameters and extracting the fibrogram. This new method can scan the two sides of the dual-beard from the holding line synchronously to generate two entire fibrograms. Also, experiments were performed to examine the key technology of this new method that is the calculation formula of the thickness parameter. The experiment results show the calculation formula of the thickness parameter is suitable for the fiber material when the weight of the beard is limited to less than 30 mg. Therefore, Image measuring method is a feasible and efficient method for the fibrogram measurement.

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Carpet fiber mobility due to traffic wear

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REZUMAT – ABSTRACT

Mobilitate fibrei din covor determinată de uzura la trafic

Tipul de fibră este cel mai important parametru care influențează performanța covorului. În timpul ciclului de viață, covoarele sunt expuse la mulți agenți mecanici și de altă natură care determină modificarea structurii suprafeței și a culorii, pierderea grosimii, mobilitatea fibrelor scurte. Mobilitatea fibrelor, care este de nedorit pentru consumator, provine de la agenții mecanici, cum ar fi traficul cauzat de mers. Acest studiu prezintă mobilitatea fibrelor care determină pierderea acestora din covoarele țesute cu fibre acrilice Wilton, cu densitate diferită a plușului și înălțimii, sub influența traficului. Uzura la trafic a fost realizată cu ajutorul testerului de covoare Hexapod Thumbler, cu scopul de a determina pierderea fibrei la fiecare 2000 cicli, până la 12000 de cicli. Analiza statistică a fost efectuată cu programul Design Expert pentru a prezenta efectele densității plușului și parametrilor de înălțime asupra pierderii fibrei (%), la un nivel de semnificație de 0,05. Rezultatele au arătat că densitatea și înălțimea plușului au un efect semnificativ, cu valoarea lui R-Squared de 95,5%.

Cuvinte-cheie: covor țesut Wilton, fir plușat acril, pierderea fibrei, uzura la trafic

Carpet fiber mobility due to traffic wear

Fiber type is the most important parameter that influences the carpet performance of its own. During the life cycle, carpets are exposed to many mechanical and other agencies that cause surface structure and colorchanges, thickness loss, fiber mobility for staple fiber, as well. Fiber mobility arisesby mechanical agencies such as under foot traffic which is undesirable for consumer. This study indicates fiber mobility in terms of fiber loss of acrylic Wilton woven carpets with different pile density and height under traffic.Traffic wear was achieved by Hexapod Thumbler carpet tester to determine fiber loss in each 2000 cycle part up to 12000 cycles. Statistical analysis was performed by Design Expert package program to put forward the effects of pile density and height parameters on fiber loss (%) at significance level of 0.05. Results showed that pile density and height have a significance effect with the value of R-Squared 95.5 %.

Keywords: Wilton woven carpet, acrylic pile yarn, fiber loss, traffic wear

INTRODUCTION

Carpet is a floor covering that comprises warp (stuffer and chain), weft and pile yarns within its three dimensional structures [1]. Pile yarn properties lead directly to carpet performance such as resilience ability after static (represents table, chair and furniture etc. foot) and dynamic loading (represents deformation due to walking etc.), antibacterial activity, felting effect after abrasion. So there are some researchers study on pile properties as well as effect on carpet performance [2–15]. Korkmaz *et al.* concerned about the determination the effects of pile density and height of acrylic Wilton carpets on resilience behavior under short and long-term static loading. They conducted that the carpetappearance by changing thickness loss-recovery behavior arises under the influence of these carpet parameters [4]. Çelik *et al.* also studied the carpet behaviors during the recovery period, including the energy absorption, damping characteristics and the hysteresis effect of pile material sofacrylic, wool, and polypropylene carpets after prolonged heavy static loading. They demonstrated that carpets made of wool pile type had better, on the other hand acrylic pile type had poorest resilience property [6]. Javidpanah *et al.* determined the thickness loss of carpets produced from different air textured polyester yarns (conventional, frieze, heat-set, both twist and heat-set) under static loading. Twist and heat-setting process at higher temperature had found to improve carpet thickness loss. It is suggested that compression behavior are directly affected by physical and mechanical properties of pile yarns.

Some researchers investigated that the resilience behavior of carpets under dynamic loadings which is another important parameter that can be taken into consideration [5, 11]. In addition, to analyze the compression behavior of carpets, some parameters, for example: fiber blend ratio for acrylic pile yarns, fiber cross section for polypropylene pile yarns, and yarn type that is acrylic yarn, polypropylene bulk continuous filament (BCF) yarn and heat set polypropylene BCF yarn were investigated by some researchers [2, 8–9].

Although, fiber loss has an important problem for cut-pile carpets when carpets are exposed to traffic during life cycle, there has been no comprehensive research in literature from the point of view of pile density and height effects. The present paper indicates cut-pile acrylic carpets fiber loss as percent of acrylic fiber (%) in mass which causes undesirable failure of yarn structure i.e. releasing the fiber by twist opening within. For this purpose, pile density and height were selected as independent variables to put forward effects on fiber loss during use.

The regression analysis and analysis of variance (ANOVA) of the test results were analyzed by using Design Expert 6.0.1 statistical software package at 95% confidence interval. For this purpose, general factorial design module was used to detect the relationships between independent variables (pile density and height) and response variable (fiber loss (%)).

EXPERIMENTAL PART

Material

In this work, cut-pile carpet samples were produced from Wilton face-to-face carpet weaving machine with three rapiers which enables three weft shots. The carpet structure 2/3 V was chosen to obtain uniform structure illustrated in figure 1. Acrylic fiber was used as pile with the 5.6 denier linear density. In order to determine the fiber loss four levels pile density and three levels of pile height were selected as independent variables. Therefore, a total of 12 carpet samples were manufactured and samples composition and structural properties are shown in table 1 and table 2, respectively. As illustrated in table 1, the raw materials of yarns within the carpet composition were chosen resulting from widely used. The carpet samples were different with respect to the pile height and the weft densityin ground as well as pile density (table 2).

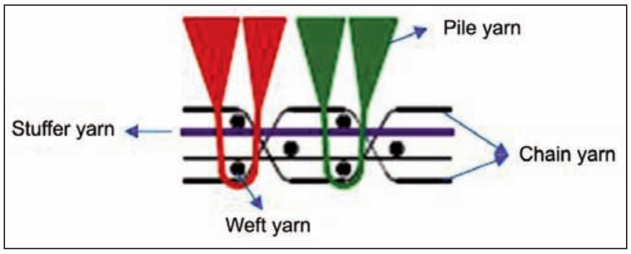

Fig. 1. 2/3 V weave construction [17]

Table 1

Yarn type		Material	Yarn linear density (tex)
Pile yarn		Acrylic	200 (Nm 15/3)
Warp yarn	Stuffer yarn	80% Polyester/ 20% Cotton	197 (Ne 12/4)
	Chain yarn	Polyester	89 (800 denier)
Weft yarn		Jute	491 (Ne L 14/1*)

** Weight in pounds/libre14400 yards of yarn*

Method

To carry out the experiments on the carpets, specimens were conditioned with (65±4)% relative humidity and (20±2)°C temperature according to ISO 139 [17]. To perform tests, samples were cut with 940 mm × 200 mm dimensions from direction of manufacture and cross-direction of manufacture in accordance with DD ISO PAS 11856 standard according to Hexapod tumbler test which simulate long-term use in heavy wear situation for mass loss method [18]. Then each carpet samples placed in Hexapod tumbler were subjected to hexapod with six polyurethane studs by rotation of the drum. To determine the fiber loss of carpet, loose fibers were gathered by means of a light fingertip brush in each 2000 cycles up to 12000 cycles. Fiber loss was calculated with equation 1.

$$\textit{Fiber loss}\ (\%) = \frac{(m_1 - m_2)}{m_1} \times 100 \qquad (1)$$

where m_1 represents pile weight per square meter which was determined according to ISO 8543 standard, m_2 is total weight of fiber loose collected during 12000 cycles in gram per square.

RESULTS AND DISCUSSION

According to the test results, the bar chart of fiber loss in g/m^2 at different pile density and height is illustrated in figure 2.

With increase in pile density and pile height, the fiber loss arises when carpet subjected to mechanical agency as seen in figure 2.

On the other hand, fiber loss in percent drawn with respect to different pile density and height are indicated in figure 3. It is clearly seen in figure 3; percent

Table 2

Warp density (ends/dm)	Weft density (picks/dm)	Pile density (piles/dm^2)	Pile height (mm)	Pile weight (g/m^2)	Carpet weight (g/m^2)
48	50	2400	7	918.549	1929.882
48	55	2640	7	1082.244	2183.333
48	60	2880	7	1205.600	2413.000
48	65	3120	7	1273.154	2561.500
48	50	2400	11	1374.654	2476.000
48	55	2640	11	1545.040	2744.440
48	60	2880	11	1611.245	2846.064
48	65	3120	11	1932.480	3268.640
48	50	2400	16	1980.400	3071.200
48	55	2640	16	2183.038	3299.923
48	60	2880	16	2431.240	3728.400
48	65	3120	16	2560.080	3944.960

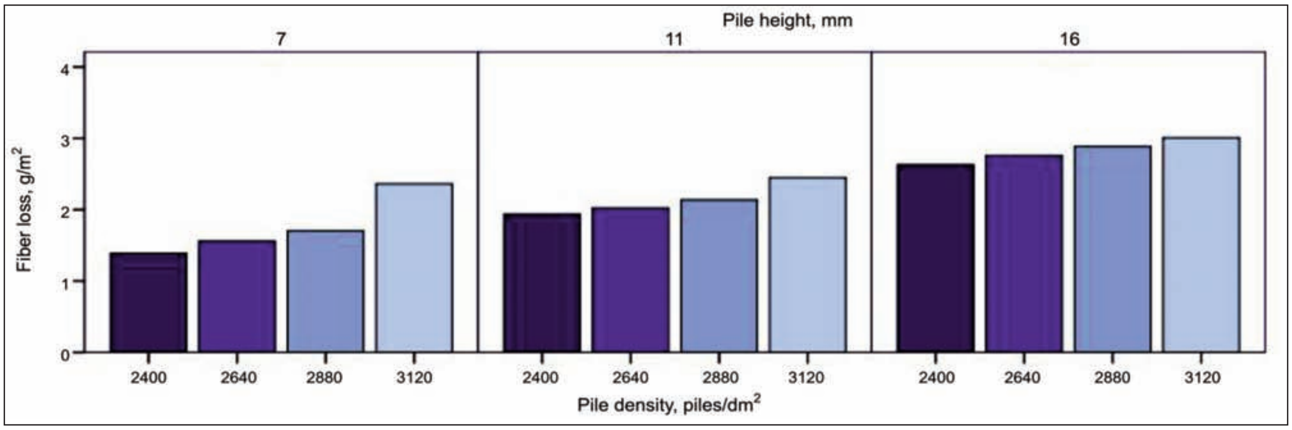

Fig. 2. Weight of fiber loss of carpet samples versus to pile height and pile density

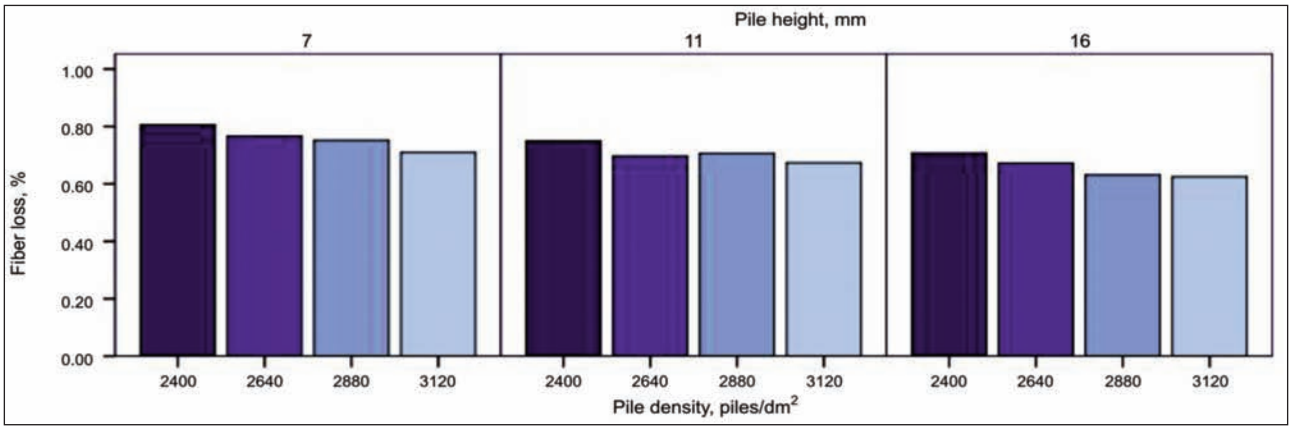

Fig. 3. Fiber loss of carpet samples versus to pile height and pile density

of fiber loss arises with the lowest pile density this is due to the dense structure of carpet which avoids the fiber shedding by increasing the weft density as well as pile density. In addition, higher the length of pile yarn contributes the fiber loss that means loss of fiber decreases from the cut-pile of carpet. It can be concluded that higher the pile weight leads to decline in fiber loss in percent as determined with equation 1. Unlike fiber loss in gram, both pile weight and fiber loss in gram should be taken into consideration together to decide the carpet performance criteria.

In statistical analysis, model analysis was performed to determine the best model for regression analysis. The model summary statistics are illustrated in table 3. The statistical analysis indicates that the best fitting model is the linear model for fiber loss of carpet samples. Model explains about 88.6% of the variability in pile height and density at α = 0.05 confidence interval. ANOVA analysis for linear model is shown in table 4. It is seen that the effect of pile density and pile height are statistically significant on fiber loss of carpet samples.

Table 3

Source	Standard deviation	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	0.013	0.9554	0.9455	0.9298	2.225E-003	Suggested
2FI	0.013	0.9555	0.9388	0.8983	3.221E-003	-
Quadratic	0.014	0.9649	0.9356	0.8673	4.204E-003	-
Cubic	0.014	0.9827	0.9365	0.6209	0.012	-

Table 4

Source	Sum of squares	DF	Mean square	F Value	Prob>F	Significance
Model	0.030	2	0.015	96.34	<0.0001	Significant
A = pile density (piles/dm^2)	0.011	1	0.011	68.72	<0.0001	Significant
B = pile height (mm)	0.019	1	0.019	123.96	<0.0001	Significant
Residual	414E-003	9	1.571E-004	-	-	-
Cor. Total	0.032	11	-	-	-	-

CONCLUSION

In this study, the fiber loss due to traffic wear in practical use of cut-pile carpet samples consisting of pile yarn with different density and height were examined. The results showed that increase in pile density and pile height avoids the fiber shedding. Model analysis was achieved to determine the effect size and relationship of these parameters on fiber loss statistically. It was observed that pile density ($p < 0.0001$) and pile height ($p < 0.0001$) have a significance effect on loss of fiber. For the further experimental study, pile density and pile height parameters need to be analyzed for behavior of cut-pile carpet samples under compression and static loading.

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Influence of titanium dioxide finish prepared by sol-gel technique on the ultraviolet protection characteristics of cotton/polyester blend fabrics used for clothing

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REZUMAT – ABSTRACT

Influența finisajului cu dioxid de titan preparat prin tehnica sol-gel asupra caracteristicilor de protecție la radiații ultraviolete ale țesăturilor în amestec bumbac/poliester pentru îmbrăcăminte

În această lucrare au fost investigate prin analiza varianței factorul de protecție UV (UVF), factorul de transmisie la ultraviolete A (UVA) și UV B (UVB) al țesăturilor în amestec bumbac/poliester, care sunt caracteristici importante pentru astfel de țesături. Finisajul cu dioxid de titan (TiO_2) preparat prin tehnica Sol-Gel a fost aplicat pe mostre de țesături, realizate din fire în amestec bumbac/poliester de 67/33% și 35/65%. Efectele parametrilor structurali ai firelor și țesăturilor, cum ar fi modelele de legături și materiile prime ale firelor, precum și finisajul cu dioxid de titan, care au fost analizate și raportate în acest studiu pentru realizarea țesăturilor de îmbrăcăminte, nu au fost studiate în referințe. Se observă că, în timp ce factorul UPFal țesăturilor de îmbrăcăminte a crescut odată cu scăderea porozității, factorul de transmisie UVA și UVB al țesăturilor a scăzut. Atunci când grosimea țesăturii a crescut, factorul UPF al țesăturilor a crescut, în timp ce factorul de transmisie UVA și UVB al țesăturilor a scăzut. Dacă porozitatea țesăturilor a fost aproape egală, grosimea țesăturii a determinat proprietățile de protecție și de transmisie UV. Țesăturile cu legătură diagonal, datorită gradului cel mai scăzut de porozitate, prezintă cea mai bună protecție UV și performanță a factorului de transmisie. Factorii UPF ai țesăturilor în amestec bumbac/poliester 35/65% au fost mai mari decât cei ai țesăturilor în amestec bumbac/poliester 35/65%. În schimb, efectul a fost contrar pentru factorii de transmisie UVA și UVB. Finisajul cu dioxid de titan a îmbunătățit caracteristicile de protecție și de transmisie UV.

Cuvinte-cheie: țesături pentru îmbrăcăminte, factor de protecție la radiații ultraviolete, factor de transmisie UVA, factor de transmisie UVB, țesături cu legătură diagonal, legătură cu structură celulară, legătură în carouri

Influence of titanium dioxide finish prepared by sol-gel technique on the ultraviolet protection characteristics of cotton/polyester blend fabrics used for clothing

In this work, ultraviolet protection factor (UPF), ultraviolet A (UVA) and ultraviolet B (UVB) transmittance of cotton/polyester blend clothing fabrics, which are important characteristics for such fabrics, were investigated by analysis of variance. Titanium dioxide (TiO2) finish prepared by Sol-Gel technique was applied to fabric samples, made from 67/33% and 35/65% cotton/polyester blend yarns. The effects of yarn and fabric structural parameters, such as weave patterns and raw materials of yarns, and also titanium dioxide finish, which were analysed and reported in this work for clothing woven fabrics, were not studied in the references. It is observed that while the UPF of clothing fabrics increased by decreasing porosity, UVA and UVB transmittance of fabrics decreased. When the fabric thickness increased UPF of fabrics increased, whereas UVA and UVB transmittance of fabrics decreased. If porosity of fabrics were almost equal to each other, fabric thickness determined the UV protection and transmittance properties. Matt twill fabrics thanks to their lowest porosity show the best UV protection and transmittance performance. UPFs of 35/65 cotton/polyester blend fabrics were higher than those of 35/65 cotton/polyester blend fabrics. Opposite was happened for UVA and UVB transmittances. Titanium dioxide finish improved the UV protection and transmittance characteristics.

Keywords: clothing fabrics, ultraviolet protection factor, UVA transmittance, UVB transmittance, matt twill weave, cellular weave, diced weave

INTRODUCTION

The beneficial effects of human exposure to ultraviolet radiation (UVR) are well known. The main benefit is promoting the synthesis of vitamin D from precursors in the skin. Other beneficial effects of UVR are mainly therapeutic. However, prolonged and repeated, both occupational and recreational, sun exposure of the population causes some detrimental effects. The most obvious short-term effect of over-exposure to UVR is sunburn, also known as erythema. Chronic sun damage leads to skin photo aging and non-melanoma and melanoma skin cancer [1].

The proportion of the UV region (100–400 nm) is about 5–6% of the total incident radiation and can be classified by wavelength into three regions. Light radiation of wavelength 315–400 nm represents UVA region. UVB radiation is in the range of 280–315 nm [2]. The region below 280 nm is UVC radiation, which is extremely dangerous. Fortunately, UVC and some UVB radiation (100–290 nm) do not reach the earth's surface due to absorption by the stratospheric ozone in the atmosphere.

The regions where the UV index is high, it is necessary for the population, especially for outdoor workers, children and adolescents, to protect themselves.

In addition to the outdoor natural source of UVR, there are also interior artificial UVR sources such as different types of lamps for medical care and phototherapy, work places' lightening, industrial arc welding, advertising lamps, etc. Obviously, UV exposure of people takes place in their work and leisure places, homes and outdoors. Therefore, the UVR protection provided by clothes becomes a subject of considerable interest.

There are several possible pathways for UV light distribution when UVR reaches textile fabric. UVR can be reflected, absorbed and transmitted by fabric. Part of the radiation is absorbed by the fibres, i.e. it is converted to a different energy form [3]. Another part of the radiation passes directly through the fabric via gaps between the fibres and yarns and this part is referred to as the 'transmission' [4]. Some radiation is reflected or scattered by the fibres, which may contribute to transmitted radiation if it isnot absorbed by other fibres. It is clear that all clothing provides some degree of UV protection. Therefore researchers investigated the UV protection properties of woven fabrics: Dubrovski and Darko Golob investigated the effects of woven fabric construction and color on the ultraviolet protection factor [5]. They found that color had the biggest influence on the ultraviolet protection factor of fabrics, whereas woven fabric construction was essential when light pastel colored fabrics were used as ultraviolet protection.

Dimitrovski, Sluga and Urbas searched the UP protection properties of high-module monofilament PET plain, twill and sateen woven fabrics which differ in their monofilament diameter, warp and weft densities [6]. Research showed that three woven fabric constructional parameters were essential, type of weave, yarn fineness, warp and weft densities, for development of fabrics with acceptable UPF properties. Fabrics made of twill and satin offered better protection than fabrics made of plain weave.

Hatua, Majumdar and Das studied UPF of fabrics made of 100% cotton and 100% bamboo viscose yarns [7].

They inferred from the analysis that that the apparently higher UPF of bamboo viscose fabrics could be attributed to their higher cover percentage and a real density instead of bamboo's inherent UV protective property.

Riva and Algaba studied the UV protection and transmission properties of plain cotton, modal and sun modal (Modal fibre that incorporates an UV absorber in the spinning bath) fabrics [8]. While the raw fabrics made with the cotton fibre were most transparent to the passage of ultraviolet radiation, the Modal Sun fibre is very convenient for ultraviolet-radiation-protective clothing. The diffuse transmittance of the ultraviolet radiation through the fabrics decreased when the warp yarn number, weft yarn number and weft thread count increased.

Urbas, Kostanjsek and Dimitrovski investigated the six different structures of woven cotton fabrics – one-layer fabric, double-weft fabrics and double fabrics [9]. The same fineness of yarn in the warp and weft direction (8×2 tex), the same settings of red and blue coloured yarns in warp and weft, the same density of warp (40 ends/cm) and weft (60 picks/cm), and the same weaving conditions on the loom were retained. They found that UPF negatively correlated with the lightness of red and blue samples. Double-weft fabrics and double fabrics had better UPF values than one-layer woven fabric. Apart from the construction, the colours of used yarns played an important role on UPF.

On the other hand, there are studies to improve UV protection properties of woven fabric: Sundaresan et al. assessed the performance of ultraviolet (UV) protection of titanium dioxide (TiO_2) with acrylic binder on the cotton fabric using pad-dry-cure method [10]. Titanium iso-propoxide was used as precursor with two different mediums of water and ethanol to synthesize nano-sol by sol-gel technique. They found that the fabrics treated with 12 nm particles exhibit higher UPF values than the fabric treated with 7 nm particles.

Zhang and Yang immobilized TiO_2 particles onto the surface of gray woven cotton fabric by hydrothermal process. The cotton fabric loaded with the TiO_2 particles exhibited a good UV absorption ability [11].

Zhang and Zhu immobilized TiO_2 particles prepared by hydrothermal precipitation method on the surface of wool fiber, and then dyed 2/1 twill woven wool fabric with C.I. Reactive Blue 69 [12]. While the capability of TiO_2 loaded fabric against ultraviolet radiation was enhanced, the whiteness of wool fabric after treatment was decreased significantly.

Sivakumar, Murugan and Sundaresan tested the ultraviolet protection factor of ZnO finished cotton fabrics [13]. They found that the fabrics treated with 38 nm particles exhibit higher ultraviolet protection factor values than the fabric treated with 24 nm particles.

Khalilabad and Yazdanshenas treated the plain woven fabric with $AgNO_3$ [14]. The UV transmittance of Ag-coated sample decreased and percentage of transmittance in the UV-B was lower than UV-A.

Ibrahim et al. treated cotton fabrics with copper acetate [15]. They found that the extent of improvement in UV protection depended on the history of the treated cotton fabric and followed the descending order: Gray>> mill-scoured and bleached _mill-scoured, bleached and mercerized cotton fabric.

The studies in literature focused on plain and twill fabrics woven with only cotton, modal, wool or polyester fibres. The aim of this study was to determine the effects of selected yarn and fabric structural parameters and also titanium dioxide finish on the ultraviolet protection factor, the UVA and UVB transmittances of certain clothing fabrics woven with cotton/polyester blends. In this regard, an experimental study was carried out, the effects of the parameters were detected firstly by graphics formed by obtained data and secondly by analysis of variance.

EXPERIMENTAL WORK

Materials and Method

Materials

In this research 8 kinds of clothing woven fabric samples, whose weave pattern were 2/2 twill, matt twill, cellular weave, diced weave, were produced in Weaving Workshop of in-house by CCI automatic sample rapier loom (Evergreen 8900, Taiwan) with sized cotton/polyester blend yarns. Weave patterns are shown in figure 1. Nm 30/1staple fibre 67/33% and 35/65% cotton/polyester yarns were used as both warp and weft yarns. Cotton and staple fibre polyester were used as raw material of yarns so fabric samples were produced in raw colour namely ecru.

Fabric samples were coded according to weave pattern and raw material of yarns as in table 1. While the letters in fabric codes represent weave pattern, the numbers represent raw materials of yarns respectively.

Achwal proposed that the UPF increases with fabric density and thickness for similar construction, and is dependent on porosity [16]. Algaba, Va and Crews found that a high correlation exists between the UPF and the fabric porosity but is also influenced by the type of fibres [17]. Crews and Kachman gave the relative order of importance for the UV protection by % porosity > fibre type > fabric thickness [18].

Therefore, in assessing UPF and UVA, UVB transmittances of woven fabrics with different constructions, there is a need to define those constructional parameters which have a direct connection with UPF. The following constructional parameters of woven fabric were taken into account during our research: 1. Thickness, 2. Weight per unit area, 3. Porosity. Hseih defines porosity as [19]:

$$\varepsilon = 1 - \frac{\rho_a}{\rho_b} \quad (1)$$

Where ρ_a is the fabric density (g/cm^3), ρ_b is the fibre density (g/cm^3) and ε is the porosity. Fabric density was calculated by dividing the fabric weight per unit area, by fabric thickness. Fibre density was calculated according to percentage of fibre in blend yarns.

Table 1

THE SPECIFICATIONS OF SAMPLE FABRICS

Fabric code	Weave pattern	Raw material of yarns	Warp density on the loom	Weft density on the loom	Fabric thickness (mm)	Fabric unit weight (g/m^2)	Porosity* (%)
A1	2/2 twill	67/33 cotton/polyester	35	29	0.424	242	6.26
A2	2/2 twill	35/65 cotton/polyester	35	29	0.410	233.72	6.13
B1	Matt twill	67/33 cotton/polyester	35	28	0.432	238.33	6.25
B2	Matt twill	35/65 cotton/polyester	35	28	0.417	230.18	6.11
C1	Cellular weave	67/33 cotton/polyester	35	33	0.644	234.67	7.57
C2	Cellular weave	35/65 cotton/polyester	35	33	0.622	226.64	7.48
D1	Diced weave	67/33 cotton/polyester	35	30	0.582	231.00	7.35
D2	Diced weave	35/65 cotton/polyester	35	30	0.562	223.10	7.26

* Calculated according to equation 1.

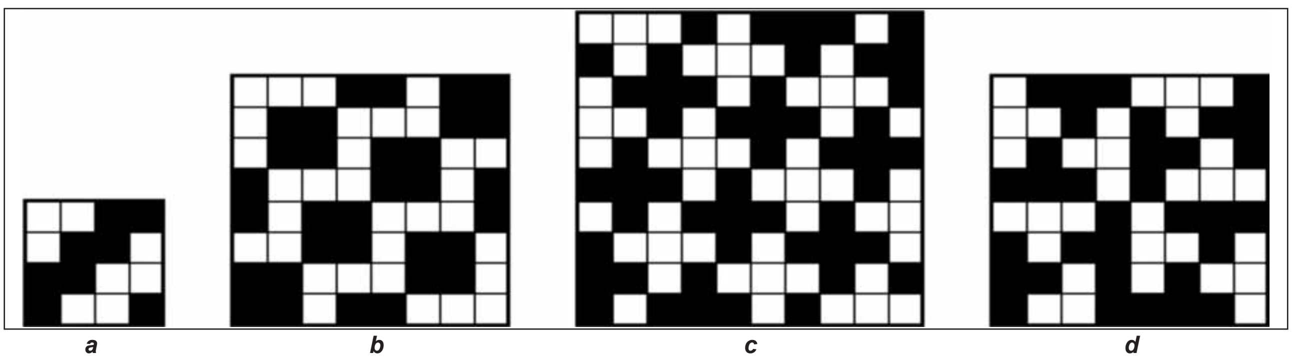

Fig. 1. Weave patterns: *a* – 2/2 twill, *b* – matt twill, *c* – cellular weave, *d* – diced weave

Methods

Yarn sizing and desizing

The yarns were not enough tensile strength, therefore; they are sized. Synthetic sizing liquors were prepared in-house finishing laboratory; Ensize TX11 5% was used for size recipe. Moreover, Wachs 2% of sizing agent was also added to all size recipes. Size liquors were heated up to 80°C and scoured at 80°C during 20 minute. The temperature of sizing chamber was set 80°C, whereas temperature of heating chamber was set 86°C during sizing process. All conditions mentioned did not change during the process, so it can be claimed that the conditions for all the yarns tested were the same.

All fabric samples after woven, were applied desizing process, in order protect test result from sizing agents, in fastness laboratory of in-house at 60°C during 20 minute.

Synthesis of titanium dioxideby Sol-Gel technique using titanium isopropoxide

The synthesis of titanium dioxide by Sol-Gel techniques are given below:

Procedure I: Titanium (IV) isopropoxide (97%), and glacial acetic acid were added as starter and catalysts respectively to the solvent of isopropanol. The mixture was stirred at room temperature during 30 minutes and then tetraethyl orthosilicate was added to this mixture as starter. Transparent solution was prepared by stirring the mixture at room temperature for 3 hours.

Procedure II: Fabric samples were immersed into transparent solution during 30 seconds and then squeezed in foulard. Later, they were dried at 80°. Immersing, squeezing and drying were repeated three times. Poly-condensation of Sol-Gel on fabric was carried out at 150° during 5 minutes.

Determination of Ultraviolet Transmittance Spectra-Average Transmittances of UVA and UVB

The transmittance spectra were determined using the SDLATLAS Ultraviolet Protection Measurement Device (USA) (figure 2) by the in vitro method, according to the indications of the standard AS/NZS 4399 [20]. Five specimens of each one of the 8 fabrics were taken. The transmittance spectra of each specimen was determined in duplicate, one measure in the direction of the warp and another in the direction of the weft, giving a total of 10 measurements per fabric sample using the Sun Protection Measurement Program.

The proportion of the incoming light that is transmitted is different for every wavelength. The diffuse transmittance spectrum is the representation of the proportion of ultraviolet radiation transmitted against the wavelength (from 290 to 400 nm). Because of the fact that there is a great difference in the effect that the UVA and UVB radiation has on the human skin, it is interesting to have a parameter that quantifies the

Fig. 2. Ultraviolet Protection Measurement Device

amount of both UVA and UVB radiation that passes through the fabric. According to the Standard AS/NZS 4399 [20], the UVA and UVB transmittances through the fabric is defined as the arithmetic mean of the transmittances in the ultraviolet range wavelengths, from 315 to 400 nm and from 290 to 315 nm, respectively (equation 2 and 3).

$$UVA_{AV} = \frac{T_{315} + T_{320} + ... + T_{400}}{18} \quad (2)$$

$$UVB_{AV} = \frac{T_{290} + T_{295} + ... + T_{315}}{6} \quad (3)$$

Where T_λ is the spectral transmittance at wave length λ.

It is especially important that the UVB transmission is as low as possible, as the radiation in this wavelength interval is much more damaging for the human skin.

Determination of Ultraviolet Protection Factor

The UPF of the fabrics was also determined using the SDLATLAS Ultraviolet Protection Measurement Device by the in vitro method, according to the indications of the standard AS/NZS 4399[20]. The UPF of each specimen is calculated using the Sun Protection Measurement Program as follows:

$$UPF_i = \frac{\sum_{\lambda=290}^{400} E_\lambda \times S_\lambda \times \Delta\lambda}{\sum_{\lambda=290}^{400} E_\lambda \times S_\lambda \times T_\lambda \times \Delta\lambda} \quad (4)$$

Where E_λ is Commission Internationale de l'Eclairage relative erythemal spectral effectiveness, S_λ – solar spectral irradiance, T_λ – spectral transmittance of the fabric, $\Delta\lambda$ – wave length step in nm and λ – wavelength in nm.

The Rated UPF of the sample is calculated introducing a statistical correction. Starting from the standard deviation of the mean UPF, the standard error in the mean UPF is calculated for a 99% confidence level. The Rated UPF will be theme an UPF minus the standard error, rounded down to the nearest multiple of five.

Table 2

UPF CLASSIFICATION SYSTEM OF SUN-PROTECTIVE CLOTHING, FOR THE PURPOSES OF LABELLING [16]			
UPF range	**UVR protection category**	**Effective UVR transmission (%)**	**UPF rating**
15–24	Good protection	6.7–4.2	15, 20
25–39	Very good protection	4.1–2.6	25, 30, 35
40–50, 50+	Excellent protection	≤2.5	40, 45, 50, 50+

$$UPF_r = \overline{UPF} - t_{\frac{\alpha}{2},N-1}\frac{SD}{\sqrt{N}} \quad (5)$$

where $\overline{UPF}$ is mean UPF, $t_{\alpha/2,N-1}$ is t variate for a confidence level α = 0.005, SD is standard deviation of UPF. If the rated UPF determined using the above formula is less than the lowest individual UPF measurement for that sample, then the rated UPF shall be the lowest UPF measured for the specimens, rounded down to the nearest multiple of five. The Australian/New Zealand Standard establishes, in addition, a classification system of fabrics according to their sun-protective properties. For the purpose of labelling, sun-protective clothing shall be categorised according to its rated UPF, as shown in table 2.The rated UPF is always a multiple of five. For UPF ratings of 51 or greater, the term 50+ shall be used.

Results and discussions

Results experimentally obtained for upholstery fabric samples have been evaluated graphically and then statistically by Analysis of Variance (ANOVA) according the General Linear Model with SPSS 15.0 Statistical Software. Significance degrees (p), which have been obtained from ANOVA, have been compared with significance level (α) of 0.05. The effects, whose significance degrees have been lower than 0.05, have been interpreted as statistically important.

Ultraviolet Protection Factor

UPF values of untreated and titanium dioxide treated fabric samples are given in figure 3 and 4. It is observed from figure 3 that UPF of fabric samples increased in agreement with polyester fibre ratio. This because of the fact that polyester has a higher degree of UVR absorption than cotton fibres [21, 22]. The samples C1, C2, D1 and D2 have lower degree of UPF than A1, A2, B1, and B2. This due to the fact that cellular and diced woven fabric samples have higher porosities than 2/2 twill and matt twill woven fabric samples. Although the porosity of cellular weave are bigger than that of diced weave, the UPFs of C1 and C2 were higher than those of D1 and D2. This is because of the fact that the thickness of cellular weave is higher than diced weave. The sample B1 and B2, whose weaves are matt twill weave, have higher UPF values than A1 and A1, whose weaves are 2/2 twill weave, 2/2 twill weave has a bigger porosity than matt twill weave though. The reason for the cellular and diced weaves is also valid here. The differences between the UPF of A1, A2, B1, B2 and those of C1, C2, D1, D2 are lower than expected, considering their porosities. Because, the thickness of cellular and diced woven fabric samples are higher than 2/2 twill and mat twill woven fabric samples. These are also valid for the titanium dioxide treated fabric samples.

Figure 3 shows that the UPF values of the treated fabric had higher 67.48% on the average than those of untreated fabrics. Because titanium dioxide is a photo catalyst; when it is illuminated by light of energy higher than its band gap, electrons in TiO_2 will jump from the valence band to the conduction band, and the electron (e) and electric hole (h^+) pairs will form on the surface of the photo catalyst. The negative electrons and oxygen will combine to form O_2, radical ions, whereas the positive electric holes and water will generate hydroxyl radicals OH^-. Since both products are unstable chemical entities, when the

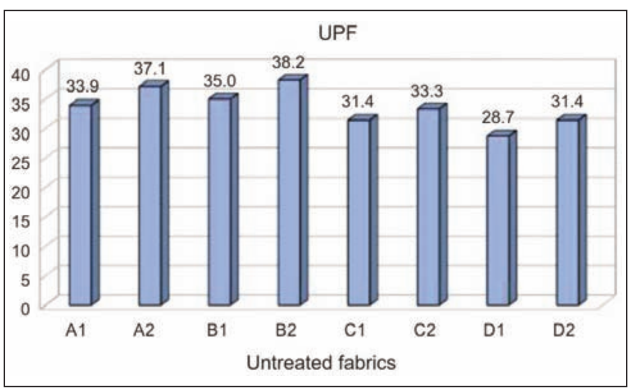

Fig. 3. UPF of untreated fabric samples

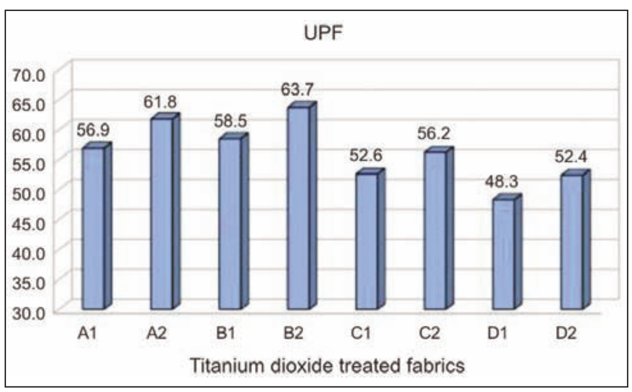

Fig. 4. UPF of titanium dioxide treated fabric samples

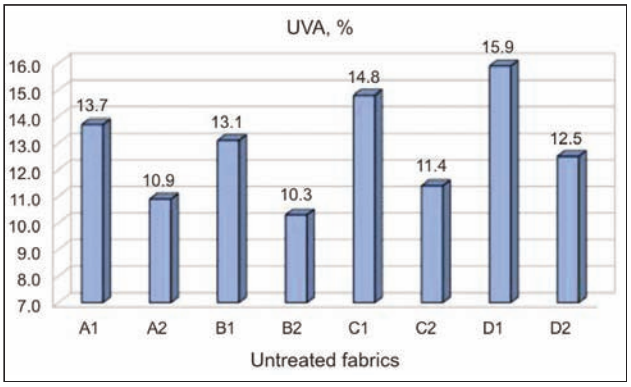

Fig. 5. UVA transmittance of untreated fabric samples

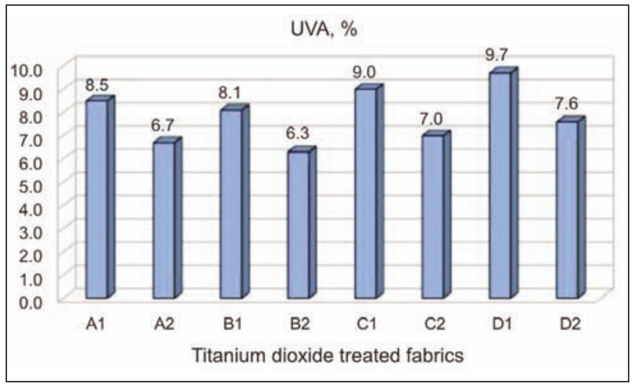

Fig. 6. UVA transmittance of titanium dioxide treated fabric samples

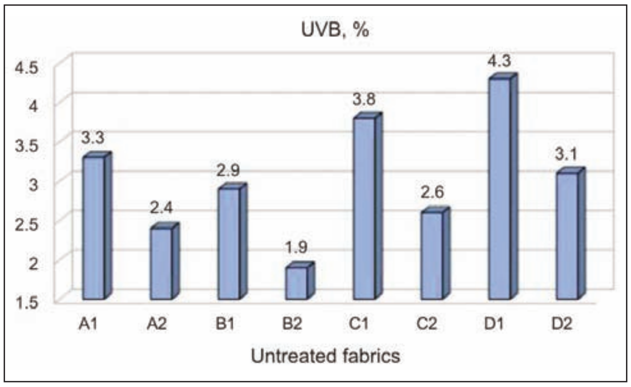

Fig. 7. UVB transmittance of untreated fabric samples

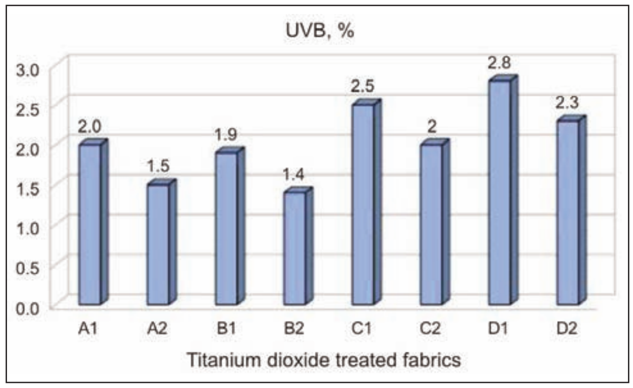

Fig. 8. UVB transmittance of titanium dioxide treated fabric samples

organic compound falling on the surface of the photo catalyst, it will combine with $O2^{-}$ and OH^{-} and turn into carbon dioxide (CO_2) and water (H_2O) [23].

The variance analysis showed that both the effects of weave, raw material and titanium dioxide finish on UPF of the cotton/polyester blend fabrics are statistically significant, getting the p-values of (0.013), (0.022) and (0.001) respectively.

UVA and UVB Transmittance Spectra

Average percentage of UVA and UVB transmittances of untreated fabric samples are shown figure 5 and 6 respectively, whereas those of titanium dioxide treated fabric samples are shown Figure 7 and 8 respectively. It is seen from the figure 5 and 7 that the UVA and UVB transmittances of A2, B2, C2 and D2, woven with 35/65 % cotton/polyester blend yarn are lower than those of A1, B1 C1 and D1, woven with 67/33 % cotton/polyester blend yarn. The reason for UPF is also valid here. Samples A1, A2, B1 and B2, whose weaves are 2/2 twill and matt twill weaves respectively, show better UVA and UVB transmittance performance than C1, C2, C3 and C4, whose weaves are cellular and diced weaves respectively. This is due to the fact that 2/2 twill and matt twill weaves have lower porosity than cellular and diced weaves. Although the porosity of 2/2 twill weave is almost equal to the that of matt twill weave, matt twill woven fabric samples, B1 and B2, show better UVA and UVB transmittances than 2/2 twill woven fabric samples, A1 and A2. This is because of the fact that the thickness of the matt twill woven fabric samples are bigger than that of 2/2 twill woven fabric samples. Similarly, cellular weave have almost the same porosity with the diced weave. Cellular woven fabric samples, C1 and C2, perform better UVA and UVB transmittance than diced woven fabric samples, D1 and D2. The reason for the samples A1, A2, B1 and B2 is also valid here. The differences between the UVA and UVB transmittances of A1, A2, B1, B2 and those of C1, C2, D1, D2 are lower than expected, considering their porosities. Because, the thickness of cellular and diced woven fabric samples are higher than 2/2 twill and mat twill woven fabric samples. These are also valid for the titanium dioxide treated fabric samples. The UVA and UVB transmittances of fabric samples treated with titanium dioxide decreased as a mean 38.68% and 31.96% respectively. The reason explained for UPF is also valid here.

From the results of ANOVA, it can be concluded that the effects of weave, raw material and titanium dioxide finish on the UVA and UVB transmittances of cotton/polyester fabrics are statistically important at the significance level of 0,05, getting the p-values of (0.032), (0.021) and (0.001) respectively.

CONCLUSIONS

Statistical and experimental studies have been performed within the scope of this study to determine the effects of yarn and fabric structural parameters, and also titanium dioxide finish on the ultraviolet protection factor, UVA and UVB transmittances of cotton/polyester blend woven fabrics used for clothing. The important results obtained with these analyses are summarized below:

- The UVR transmitted through textile fabrics consists of the unchanged waves that pass through the interstices of the fabrics as well as scattered waves that have interacted with the fabrics. Another part is absorbed when it penetrates the sample, and is converted into a different energy form. The portion of radiation that travels through the fabric and reaches the skin is appropriately referred to as the 'transmittance component'.
- Weave pattern is one of the basic factors that have a direct effect on UPF and UVA, UVB transmittances of fabrics by changing porosity and thickness of fabrics. The fabrics whose porosity is lower and thickness is higher show better UV protection and transmittance performances.
- Untreated and titanium dioxide treated matt twill woven fabrics, whose porosity is lowest, have the highest UPF (38.2, 63.7) and the lowest UVA (10.3, 6.3), UVB (1.9, 1.4) transmittances values, respectively. And also, when the porosity of fabrics was approximately equal to each other, fabric thickness determined the UPF, UVA and UVB transmittances of fabrics as seen between cellular and diced woven fabrics and also 2/2 twill and matt twill woven fabrics.
- Due to their high thickness, cellular and diced weaves show better UV protection and transmittance characteristics, they have high porosities though.
- Fabrics made from 35/65 cotton/polyester blend yarns have higher UPF and lower UVA, UVB transmittance values than fabrics made from 67/33% cotton/polyester blend yarns, thanks to higher UV absorption capacity of polyester fibres.
- Titanium dioxide treated fabrics show better UV protection and transmittance characteristics than the untreated fabrics because titanium dioxide absorbs UV rays. While the UPF of treated fabrics increased, UVA and UVB transmittances of these fabrics decreased significantly.

Consequently, weave pattern, which basically refers to weave construction, determines the weave characteristics such as porosity and thickness, has effects on the UV protection and UVA, UVB transmittance properties of cotton/polyester blend woven fabrics used for clothing. In addition to this, chemical characteristics of fibres, which are raw material of the yarns determine the chemical properties of yarns, they also affect properties which are mentioned above. The capability of titanium dioxide loaded fabrics against ultraviolet radiation were enhanced.

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Synthesis of halogen and formaldehyde free bio based fire retardant for cotton

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REZUMAT – ABSTRACT

Sinteza inhibitorului de ignifugare bazat pe halogeni și formaldehidă pentru bumbac

Caracterul slab ignifug al țesăturii din bumbac reprezintă unul din principalele sale dezavantaje. Există numeroase soluții de ignifugare care au fost dezvoltate și aplicate pe țesătura de bumbac. Cu toate acestea, cele mai multe dintre ele sunt fie mai puțin eficiente, fie sunt toxice, conțin formaldehidă sau halogen. In acest studiu, acidul citric chimic bio este polimerizat cu dihidrogenfosfat de amoniu. Au fost optimizați diferiți parametri, cum ar fi nivelul acidului citric, hidrogenofosfatului de amoniu și temperatura de polimerizare. Țesătura tratată cu rețeta optimizată recent dezvoltată a prezentat o lungime și o lățime superioară a zonei de carbonizare, un indice limită de oxigen % și un unghi de revenire din șifonare, mai bun, în comparație cu un produs ignifug convențional toxic pe bază de formaldehidă. Analizele SEM și FTIR au confirmat, de asemenea, aplicarea cu succes a polimerului pe țesătura tratată.

Cuvinte-cheie: ignifug, țesătură din bumbac, dihidrogenofosfat de amoniu, acid citric, lungimea zona de carbonizare

Synthesis of halogen and formaldehyde free bio based fire retardant for cotton

Poor fire retardancy of the cotton fabric is one of its major drawbacks. Therefore, there are numerous fire retardant chemistries which have been developed and being applied onto the cotton fabric. However, most of them are either less effective, toxic, contain formaldehyde or halogen. Therefore, in this research bio based chemical citric acid is polymerized with di ammonium hydrogen phosphate. Various parameters like level of citric acid, di ammonium hydrogen phosphate and temperature of polymerization were optimized. Fabric treated with newly developed optimized recipe exhibited superior char length, char width, limiting oxygen index % and crease recovery angle as compared to conventional toxic formaldehyde based fire retardant. SEM and FTIR analysis also confirmed the successful application of the polymer onto the treated fabric.

Keywords: fire retardant, cotton fabric, di ammonium hydrogen phosphate, citric acid, char length

INTRODUCTION

Cotton is the most widely used natural fiber. However, it is extremely flammable and can cause serious damage to the life and property [1–3]. Above 12 million fires breaks out, 300,000 people lost their lives and millions are injured every year in only China, Europe, United States and Russia. In addition, more than $500 million property loss is reported in only above mentioned countries [4]. Therefore, with the passage of time fire retardancy of cotton fabrics are gaining importance due to the ever increasing loss of lives and property, strict health and safety rules, and more awareness among customers [5].
Typically used effective fire retardants like N-methyloldimethylphosphonopropionamide (MDPA) commonly known as Pyrovatex and Tetrakishydroxymethyl - phosphonium chloride (HTPC) are not environment friendly. Pyrovatex contain toxic formaldehyde, which is released during synthesis, application, storage and consumer use [6–8]. Formaldehyde is a known toxic, skin and eye irritant, and most dangerous of all confirmed human carcinogenic [9]. Moreover, Pyrovatex required formaldehyde based enhancer trimethylol melamine for optimum results, which will significantly increase the amount of formaldehyde in the recipe. In addition, this recipe required high amount of chemical dosage for cotton and exhibited pungent smell. Tetrakishydroxymethylphosphonium chloride (THPC) is also an efficient flame retardant but it required an ammonia chamber during application which makes it less desirable in most of the mills. In addition, release of pungent and toxic ammonia is also a serious issue [10–11].
Ammonium phosphate salts are document as fire retardants. However, these ammonium phosphate salts are significantly less effective as compared to commercially available fire retardants like Pyrovatex and THPC. Zero formaldehyde alternatives such as butane tetra carboxylic acid (BTCA) have been examined with Pyrovatex to impart superior flame retardancy. However, BTCA is too costly and Pyrovatex contain formaldehyde. In addition, researchers did use cost effective, zero formaldehyde based citric acid with Pyrovatex in the padding recipe for cotton fabric and improvement in the fire retardancy was reported [10]. Oil and water repellency of the treated fabrics has been improved when carboxylic acid based maleic acid and citric acid was incorporated in the recipe [12–13]. Citric acid is the second most

extensively used chemical which is produced by industrial bio fermentation and abundantly available. Citric acid is also used as a cross-linker in wool and silk fabrics as an alternative to formaldehyde cross-linker [14–15]. Citric acid effect on the range of dyed cotton fabric shade has also been reported and its performance was superior to that of formaldehyde based cross-linker [16]. However, in all of the above researches citric acid was used directly to the fabric without any polymerization.

Due to excellent cross-linking properties of citric acid for cotton and existence of carboxylic and hydroxyl reactive groups, it can be used in the synthesis of fire retardant for cotton fabrics. Therefore, in this research ammonium phosphate based monomer is polymerized with citric acid at various conditions, which was then applied to cotton fabric and treated cotton fabrics performance were evaluated.

EXPERIMENTAL PART

Materials and chemicals

Bleached cotton fabric was used in this research. Fire retardant (Pyrovtex CP New) and catalyst (CHN) were donated by Huntsman. Citric acid, phosphoric acid and di ammonium hydrogen phosphate were purchased from Sigma Aldrich.

Method

Recipe was applied onto the cotton fabric by padding the cotton fabric at 75% pick up. Drying and curing of the fabric was performed at 100°C for three minutes and at 180°C for 2 minutes respectively. Conditioning of samples was carried out at 20°C and 65% relative humidity for 24 hours before performing any testing. Sample damaged char length and width was measured by using BS 5438:1989, Test 2B. Limiting oxygen index (LOI) % was assessed by following ASTM D 2863. Crease recovery performance was assessed by following BS EN 22313:1992 method. AATCC 147 method was used for the analysis of antimicrobial activity of the cotton fabrics. Gold coater was used to coat the cotton fabric samples for 4 minutes prior to the scanning electron microscope (SEM) analysis. SEM was used to assess the cotton fabric sample. Fourier transform infrared spectroscopy (FTIR) analysis was performed on the cotton samples with the background scans of 32 and from the wave number range of 650 to 4000 cm^{-1}.

RESULTS AND DISCUSSIONS

Untreated cotton fabric was burnt completely demonstrating the need to apply the fire retardant onto the cotton fabric. Pyrovatex CP New is one of the most widely used fire retardant for cotton and therefore, it has been used to set the bench mark for this research study. At the level of 20% Pyrovatex along with the manufacturer recommended amount of phosphoric acid and formaldehyde based trimethylol melamine catalyst (CHN), cotton sample exhibited char length of 95 mm and width of 29 mm, table 1. However, burnt sample char length and width was

Table 1

CHAR LENGTH AND WIDTH OF PYROVATEX AND DI AMMONIUM HYDROGEN PHOSPHATE TREATED COTTON FABRIC

Fire retardant chemical (%)	**Catalyst/ Cross-linker**	**Char length** (mm)	**Char width** (mm)
Control fabric	-	Complete burn	Complete burn
Pyrovtex, 20%	Phosphoric acid 2.5%, CHN catalyst 1.5%	95	29
Pyrovatex, 40%	Phosphoric acid 6%, CHN catalyst 2.2%	59	25
Di ammonium hydrogen phosphate (DAHP)			
5%	-	180	46
10%	-	138	38
20%	-	97	28
40%	-	100	29

reduced to 59 mm and 25 mm respectively at 40% of the Pyrovatex. Diammonium hydrogen phosphate was applied to the cotton fabric at various levels from 5% to 40%.Gradual decrease in the char length and width of the treated fabric from 0% to 20% was observed. Lowest char length and width of 97 mm and 28 mm respectively was obtained at 20% of diammonium hydrogen phosphate. However, at the level of 40%, there was slight increase in the char length and width of the fabric possibly due to the saturation effect.

Alone citric acid treated cotton fabric was completely burnt and demonstrated no improvement in the fire retardancy. However, there was improvement in the char length and width when di ammonium hydrogen phosphate and citric acid was polymerized and applied on to the cotton fabric. Polymerization reaction was carried out at four levels of temperatures 25°C, 50°C, 75°C and 100°C for one hour each. DAHP amount was varied from 10% to 40%, while citric acid amount was varied from 5 to 15%. Lowest char length and width of 54 mm and 28 mm was obtained when 10% DAHP and 10% citric acid was polymerized at the temperature of 75°C for one hour, table 2. Surprisingly, this char length and width was even lower than 40% of the Pyrovatex treated cotton fabric. It clearly demonstrated that citric acid and DAHP combination at optimum condition was more efficient in imparting the fire retardancy to the cotton fabric as compared to double the amount of conventionally used Pyrovatex fire retardant.

Limiting Oxygen Index (LOI) is an important objective method to measure the minimum amount of oxygen required to burn the sample. Greater the value of LOI percentage better will be fire retardant of the fabric. Untreated cotton fabric demonstrated the LOI% value of 18.1% which reflects that it will be highly

Table 2

CHAR LENGTH AND WIDTH OF CITRIC ACID AND DI AMMONIUM HYDROGEN PHOSPHATE TREATED COTTON FABRIC				
Fire retardant chemical (%)	**Catalyst/Cross-linker**	**Polymerization temperature** (°C)	**Char length** (mm)	**Char width** (mm)
-	Citric acid, 5%	-	Complete burn	Complete burn
-	Citric acid, 10%	-	Complete burn	Complete burn
-	Citric acid, 15%	-	Complete burn	Complete burn
DAHP, 10%	Citric acid, 10%	25	101	31
DAHP, 10%	Citric acid, 10%	50	90	29
DAHP, 10%	Citric acid, 10%	75	54	28
DAHP, 10%	Citric acid, 10%	100	61	32
DAHP, 10%	Citric acid, 5%	75	71	32
DAHP, 10%	Citric acid, 15%	75	66	32
DAHP, 20%	Citric acid, 10%	75	56	30
DAHP, 40%	Citric acid, 10%	75	58	30

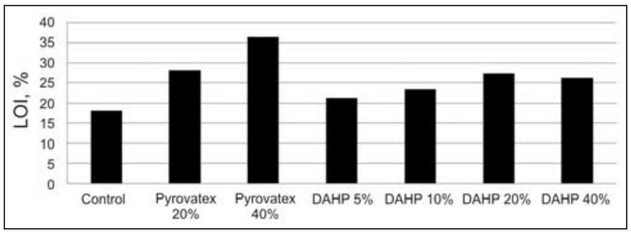


Fig. 1. LOI% ofPyrovatex and di ammonium hydrogen phosphate treated cotton fabric

flammable as the oxygen amount in normal air is around 21%. However, LOI% value of 36.3% was obtained at the 40% Pyrovatex treated fabric, figure 1. In addition, there was gradual increase in the LOI% value with the increase in the level of DAHP up to 20% as compared to untreated fabric. However, highest LOI% value of 27.4% was achieved when 20% DAHP was used in the recipe. This LOI% value was 8.9% lower than the highest Pyrovatex LOI% value. It clearly demonstrates that there is a need to enhance the performance of the DAHP if its performance needs to be competitive with commercially available Pyrovatex.

Alone citric acid treated fabric at the dosage of 5% to 15% did not exhibit any significant improvement in the LOI% values as compared to the untreated fabric, figure 2. However, there was gradual increase in the LOI% value when temperature of polymerization was raised from 25°C to 75°C. Highest LOI% of 37.4% was achieved when polymerization temperature was 75°C with the combination of 10% DAHP and 10% citric acid. Similar trends were observed between char length and width as well as in LOI% values and both methods confirm the effectiveness of the finish formulation at optimum conditions.

Typically, cotton fabric exhibit poor easy care performance. Untreated fabric exhibited poor crease recovery angle of only 128 degree, figure 3. However, slight improvement in the crease recovery angle was observed when 20% and 40% of the Pyrovatex was

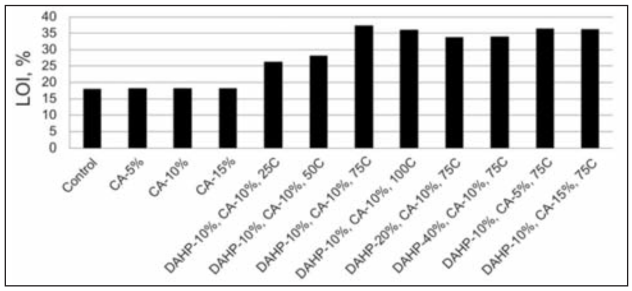


Fig. 2. LOI%of citric acid and di ammonium hydrogen phosphate treated cotton fabric

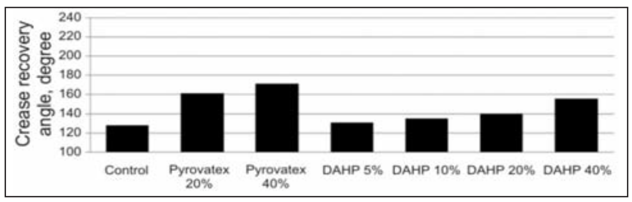


Fig. 3. Crease recovery angle of Pyrovatex and di ammonium hydrogen phosphate treated fabric

added in the recipe. Pyrovatex has methylol terminal group and capable of forming covalent bond with cotton which will increase the crease recovery angle of the treated fabric. In case of Pyrovatex highest angle of 171 degree was achieved. DAHP imparted marginal effect on the crease recovery angle of the treated fabric especially at low dosages.

There was gradual increase in crease recovery angle of the citric acid treated fabric from 128 to 198 degree when its level was raised from 0% to 15%, reflecting the effectiveness of citric acid as cross-linker. Polymerization of 10% DAHP with 10% citric acid at 25°C exhibited crease recovery angle of 191 degree which is higher than alone 10% citric acid, figure 4. However, good angle of 231 degree was reported when temperature of polymerization was raised to 75°C. In addition, highest crease recovery of 240 degree was obtained when 10% DAHP, 15% CA was polymerized at 75°C.

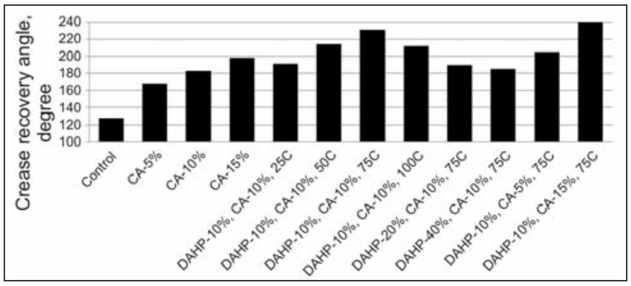
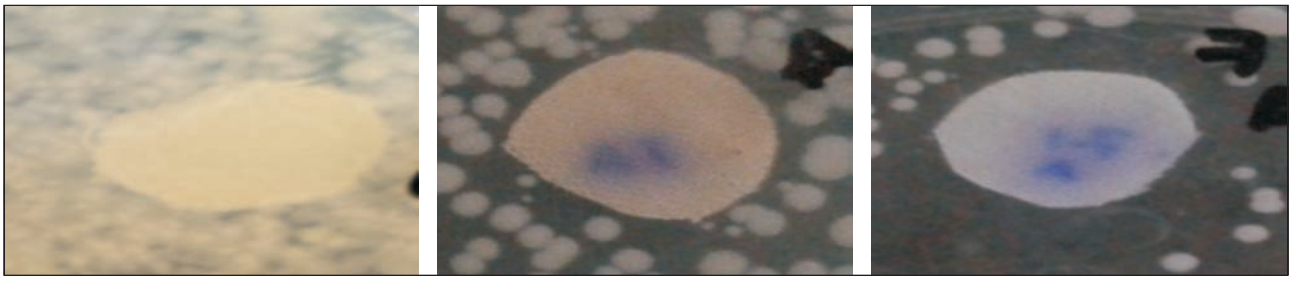


Fig. 4. Crease recovery angle of citric acid and di ammonium hydrogen phosphate treated fabric

Table 3

WIDTH OF CLEAR ZONE OF INHIBITION OF TREATED AND UNTREATED COTTON FABRIC			
Fire retardant	**Catalyst/ Cross-linker**	**Reaction temperature** (°C)	**Width of clear zone of inhibition, *E. coli*** (mm)
Control	-	-	0.00
DAHP, 10%	-	-	0.18
DAHP, 10%	Citric acid, 10%	75	0.74



a *b* *c*

Fig. 5. Antimicrobial figure of treated and untreated cotton fabrics: *a* – Untreated; *b* – DAHP (10%); *c* – DAHP (10%), CA (10%)

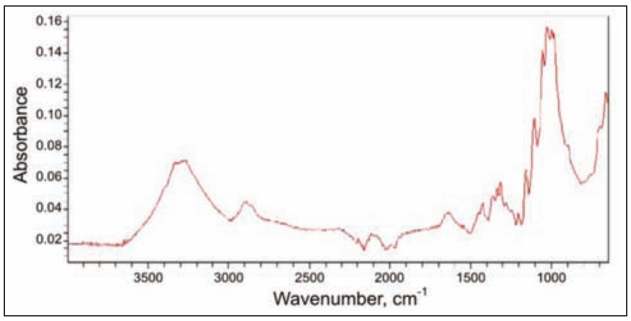
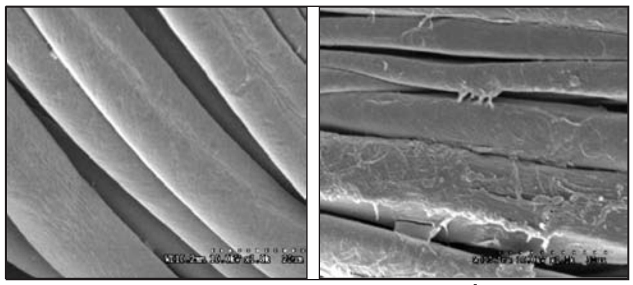


Fig. 6. FTIR analysis of untreated cotton fabric



a *b*

Fig. 8. SEM images of *a* – untreated and *b* – DAHP, 10%, citric acid, 10%, 75°C treated fabric

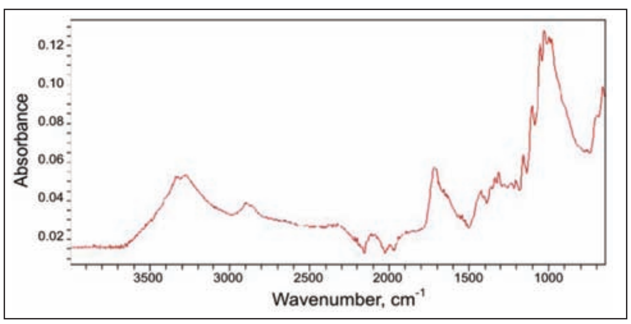


Fig. 7. FTIR analysis of DAHP-CA treated cotton fabric

Cotton being natural fabric is easily attacked by microbes (Balakumaran et al., 2016). Therefore, antimicrobial performance of the untreated and treated fabric exhibiting best results with respect to fire retardancy was assessed. As expected, untreated fabric exhibited poor antimicrobial performance, figure 5. However, width of clear zone of inhibition of 0.18 mm was achieved at 10% DAHP. However, excellent antimicrobial activity having 0.74 mm clear zone of inhibition was reported when 10% DAHP and 10% citric acid was polymerized at 75°C, table 3. It is not surprising as citric acid is a known antimicrobial agent.

FTIR analysis was performed on the selected samples. There was no presence of ester bond on the untreated cotton fabric, figure 6. However, carbon-oxygen double bond, C=O absorption was found in the range of 1680–1750 cm^{-1}, figure 7, which reflect the presence of ester bond in the treated fabric. It is the proof that citric acid in combination with DAHP did make ester bond with cotton fabric, which in turn responsible for improved fire retardancy and crease recovery angel of the treated fabric.

Scanning electron microscope (SEM) images of the untreated fabric exhibited smooth surface of the untreated fabric, figure 8, *a*. However, there was proof of coating on the surface of the fabric when it was treated with the polymerized solution of 10% DAHP and 10% citric acid at 75°C. It is the further proof of successful coating of the recipe on to the fabric in the given condition.

CONCLUSION

Polymerization of DAHP and citric acid under optimum conditions and its application on to the cotton fabric successfully improved the fire retardancy of the treated fabric. Best result was obtained when 10% of DAHP and 10% of citric acid was polymerized at 75°C for one hour. Lowest char length and width of 54 and 28 mm, and highest LOI% of 37.4% was obtained at the above mentioned optimized recipe. There was significant increase of 103 degree in the crease recovery angle at the optimized recipe as compared to the control cotton fabric. Good antimicrobial performance was also achieved by the optimized recipe. FTIR and SEM analysis confirmed the presence of coated polymer being present on the treated cotton fabric. The developed recipe has the significant potential in the field of sustainable fire retardancy as it is completely formaldehyde free, halogen free, effective in improving fire retardancy of the treated cotton fabric and overcome cotton fabric other drawbacks such as poor antimicrobial and low easy care performance.

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E-learning in advanced textiles

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MIRELA BLAGA

REZUMAT – ABSTRACT

E-learning în domeniul textilelor avansate

E-learning este util în special pentru discipline tehnologice, care sunt într-o dezvoltare continuă. O soluție pentru dezvoltarea tehnologiilor textile este adusă prin proiectul Erasmus Plus Advan2Tex: "Curs e-learning pentru domeniile textile inovatoare". O platformă de e-learning în mai multe limbi, cu 7 module contribuie la dezvoltarea instruirii în domeniul textilelor. Cele șapte module sunt: "Tehnologii avansate de tricotare", "Protopirea virtuală a articolelor de îmbrăcăminte, scanare 3D, îmbrăcăminte pentru persoanele cu nevoi speciale", "Noua metodă pentru testarea materialelor textile", "Standardizarea testării textilelor", "Noi tehnologii pentru textile durabile, LCA, Eco-etichetare", "Antreprenoriat", "Managementul inovării". Aceste module au fost realizate de 5 parteneri din 4 țări europene: INCDTP – București și UT Iași din România, Universitatea din Minho – Portugalia, TZU – Republica Cehă și Universitatea din Maribor – Slovenia. Adresa URL a platformei de e-learning este www.advan2tex.eu/portal/ și se pot face înscrieri la cursurile de e-learning în domeniul textilelor avansate.

Cuvinte-cheie: e-learning, textile, instrumente, VET

E-learning in advanced textiles

E-learning is especially useful for technological disciplines, which are in continuously development. A solution for the development of textile technologies is brought by the Erasmus Plus project Advan2Tex: "E-learning course for innovative textile fields". A multi-language e-learning platform with 7 modules is contributing to the development of textile training. The seven modules are: "Advanced Knitting Technologies", "Virtual prototyping of garments, 3D scanning, clothing for people with special needs", "New method for testing textile materials", "Standardization of textile testing", "New sustainable textile technologies, LCA, Eco-labelling", "Entrepreneurship", "Innovation management". These modules were accomplished by 5 partners from 4 European countries: INCDTP – Bucharest and UT Iasi from Romania, University of Minho – Portugal, TZU – Czech Republic and University of Maribor – Slovenia. The URL address of the e-learning platform is www.advan2tex.eu/portal/ and registrations can be performed to the e-learning courses in advanced textiles.

Keywords: e-learning, textiles, instruments, VET

INTRODUCTION

E-learning is especially useful for technological disciplines. These are in a continuously development and for this reason the learning and training content has to be updated. Textile engineering is a field with involvement of specific technologies. Textile products with high-value are market-competitive and are the result of advanced technologies. The acquisition of competences in new textile technologies is the key to promote this field and e-learning brings great benefit in this regard.

E-learning courses may be applied for various fields of teaching. A classification of disciplines for adequate content for e-learning may include:

1. Primary school learning fields.
2. Humanistic sciences.
3. Creative arts and show arts.
4. STEM (Science, Technology, Engineering and Mathematics), including textile technology.

Several arguments speak for the implementation of each of the mentioned disciplines as e-learning content. Thus, primary school learning fields are useful, taking into consideration the following [1]:

– Children are living in a digital world and have to cope with the new challenges;
– According to a survey, 86% from the children in Romania access Internet daily [2];
– An increased orientation on behalf of governmental bodies is focused on the useful integration of technology into primary school;
– A better joining of formal and informal learning is ensured.

Human sciences include a broad range of disciplines, which are specifically supported by ICT instruments. The arguments for combining human sciences with technology are still a matter of debate, however, some strong points are given by an efficient communication, understanding of written text, understanding of the social environment and support for research [1].

Creative arts and show arts are nevertheless suitable for e-learning. Applications such as interpreting texts, virtualizing tours of museums, editing video/audio scenarios or drawing painting, are going to support

creativity, which is one of the most significant competences for the learners in the 21st century.
However, for STEM (Science, Technology, Engineering and Mathematics), the results of e-learning are especially relevant, due to:
– Structured content of informatics tools adaptable to structured learning content of STEM;
– Possibility to show graphics, charts and animation related to the functioning of machinery;
– Possibility to visualize videos related to technological processes;
– Good compatibility between ICT and other STEM fields.
Particularly, textiles represent a multi-disciplinary STEM field, including knowledge of physics, chemistry, mechanics and mechatronics, biology, mathematics and specific engineering knowledge, which could easily benefit from e-learning support [3–6].
These considerations were taken into account when initiating the Erasmus Plus project: "E-learning course for innovative textile fields" – Advan2Tex. It is a strategic partnership project, funded by the European Commission for the period 2014–2016. The partnership of the project consists in research providers having an important role in the textile field of their countries. The aim of the project is to foster the implementation of innovative textile technologies, by means of a dedicated e-learning platform and by organization of blended courses: a mixed solution for face-to-face and e-learning.
The partnership of the project consists of the following research organizations: INCDTP – Bucharest and UT Iasi from Romania, University of Minho – Portugal, TZU – Czech Republic and University of Maribor – Slovenia. The textile industry in these countries is especially important on European level, while the application of new, advanced textile knowledge contributes to the manufacturing of high-value added products.
The e-learning platform has the URL address: www.advan2tex.eu/portal/. It contains seven modules in 5 languages: the 4 national languages of the partners – Czech, Portuguese, Romanian and Slovenian and English. The seven modules are:
– "Advanced Knitting Technologies";
– "Virtual prototyping of garments, 3D scanning, clothing for people with special needs";
– "New method for testing textile materials";
– "Standardization of textile testing";
– "New sustainable textile technologies, LCA, Eco-labelling";
– "Entrepreneurship";
– "Innovation management".
The envisaged target group of trainees consists of professionals in the textile field, young entrepreneurs and students in higher textile education and the results of the blended courses showed a great impact with 176 trainees on the e-learning platform.

The Advan2Tex e-learning platform

The e-learning platform performed as part of the project is a Moodle one [7–8]. The e-learning platform is multi-language: it has a menu for switching between the languages of the project's partnership (figure 1):

Fig. 1. Multi-language menu

This menu switches only the platform's language background commands. Moodle provides versions of the platform in many languages, including the partnership languages, which are configurable from "Site administration → Language". However, the implemented e-learning content (the seven modules + quizzes) was as well prepared in all of the languages: Czech, English, Portuguese, Romanian and Slovenian. When navigating, for instance to the Czech course, the Moodle platform changes automatically the background language of the platform. The English language content was provided as an exchange and communication modality between the partners and for the visibility of the project's outputs on European and international level. Hence, the content of the platform includes the 7 modules and quizzes in all these five languages, addressing a wide European audience. Five course categories were configured, including the course in each language.
The e-learning course is structured in weekly format: the teaching of a module is foreseen for one week. Hence, a complete course lasts for 7 weeks, covering all the 7 modules.
Each course module/week comprises three Moodle elements (figure 2):

I. A Book resource with the content of the module
II. A Chat activity for interaction tutor-trainee
III. A Quiz activity for self-assessment and final multiple-choice tests

The course planning during one week: the first three days for learning the content of the Book module of approx. 50 pages with pictures, graphs and diagrams, the fourth day is for self-assessment and for an online chat session between the tutor and the trainees, while the fifth day is for rehearsal of the content. At the end of all the 7 weeks, a final assessment test is planned for the trainees.
I. The Book resource is configured on chapters and sub-chapters and it has a table of contents for their quick accessing. It has also navigation buttons for accessing the content. Here is a snapshot from the course on Virtual Prototyping (figure 3):

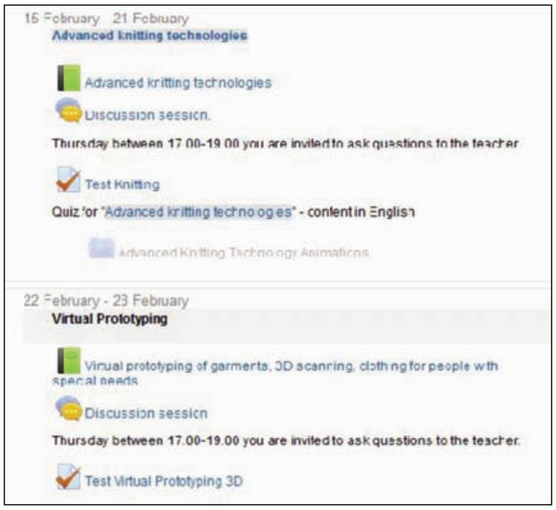


Fig. 2. The weekly structure of the e-learning course

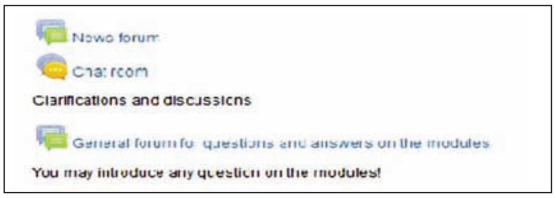
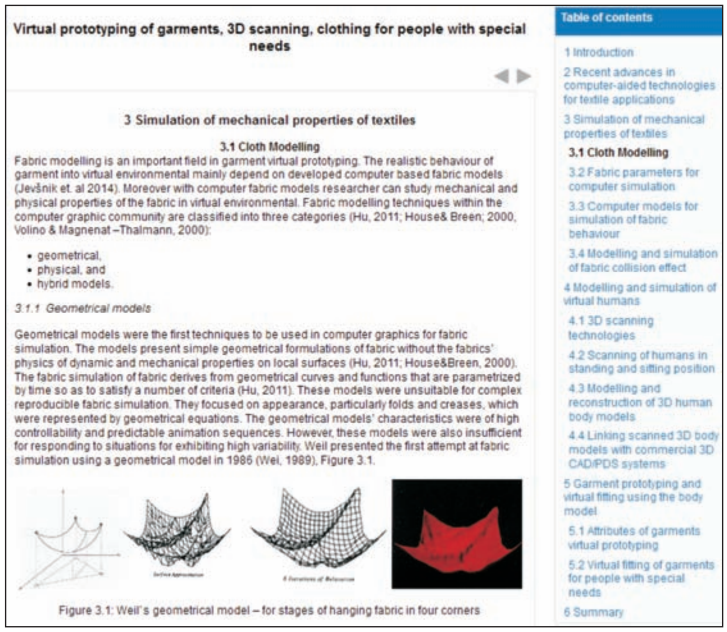


Fig. 4. Communication options between tutor and trainee



Virtual prototyping of garments, 3D scanning, clothing for people with special needs

3 Simulation of mechanical properties of textiles

3.1 Cloth Modelling

Fabric modelling is an important field in garment virtual prototyping. The realistic behaviour of garment into virtual environmental mainly depend on developed computer based fabric models (Jevšnik et. al 2014). Moreover with computer fabric models researcher can study mechanical and physical properties of the fabric in virtual environmental. Fabric modelling techniques within the computer graphic community are classified into three categories (Hu, 2011; House& Breen; 2000, Volino & Magnenat –Thalmann, 2000):

- geometrical,
- physical, and
- hybrid models.

3.1.1 Geometrical models

Geometrical models were the first techniques to be used in computer graphics for fabric simulation. The models present simple geometrical formulations of fabric without the fabrics' physics of dynamic and mechanical properties on local surfaces (Hu, 2011; House&Breen, 2000). The fabric simulation of fabric derives from geometrical curves and functions that are parametrized by time so as to satisfy a number of criteria (Hu, 2011). These models were unsuitable for complex reproducible fabric simulation. They focused on appearance, particularly folds and creases, which were represented by geometrical equations. The geometrical models' characteristics were of high controllability and predictable animation sequences. However, these models were also insufficient for responding to situations for exhibiting high variability. Weil presented the first attempt at fabric simulation using a geometrical model in 1986 (Wei, 1989), Figure 3.1.

Figure 3.1: Weil's geometrical model – for stages of hanging fabric in four corners

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2 Recent advances in computer-aided technologies for textile applications
3 Simulation of mechanical properties of textiles
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3.2 Fabric parameters for computer simulation
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4 Modelling and simulation of virtual humans
4.1 3D scanning technologies
4.2 Scanning of humans in standing and sitting position
4.3 Modelling and reconstruction of 3D human body models
4.4 Linking scanned 3D body models with commercial 3D CAD/PDS systems
5 Garment prototyping and virtual fitting using the body model
5.1 Attributes of garments virtual prototyping
5.2 Virtual fitting of garments for people with special needs
6 Summary

Fig. 3. Book resource with the content of a module and table of contents

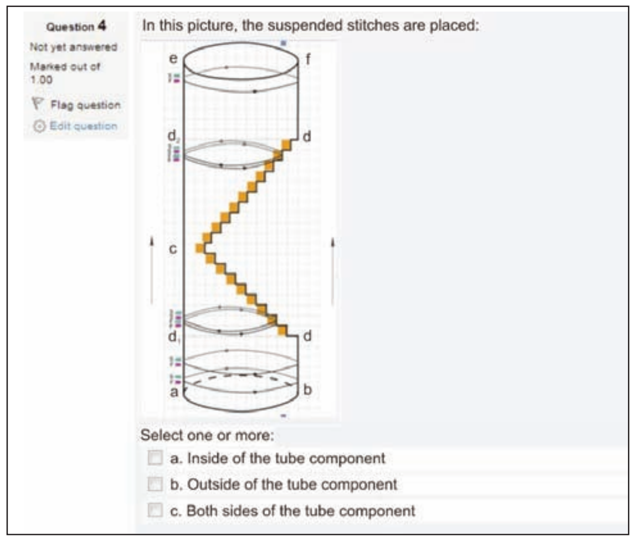


Fig. 5. Multiple choice question with pictures

II. The communication between tutors and trainees is performed via synchronous (Chat) and asynchronous (Forum) methods.

A synchronous chat activity is planned in each of the course's weeks for two hours. The registered trainees could ask clarification questions to the module's responsible tutors. Several interesting chat sessions have been noticed during the project's teaching, especially at the University Minho in Portugal.

Moreover, if a question asked by a trainee was addressed for a module's responsible of a project partner, a translation in English was provided in English by the national responsible on the General forum for questions and answers of the course (figure 4).

III. The self-assessment Quizzes comprise 12 questions on three levels of difficulty: low, medium and high, with 4 questions per level. The questions bank has a total number of 60 questions per module. A part of the questions have pictures (figure 5) and were uploaded via the GIFT (with media format). The action for uploading the Quizzes on the platform represents a special effective organization for the project's partners, for a number of 60 questions x 7 modules x 5 languages = 2100 questions were uploaded.

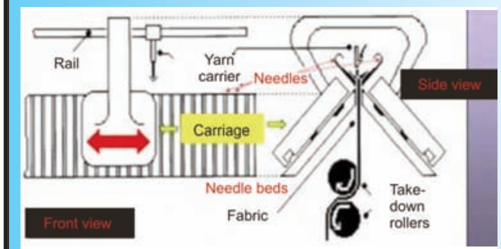
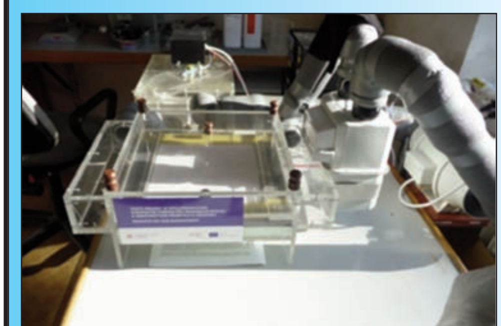
The final assessment Quiz was configured with a total number of 3 questions per module x 7 modules = 21 questions. The 3 questions had each one level of difficulty (low, medium and high).

The upload of the users was performed via upload of formatted Excel *.csv files, while the registration of the trainees was performed in cohorts assigned to each of the language's courses. A user manual for the platform was conceived, available at the URL address: www.advan2tex.eu/portal/.

The content of the modules

The content of the modules envisaged advanced knowledge in the textile field. The content was prepared by research teams of the project partners with special expertise in the dedicated disciplines. However, the level of knowledge was adapted by the authors in order to meet the learning needs of VET trainees. The content addresses especially professionals from the industry, able to implement the acquired knowledge into industry practice. It also supports young entrepreneurs with new technological ideas to be used for new businesses. The knowledge content addresses higher-education students, too, offering alternative, modern materials to the textile universities curricula. The level of knowledge was conceived from medium to high, in an accessible manner, to support an as broad as possible group of trainees. An important target group of trainees, not initially envisaged, could be attracted from high-school teachers from the NE region of Romania, by the Technical University of Iasi. Their interest and enthusiasm was considerable high and the knowledge was taken over by the teachers, in order to be further taught to high-school students. This is only one of the good results of Advan2Tex, related to the widespread of the modules and the impact of the project.

The following strong points regarding STEM e-learning are valid for Advan2Tex modules:

Module	Description	STEM e-learning strong points
Advanced knitting technologies 	The advanced knitting technologies module presents the technical potential of the electronic flat knitting machines, their systems of computer assisted design and the possibility of producing tridimensional knitting products.	Multi-disciplinary approach of textiles and mechatronics, supported and high-lighted by many graphics and animations for the functioning of advanced knitting machines. Visually relevant images to explain tridimensional knitted shapes and attractive presentation manner.
Virtual prototyping of garments, 3D scanning, clothing for people with special needs 	The virtual prototyping module aims to describe the 3D scanning devices for being able to manufacture garments for persons with disabilities. A virtual model for garments is studied, offering the possibility to simulate the behaviour while wearing the customized garments. Several medical diseases are tackled as applications of customized clothing.	Multi-disciplinary approach of textiles, informatics, mathematical modelling and 3D scanning physical and electronic methods. Moreover, deep medical knowledge for people with special needs (scoliosis, osteoporosis etc.) is included, in order to be able to tailor customized clothing. The informatics and mathematical modelling chain is applied for textiles with applications in medicine in an orderly manner.
New methods for testing textile materials 	The textile testing module presents some of the main tests performed on textile materials: thermoregulatory properties (thermal and water-vapor resistance, air permeability), measurements by means of a manikin, colorfastness tests, microbiology tests.	The investigation methods in textiles is based on using various testing instruments: the images of the instruments, the working modality, the description of the physical / chemical / biological phenomena to be investigated related to the specific test are compatible elements with the available Moodle e-learning tools.
Standardization of textile testing 	The standardization module presents the classifications of standards, the organization of the standardization process, the standards development methodology, the testing standards in the textile industry, the standards and the legislation, the standards and the environmental issues and the standards as business support.	The standardization module extends the textile testing module with aspects regarding the conditions in which the tests are preformed. The module was prepared in an attractive and accessible manner and highlights topics of interest, such as the support for environment and business. The structured and attractive content fits well with the Book resource of the Moodle platform. Suggestive images supplement de module.

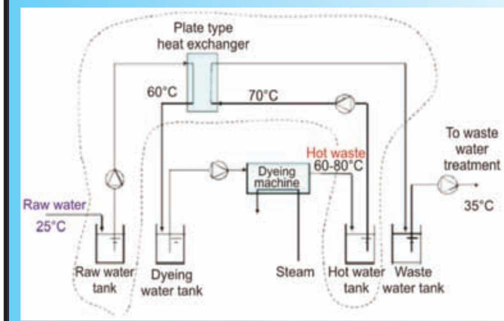
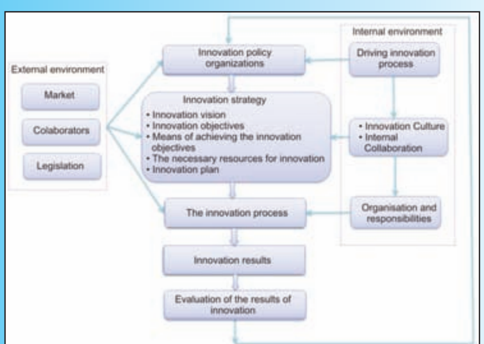
Sustainability of textiles 	The sustainability module deals with three components: methods for reducing the impact on the environment in textile enterprises, life cycle assessment calculations for quantifying the impact on the environment and eco-labels for certifying textile products with eco-friendly character and/or eco-friendly producing method.	This module connects textiles with sustainable development and environment protection. The e-learning content follows several themes: technical methods, LCA cases, classification of eco-labels. All these themes are well balanced with an adapted presentation modality. A LCA showcase in an specialized software program (SimaPro7[9]) was added, in order to evidence the impact categories.
Entrepreneurship 	The entrepreneurship module aims to motivate young people to start a new business in the textile field. Some of the main topics of the module are: entrepreneur profile, business plan, organizational knowledge management, sustainable development and women entrepreneurship.	These two modules belong rather to the economic sciences: however, they were of great interest for all the trainees, regardless their technical specialization, due to their attractiveness and their motivation character. Promoting entrepreneurship and innovation management towards the young trainees had a special impact. The content of the both modules is well structured on chapters, subchapters and ideas and fits well the Book resource (Table of contents) of the Moodle platform. Navigation is easy through the concepts. The chat activity registered a special success at these modules, with 15 participants in one single session at the University Minho, in Portugal.
Innovation management in the textile field 	The module on innovation management has four main pillars: the innovation management in the knowledge economy, the management of intellectual property, the technology transfer and the assessment of the innovation capability of a company in the textile-clothing field	

Fig. 6. Blended courses organized as part of the project (University Maribor – Slovenia)

The content of all the 7 modules was harmonized between all partners priory to the translation in national language, with regard to redundant text sections, scientific terms and bibliography (Harvard referencing system). As weak point of STEM e-learning related to the Advan2Tex modules, it could be mentioned that more animations and videos regarding technological processes/tests could be added. Based on the accomplished e-learning platform, a number of 6 blended courses was organized by the project partners (figure 6), with a total number of 176 trainees.

The trainers and trainees received user accounts on the advan2tex.eu/portal platform with appropriate permissions. The platform registered a total number of 89183 records for views during the two years of the project's implementation phase.

CONCLUSIONS

E-learning is applicable to various target groups, starting with children education up to academic and vocational education and training. The content presented could cover many fields of teaching, such as economic sciences, STEM, humanistic sciences or creative arts. Each field of teaching has particular aspects regarding the e-learning implementation methods. While for humanistic sciences communication is in forefront of the e-learning benefits, STEM (Science Technology Engineering and Mathematics) is especially suitable for e-learning, due to the compatibility of the two domains. The e-learning instruments, such as the Moodle resources (e.g. Books with navigation bars, table of contents and multimedia content) present in an adequate and attractive manner the structured STEM disciplines. Textile technology is a particular and special branch of STEM. It is a multi-disciplinary field, covering physics, chemistry, mechanics and mechatronics, biology, mathematics etc. Advances in textile technologies VET e-learning is a prerequisite for improving the competitiveness of textile enterprises.

The Erasmus Plus VET project Advan2Tex tackles this particular need: it fosters the competitiveness of textile enterprises trough vocational education and training. The target group envisaged by the project comprises professionals from the textile industry, young entrepreneurs and students from higher textile education. The initial target group of 115 trainees was exceeded during the implementation phase of the project with a total number of 176 trainees. The initial target group was also enlarged, by the category of teachers from high schools (29 teachers), who's main ability is to drive forward the knowledge to their students.

The modules prepared as part of Advan2Tex cover many fields of textiles, mainly technologies (advanced knitting and virtual prototyping), investigation (textile testing, standardization), environment protection (sustainability of textiles) and economics (entrepreneur- ship, innovation management).The e-learning particularities for each of these fields with regard to STEM e-learning were highlighted in this paper. The Advan2Tex project had a significant impact on its trainees.

The seven modules presented are of great importance for the world-of-work in textiles. The trainees may find new solutions and visions upon the innovative textile product's manufacturing and valorizing. The activities as part of this project have been funded as part of the Erasmus Plus Strategic partnership – VET project 2014-1-RO01-KA202-2909. This project has been funded with support from the European Commission.

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Thermal solar panels for heliostat walls in the textile and leather industry

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REZUMAT – ABSTRACT

Panouri termosolare pentru pereți heliostatici în industria textilă și de pielărie

Energia solară este în mod natural abundentă și gratuită, iar în mediul științific actual de inginerie tehnică se depun eforturi pentru idei de simplificare operațională a folosirii sale extinse, și anume prin introducerea pentru utilizare a sistemelor neconvenționale de energie în industria textilă și de pielărie. Punctul de vedere al autorilor acestui articol este că punerea în aplicare a sistemelor neconventionale pentru producere de energie pe bază solar, arată nevoia de standarde în cadrul actualului regim energetic industrial-productiv în industria textilă și de pielărie. Acesta nu poate fi încă luat în considerare ca simplu sau implicit/intrinsec în domeniul convențional al actualului sistem energetic. Articolul realizează analiza regimului termic în clădiri, cu aplicație pentru cele din industria textilă și de pielărie, în scopul de a identifica recomandări pentru participarea energiei solare la îmbunătățirea regimului energetic folosind în premieră pereți heliocaptatori.

Cuvinte-cheie: industria textilă și de pielărie, energie regenerabilă, energie solară, pereți heliostatici, sistem energetic global, panou termosolar

Thermal solar panels for heliostat walls in the textile and leather industry

Solar energy is naturally abundant and free of charge, and in the current technical engineering environment the idea of its operational simplification is assumed, namely of the introduction for use in conventional energy systems in the textile and leather industry. The view point of this article is that implementing the unconventional area for solar energy, considered unconventional by standards under the current industrial-productive regime in the textile and leather industry. This cannot be considered yet simple or implied/intrinsic in the conventional field of the general current energy system. The article achieves the analysis of thermal regime in buildings in the textile and leather industry in order to identify recommendations for the participation of solar energy for improving it using for the first time heliostat walls.

Keywords: the textile and leather industry, renewable energy, solar energy, heliostat walls, overall energy system, thermo solar panel

INTRODUCTION

In Romania advantages and specific incentives are in place for setting a fast pace of development in renewable energy sources, thus being promoted an important alternative option for the future in producing electricity and heat. Given that solar energy is naturally abundant and free, in the current technical engineering environment the idea of simplifying its operation, namely the introduction for use in conventional energy systems is assumed. Presently and in future, the top operational priority is the modeling of the solar thermal transfer process. Research conducted in the context of obtaining variants/alternatives of control/ improvement of buildings' thermal regime in the textile and leather industry, lead to the thesis that the next stages of development in the area is likely to occur, with the formalization and generalization of energy smart buildings (CIE).

EXPERIMENTAL WORK

Requirements and transformative research in the context of the need to improve the thermal regime in buildings of the textile and leather industry

The concept of passive house energy is a concept that ensures a high thermal comfort at low cost. Practical steps, as required to be taken in such a complex process are shown in figure 1 [4].
The concept should not be confused with a high performance energy standard. Passive heated houses are buildings where high thermal comfort can be achieved by simply post-heating or post-cooling fresh air introduced into these buildings in the textile and leather industry. In this case, the air is not recycled. Renewable energy is a form of energy that is not subject to exhaustive human consumption. Almost all forms of renewable energy, ultimately, originate from the inclusion of solar energy in their substance and form. It is estimated that renewable energy sources, as per the economic perception, are sufficient for at least the following interval which should last 4 million years. The main objective of the present investigation is to research complex systems of heating, ventilation, air conditioning and heating water for general consumption in civil buildings that use renewable

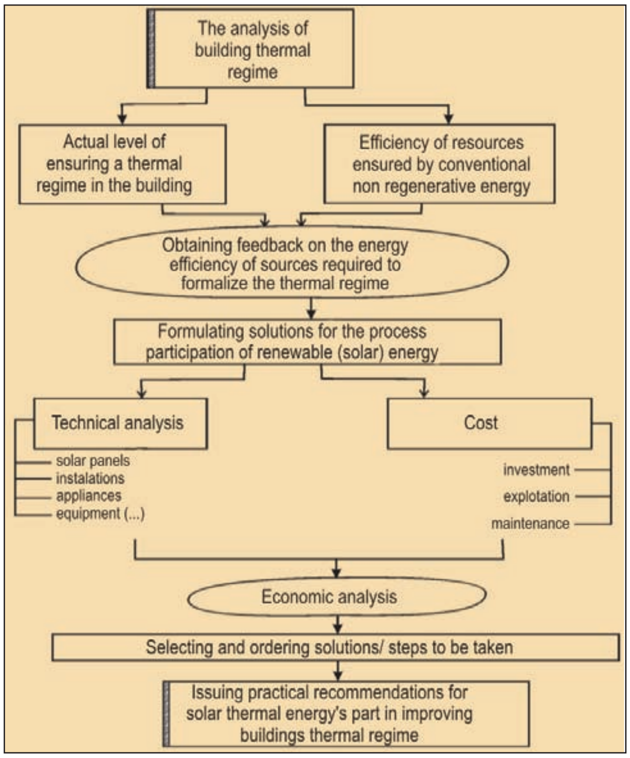

Fig. 1. Start of the thermal regime analysis to identify recommendations for participation of solar energy to its improvement

sources, consistent with the structure of the protective exterior of the building and its dissipative characteristics. The share of electricity produced from renewable sources in the gross national electricity consumption has the potential to reach about 33% in the period 2015–2018. The share of renewable in the total consumption of primary energy sources in Romania is set to rise to 18.2% in 2018. The contribution of renewable leads to reducing imports of primary energy resources and should reach by 2018 the equivalent of approx 5.537 million toe in Romania. We appreciate that in Romania advantages and specific incentives are established for setting a fast pace of development for renewable energy sources, thus an important alternative option for the future in producing electricity and heat is being promoted. Given that solar energy is naturally abundant and free, in the current technical engineering environment the idea is assumed that simplifying its operation is required, namely the introduction for use in conventional energy systems. In our assessment, implementing an unconventional area such as solar energy (considered as non conventional under the current industrial-productive regime) in a conventional field of general current energy system cannot be considered simple or implied/intrinsic. An overall calculation shows that solar energy that reaches Earth's surface (per year) is 6,000 times greater than the amount of energy used worldwide in 1990–2010. In Romania the average captured is 900–1450 kWh/m^2 of horizontal surface. In Romania solar potential exceeds 1000 kWh/m^2. Transformative research requirements with the need to improve the thermal regime in buildings relates to the systematized knowledge of the conceptual plans and to effective technological configurations for solar thermal panels and photovoltaic cells, in order to generate configuration opportunities of heat production facilities, respectively of electricity from solar radiations. Concrete statistics show that from the EU's total energy consumption 40% is for buildings' operations. Such a level of consumption requires as priorities: a) reducing or b) replacing the quantity of consumables energy supplies with which from renewable resources, ideally from the regenerative resources category, amongst which solar energy has precedence. The houses and buildings in the EU and Romania generate approx. 36%, respectively 50% of carbon emissions uncovered by trading schemes. By 2020 the construction sector in the EU should ensure reducing consumption of 165 million tons of oil equivalent. Meanwhile, renewable energy sources by the year 2020 in the EU have to provide a contribution of at least 50 million tons of oil equivalent-energy. Residential buildings and tertiary sectors (office, retail, hotels, restaurants, schools, hospitals, gyms, indoor) are the largest consumers of final energy. This represents heating, air conditioning, lighting, appliances and office equipment (in the EU they account for over 40% of total consumption). Some studies and specialist experience show that in these sectors there is a considerable energy saving potential. From general systematization of data and scenarios related to buildings in the textile and leather industry in Romania it can be concluded that an overall poor energy performance is registered here. The main reason for this appreciation results from an inadequate degree of isolation of building components and low yield of preparation, supply and utilization of thermal energy. By burning conventional fuels (90% of individual houses are heated by stoves) obtain necessary heat and hot water. As such, in Romania the highest values in Europe are recorded, compared to a conventional apartment located in a climate zone with outside temperature of 15°C and 20°C inside temperature (considered constant). Scientific review is performed in relation to how to use indoor space and adapt to climate conditions in order to improve the thermal regime through solar energy participation in a substitutive manner, in the total energy resources for consumption. Pragmatic aspects of starting and undertaking a buildings energy revolution is linked to arrangements for financial support of technical, technological and conceptually effective approaches, in reaching the desirable goal that every building should produce at least as much energy as it consumes. The self-sufficient energetic building in the textile and leather industry marks the general preoccupation of research and development in practical transposition of introducing on a wide scale the use of renewable energy resources, including of solar sources. In this context, the legitimacy, motivations and justifications of the present papers' approach to research on applications of solar energy contributive to improving buildings' thermal regime in the textile and leather industry are clearly visible. The aspect of own production of buildings' energy is mandatory and applicable to all buildings, regardless of the type of ownership (public or private). In 1997, the European Commission proposed that by 2015, the surface of solar collectors installed in Europe was to reach 100 million m^2. Of the total global solar energy supplied, around 60% is used in areas with high density and poor population in China. It is estimated that the need for thermo technical rehabilitation and modernization interventions in Romania is for approx. 2.4 million apartments (58% of the existing block of flats). In Romania, the total energy consumed (approx. 40%) is for public buildings, but their infrastructure is poor overall, with heat loss amounting to about 40%. Installations in construction of civil and industrial buildings (i.e. the textile and leather industry buildings) require large amounts of heat (for heating, hot water and consumption), and for this appreciable amounts of classic fuel are being consumed. We appreciate that, currently, in Romania thermal rehabilitation and structural strengthening works of buildings are inadequate, having a mostly-exponential demonstrative character. Therefore, schemes are required that can connect solar thermal installations with the corresponding thermal behavior building model, using the solar panel as an integrated module, which enables the participation of renewable energy for thermal regulation in buildings in the textile and leather industry. It takes into account:

– Calculation factors for choosing or sizing equipment or for sizing systems in the general scheme of experimentation;
– Guidance on the modeling and numerical simulation calculus for the operation of systems in their interaction with external climate and conditions of use (building, interior sources of heat and humidity, etc.);
– Examples of numerical solutions and applications;
– Economic considerations and regulations in this area;
– Strategy elements in defining supply options of power systems for heating and cooling (air conditioning) buildings installations.

We appreciate that the level of performance of a building is an order value imposed for a specific performance criterion. In the same analytical framework, it is inferred that the constructive system influences the thermal regime of buildings, in connection with the height differential regime. In our assessment, the present building functions in the textile and leather industry as an outer-system in a productive economic environment, hyper compact/hyper dense socially and culturally. Building components in the textile and leather industry are becoming increasingly interlinked and flows are multiple and multidimensional/multifunctional. In Romania, which is located at the latitude where solar irradiation is at a rate of approx. 50% which is due to indirect radiation. It is expected that solar thermal collectors have the variable angle of functional positioning in order to effectively exploit the diffuse component of the global radiation. Introduction of the variable angle in the constructive and functional configuration of solar panels involves additional expenses/costs. Sunlight is composed of parallel rays which determine differentiated situations with regard to reaching areas considered buildings facades. From the situational macroclimatic expression up to the microclimatic, having formalized a climate database, the alignment of practical examination of the relationship “sunshine to building” is created. The design conditions of the introductory solutions and efficient use under a comparison regime and/or competitive solar energy are therefore formulated. The location of the building of the textile and leather industry in a particular climate zone (macroclimate) gives it the specific energy behavior due to global factors, of microclimate nature. Retrieving the building in a complex sub-macroclimatic area respectively in a region characterized by certain topography, reserves (water, air, light, etc.) cause the apparition of mezzo climatic energy behavior of the building. The neighborhoods and buildings’ proximity induce advantages and disadvantages, found in the multitude of factors that quantify a certain microclimatic energy behavior of the building. We appreciate that linking under an integrative regime of types of behavior as listed above is of maximum relevance and importance in the context of the study identifying ways and solutions, “of conventionalization” the use of solar energy. Concerns for making buildings more efficient are not limited to solving current energy consumption optimization, related to the entities in question, but to essentially target the innovative aspect of the rehabilitation/modernization process. In fact, in addition to more efficient “savings”, there is an appeal to “structural substitutions” by types of energy. This is the case for introduction of renewable energy in relation to energy obtained from fossil fuels. The requirement of “tire outward breathability” is relevant and if satisfied, will ensure the building is protected against seasonal fluctuations in temperature and humidity. The building in the textile and leather industry is therefore a system as a whole, where the transitional, transactional, technical, technological balance helps improve the conventional required/requested thermal regime. Solar thermal energy becomes a contribution to formalizing buildings’ interspaces and thus to the establishment or adjustment of improved thermal conditions. The size of thermal insulation and mounting technology for producing energy subsystems are directly influenced by technical and technological participatory size of thermal solar energy that formalize the improved buildings’ thermal regime. The main technical issue under discussion is the conversion of solar radiation into thermal energy. It is noted that the conversion problem is purely technical, as long as the essential principle (transformation from one form to another) is assumed. In essence, the technique put on the agenda is the issue of transforming and formalizing energy, respectively quantifying energy forms in trans-forms.

RESULTS AND DEBATES

Some proposals and recommendations in the field

Energy efficiency in Romania is appreciated as low, compared to other European Union countries. By extending contextual analysis, if the expected overall increase in energy consumption in Romania is 3% per year, the estimated economic potential for improving energy efficiency in the residential sector is 35 to 50% and 13 to 19% in the tertiary sector. It is estimated that the introduction of thermal insulation, of new heating systems or of cooling or ventilation systems, with equipment for producing renewable energy, could reduce by approx. 20% the energy consumption in buildings. The European Commission requires the realization of approx. 7 million checks of heating and cooling systems and approx. 2 million energy performance certifications of existing buildings. In Romania thermal solar panels are active only from March to October in a quasi-normal regime, ensuring the achievement of yields of 90%. According to some calculations the exploitable potential of production of electricity through photovoltaic systems in Romania is noted to be about 1200 GWh/year, with the purchase price of a solar module for 1 W installed being about 5–6 USD. The price of electricity produced from renewable solar photovoltaic sources ranges between 25–50 US cents/KWh. For a solar photovoltaic system with installed capacity of 1 MW in Romania, it would require a module/photovoltaic park of approx. 30,000 m^2 [4]. Systematizing some data and conclusions from the practice of using solar energy worldwide in the construction sector (buildings) and extrapolating judgment values in the case of Romania as a country with specific planetary geo-location, the result is that the North-South orientation of housing is the most favorable. Depending on the needs for natural light, minimal sizing of windows oriented East or West is resorted to. Renewable sources, still considered to be unconventional, as far as their introduction into widespread use becomes possible, undergo a process of amending their non conventional nature, tending towards having a conventional status. It is recommended to consider the induction of deliberate design to achieve energy efficiency in the context of buildings improved thermal regime. We believe that in the new conceptual architectural context of the transition from the “shield building”, designed to protect man against various exposures, to the ecological concept of the building, thermal comfort is organically associated with technical comfort. Heliostat walls are a basic, intrinsic solution involved in the construction of buildings and not as a complementary palliative in construction for solving energy consumption and economy [4]. On the basis of observations in this paper, we come to the conclusion that if a building could achieve perfect, total, complete isolation its overall functional status of the overall infrastructure would not be adequate. It requires the identification or systematization of the main technical properties of insulating materials, which should serve in decision making to formulate possible variants to be applied with maximum effectiveness, to piping systems for solar thermal installations. In connection with this alignment, there is recourse to a pre-staged related characterization of “pre-isolation systems” concerned. Key recommendations that take into account the constructive and functional experiments for optimal patented solar panel configuration in the textile and leather industry is, in principle, to pursue the quasi-symmetric location of points (locations) of input or output of the heat carrier fluid, that in its path across the grid/metal mesh in such an alternative marks the feasible medium of the most favorable heat accumulation from solar radiations. Grouping, respectively seeking tangents and common characteristics for different technical variants, in the current paper we have developed a basic systematization in the field, which is capable of recording improvements of specific technical progress. For Romania, in some geographical areas, for example, with tourism infrastructure, scientific research, monitoring, etc., it is useful to reconsider electrical power feed through the traditional formula of power lines. Acceptance of solar energy as an alternative source of electricity production would be possible, however, only if this option requires the installation and quasi-continuous authorized maintenance [1]. Therefore, in the context of these requirements, the proposal is to build a distinct module/system, relatively portable for equipment collecting, storage and distribution of energy captured from solar resources. Identification of an adjacent thermal regime for a building must follow, in our assessment, an algorithm of choice of conceptual or operational steps. From research conducted for this paper, that new participatory implementation of the restructuring process of formalizing energy in buildings thermal regime requires interventions, mainly on 1) buildings (new compliance), 2) installations for production, storage and heat distribution and 3) the type of energy used. We believe that, in civil engineering and largely in the sphere of industrial and special constructions, a new participatory structure is required to generate/establish a favorable thermal regime that is conventionally assumed and accepted as effective and improved. We find that present solar energy frequently manifests a certain rigid axiom, due to the nanotechnology aspect belonging to solar thermal systems. In our opinion, it is necessary for a methodological and definitive framework, apt to facilitate “industrialization” of the production process, of transfer and use of solar energy. In essence, there is a need to adapt to the information dynamic in the field. We believe that to simulate the dynamic behavior of solar thermal systems studied, we must formalize a relevant energy balance, primarily as a collector solar (panel) patented, the outcome concerned being the pursuit of the process and capturing energy levels. Therefore, this assertion launches the thesis of the primordial process /operation of capturing solar power in relation to other sub-processes or operations in the entire solar thermal system. From our observations, a number of priority areas are observed, where action is recommended to improve panels /solar panel systems, so that these integrate functionally/operationally in the overall process of configuring a suitable thermal regime of improved buildings conditions. We identify at least four groups of particular mechanisms to support promoting the use of solar energy: a) specific tariffs for solar energy; b) conditioning (quotation) of using solar energy; c) contracts on the basis of tenders and d) favorable loan conditions in order to finance renewable energy production.

Future research directions in the field

A considerable achievement, with extensive potential for future, is the mutual understanding and collaboration with energy industry partners on the Romanian market. The fundamental contemporary problem is related to seeing the signs that "a building could or should generate/produce energy at least as much as the volume they consume, if not more" [2]. The eco house and economic house concept development may be relevant to the extent that sustainability is induced by participation in regulating the thermal solar energy buildings' regime. Aggregation of solar panels (from the patented solar panel category) may be a favorable substitution source, by accepting the substitute energy contribution to the adjustment process of optimization and restructuring of the thermal regime of buildings, indirectly improving this. In our view, in present and in future, the operational requirement priority area is related to the modeling of the solar thermal transfer. Research conducted in the context of obtaining variants/alternatives to control/ improve buildings' thermal regime, lead to the thesis that the next stages of development in the area likely to occur are the formalization and generalization of building energy smart buildings (CIE) in the textile and leather industry. The motivating contribution to the above concept is to maximize the use of free solar energy [3]. A systematization based on principles, concepts and particular notions in the domain covers: the clean energy revolution of buildings; heat substitution compliance regime in buildings by using solar energy; building as a super-system/hyper compact and hyper dense in a economic, social and cultural production environment; composition/articulation of specific energy behavior with the buildings microclimate energy; "Conventionalization" of using solar energy; deriving behavioral inclusions to obtain "finite element" type results and a complex behavior of climatic nature; a scalar contributory element to decision-making and implementation of full operation technologies for solar thermal installations; an urban environmental ambient crisis; crystallizing a typology of environmental personal consciousness; thermal mass of the buildings; "green" architecture; clean architectural technologies; distancing authentic operational architecture, exclusive for construction; dematerializing buildings through new variants of using light and transparency; triple generating complex energy installations; a new report between comfort/unit and global thermal regime by sustainable participation of thermal solar energy in total energy consumption for buildings; systematization of intermediate forms of energy conversion/reversible heat in ensuring buildings thermal regime; quasi-conventional completeness of conversion processes for solar thermal energy; the algorithm shift to natural methods of heat management; deliberate design for procedural situations which foresee switching to natural methods of heat accumulation; "energy efficiency through economy" which is associated with "structural substitutions" of different types of energy; reconsidering architectural conceptual buildings to meet energy efficiency; the rapport between the environmentally friendly house and the economic house; required operating energy by conventional buildings' comfort levels and operating conditions; operating energy in buildings; pre-defined environmental conditions to simulate almost all the stresses to which thermal-solar installations are subject; intra-technological dynamism and quality of the thermal regime in buildings; quasi-structural amorphousness of solar energy; solar collectors under a variable geometric regime; sub-concentration/pre-concentration of solar radiations; a thermal energy network system; axiomatic arid solar energy; quasi-principled regeneration of buildings using solar energy; complementary participatory transformation of solar energy to thermal self compliance of buildings [5–8].

RESULTS

From the research, it appears that the legitimacy of approaching solar thermal systems based on solar panels gains a practical lead for efficient participation, at least as a substitute for adjusting/improving the buildings thermal regime in the textile and leather industry. Typically, the construction system in Romania lacks the calculation of necessary energy requirements that should be developed by the architect or designer. This makes it difficult to identify the optimal energy solution. Highlighting the values of participatory elements in compliance for buildings thermal regime is difficult to materialize through traditional analytical formulas. As such, the reliance is on computerized expert systems. The automatic numerical calculation can determine values of the elements that define the energy performance of the building, resulting as an estimate of the energy actually consumed or estimated to meet the needs related for the intended use of the building in the textile and leather industry. It is important to watch the level of thermal heat loss. This usually is due to the high temperature self-saturation of the absorbent elements. "Insertion" of solar thermal energy in total energy for the building is associated with the thermo technical and energetic characteristics of the construction and corresponding installations. The overall efficiency coefficient of patented solar panels is favorable in comparable terms, representing the ratio of the actual useful heat transferred to the heat carrier fluid and the heat received by the absorbent surface considered at equal temperature with the inlet temperature of the captor fluid. In this framework we can draw diagrams that provide direct values for the maximum useful energy, depending on the set temperature values (inputs-outputs).

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Criteria for process improvement in the Textile and Clothing sector

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REZUMAT – ABSTRACT

Criterii de îmbunătăţire a proceselor în sectorul de Textile & Îmbrăcăminte

Sectorul Textile & Îmbrăcăminte constituie un pilon puternic al industriei producătoare europene, înregistrând valori semnificative în ceea ce priveşte cifra de afaceri şi numărul de angajați. În contextul unui trend de creştere a produselor cu valoare adăugată mare, sectorul Textile & Îmbrăcăminte trebuie să îşi concentreze eforturile şi în direcția dezvoltării unor modele solide de afaceri bazate pe inovare, care să susțină implementarea schimbărilor care se produc la nivel organizațional. Astfel de modele de afaceri ar trebui să fie fundamentate pe continua îmbunătățire a proceselor. Scopul articolului este astfel de a propune mai multe criterii pentru îmbunătățirea proceselor în sectorul Textile & Îmbrăcăminte, pornind de la cele şapte principii ale managementului calității dezvoltate de experți ai Organizației Internaționale de Standardizare (ISO) şi reprezentând baza managementului calității reglementat de standardele specifice. Criteriile propuse pentru îmbunătățirea proceselor vizează organizațiile din sectorul Textile & Îmbrăcăminte care urmăresc să fie performante în contextul inovării deschise, necesitând astfel ca procesele pe care le desfăşoară să fie caracterizate prin eficacitate şi eficiență. Astfel de criterii sunt menite să faciliteze proiectarea unor noi modele de afaceri bazate pe inovare, care să reprezinte cheia pentru ajungerea pe piață a inovațiilor şi pentru dezvoltarea durabilă.

Cuvinte-cheie: inovarea deschisă, model de afacere, modelarea proceselor

Criteria for process improvement in the Textile and Clothing sector

The Textile & Clothing (T&C) sector represents a strong pillar of the European manufacturing industry, recording significant overall figures in terms of generated turnover and number of employees. While registering an increasing trend towards higher value-added products, T&C sector should also focus on developing reliable innovation oriented business models to support the implementation of the changes taking place at organizational level. Such business models should have at their core continuous process improvement. The aim of the paper is thus to propose several criteria for process improvement in the T&C sector building on the seven quality management principles developed by experts of the International Organization for Standardization (ISO) as basis for quality management regulated by specific standards. The proposed criteria for process improvement are designed for the organizations in the T&C sector that strive to better perform in the open innovation framework and thus require having efficiency and effectiveness of all their processes. Said criteria should facilitate designing new innovation orientated business models which are the key for innovation market uptake and sustainable change.

Keywords: open innovation, business model, process modeling

INTRODUCTION

As characterised by [1], [2] and [3], T&C sector comprises a range of activities covering value flow from the transformation of natural or synthetic fibres into yarns and fabrics, to the production of a large variety of products, covering from clothing to industrial products and hi-tech products. T&C sector employs 1.7 million people and produces a turnover of EUR 166 billion [3]. As observed at European Union level, organizations performing in the T&C sector view product quality improvement and new technologies or product development as means to increase their market share in a competitive environment. This allows organizations to focus on bringing to market products with higher value-added this being the sector trend [1–3]. So, there are required concrete measures to enhance the performance of the organizations and one of the solutions is implementing and developing the performance management practices in the companies that operate in this field [4]. The performance evaluation of enterprises not only in terms of quantity, but also quality can be achieved by creating an index of European consumer enthusiasm regarding multiple periods, on the intertwined sections [5].

While the face of T&C sector is systematically changing so is the face of innovation.

Moving from closed innovation to open innovation starting 2000, organizations understand now that knowledge is the asset determining how management and strategy should be driven. Open innovation paradigm is based on the assumption that organizations should use both internal and external knowledge to create value, and internal and external channels to market, in their approach to technological advancement, while creating mechanisms to generate and claim value in a collaboration based environment. Open innovation considers research and development as an open system [6–7]. The open innovation paradigm does not promote development strategies based on always being the first to innovate, but based on designing and implementing sustainable

innovation oriented business models supporting the organization in effectively and efficiently developing and exploiting innovation [6–7].
Considering the practice of open innovation at European Union level and the trend in the T&C sector towards value-added products, it is imperative for organizations to have a solid approach from a business process perspective in order to facilitate the design of innovation orientated business models based on process improvement. For this purpose criteria for process improvement should be continuously researched, confirmed and reassessed.

METHODOLOGY

The authors have performed a secondary research in order to identify the main trends in the T&C sector. Furthermore, the role of open innovation is emphasized in order to describe the current context of development in the European Union. Based on that and building on the seven quality management principles developed by experts of the International Organization for Standardization (ISO) as basis for quality management systems standards, several criteria for process improvement in the T&C sector are proposed to organizations wanting to perform in an open innovation context.
The seven quality management principles are defined as being "a set of fundamental beliefs, norms, rules and values that are accepted as true and can be used as a basis for quality management", their level of importance varying from organization to organization and depending on context [8]. These principles are:
– Customer focus
– Leadership
– Engagement of people
– Process approach
– Improvement
– Evidence-based decision making
– Relationship management [8].

As presented in [8], each quality management principle is described in a statement, it has a rationale explaining why said principle is important for the organization, and it has key benefits and also actions to be taken when applied in order to improve the organization's performance.
The above quality management principles are accepted as being true and derive from the collective experiences of the ISO experts. The hereinafter new principles for process improvement derive from the open innovation practice as observed by authors as a result of the secondary research they have performed; said principles are proposed to organizations performing in the T&C sector which should be supported in their trend to innovate. The proposed principles should be viewed as criteria for process improvement and do not aim directly at generating process and product innovations specific to the T&C sector but at supporting the business process beyond it.

FINDINGS

Process improvement focuses on process components: the input data, the activities for transforming input data into output data with the help of procedures, and the output data. Generically, the criteria for process improvement refer to process control and process performance. Figure 1 shows a process as adapted from ISO 9000 Quality Management Systems standards [9], where the criteria for process evaluation and improvement are effectiveness (generating performance results as established by specific objectives) and efficiency (balance between resource consumption and results).
Establishing a correlation between monitoring, measurement and analysis, on one side, and procedures,

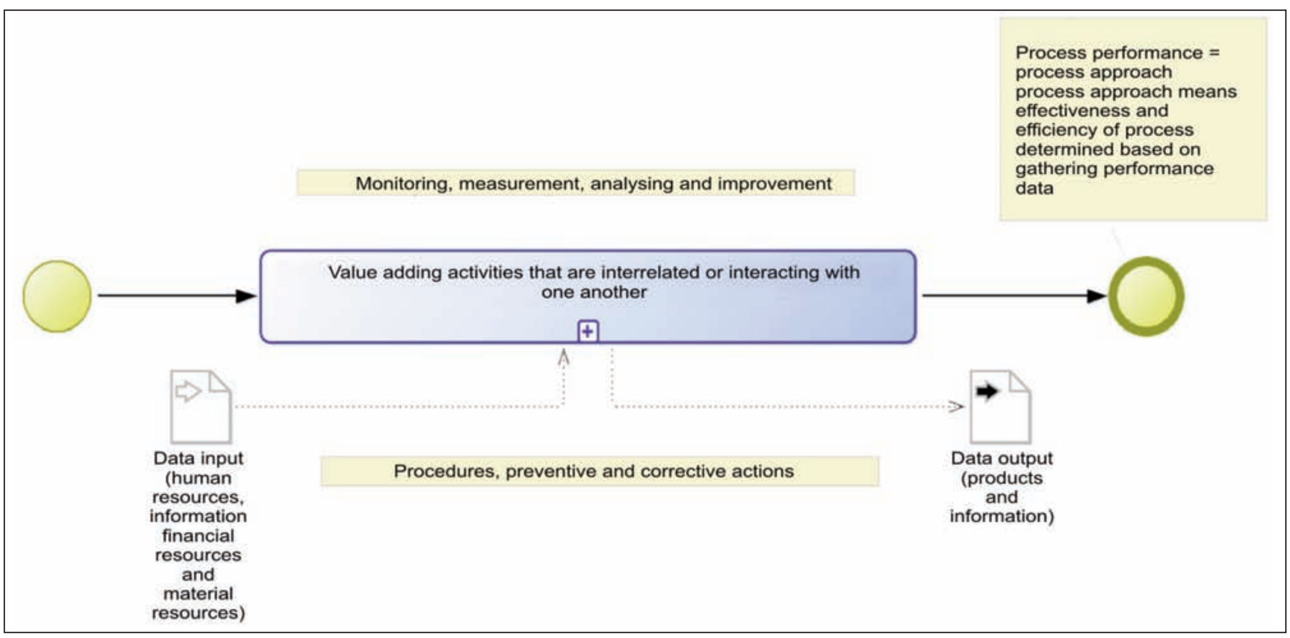

Fig. 1. Generic process flow. Adapted from [9]

preventive and corrective actions, on the other side, allows for process control and performance. Such systematic approach represents a process approach based on effectiveness and efficiency.
ISO 9000 Quality Management Systems standards rely on the aforementioned seven quality management principles aiming at improving organization's performance through process performance, thus promoting a process approach strategy. According to [8], each organization can implement them in different ways depending on factors such as the nature of the organization and the challenges it particularly faces. This is also the case with organizations in the T&C sector performing at different pace depending on a range of market and technological factors, where "economies of scope often exceed economies of scale, giving a certain advantage in manufacture to firms that are small and adaptable" [2].
Considering the specific of open innovation as framework for development within the European Union, the ISO 9000 quality management set of principles can be extended to further comprise other principles that should be viewed as criteria for process improvement. The following principles, as presented in figure 2 and further described, are proposed to organizations with the aim of facilitating the design of new innovation orientated business models which are the key for market uptake of innovation and sustainable change:
– ***Innovative approach on organization*** *as a system in relation with external environment*; It requires research, design/identification and implementation of innovative and flexible instruments, politics and management strategies bringing an open approach on the organization as a system in relation to external environment. The T&C organizations should understand the interdependency between their systems and elements of the external environment and should consider the latter as additional components of their systems, thus trying to exploit the established relationship as a common development undertaking. The key benefits when implementing this principle refer to the possibility of creating products with potential impact at sector level; the possibility of designing a "suprasystem" extending beyond own organization and the possibility of having joint objectives with strategic partners and a better control over joint costs and results.
– ***Approaching product and process innovation starting from inventions***; It requires approaching innovation primarily as research and development activities generating inventions and not just as activities for bringing improvements to existing products and processes. As such, continuous analysis and measurement of the innovation capacity is required taking into account both internal and especially external resources that an organization is able to access. Furthermore, continuous and efficient identification of market needs is required in order to be able to create innovative solutions to those needs. The key benefits of such approach refer mainly to the possibility of creating a competitive advantage and the possibility of opening up new markets.
– ***Process approach by adaptation of macro-models***; This is both a top-down and a bottom-up principle. On one hand, it requires implementing standardized processes to accomplish business objectives (top-down) and, on the other hand, it requires collaborating with experts in process modeling able to design custom processes fit for accomplishing business objectives yet having a macro approach allowing other organizations to use it as best practice models (bottom-up). In order for this principle to be efficiently implemented, organizations must establish collaborations with other organizations in their field of activity and beyond. Furthermore, Business Process Management instruments and standard languages should be employed. The key benefits when implementing this principle refer to the possibility of process improvement by process transparency.
– ***Designing processes based on strategic partnerships with as many stakeholders having input in the product life cycle***; It requires an integrated approach on product life cycle, respectively establishing partnerships with all entities needed for the creation, development and exploitation of products. It also requires designing new indicators to measure and evaluate processes. The key benefits of such approach refer mainly to the possibility of increasing predictability of process results and predictability of process results exploitation and the possibility of aligning own process objectives with the objectives of process partners.
– ***Multidisciplinary approach in process execution***; It requires an integrated approach on process know-how, respectively having a multidisciplinary process team. As such, the effectiveness of a process should be viewed as interlinked with team complexity and team complementary expertise identified and exploited for process results. The key benefits when

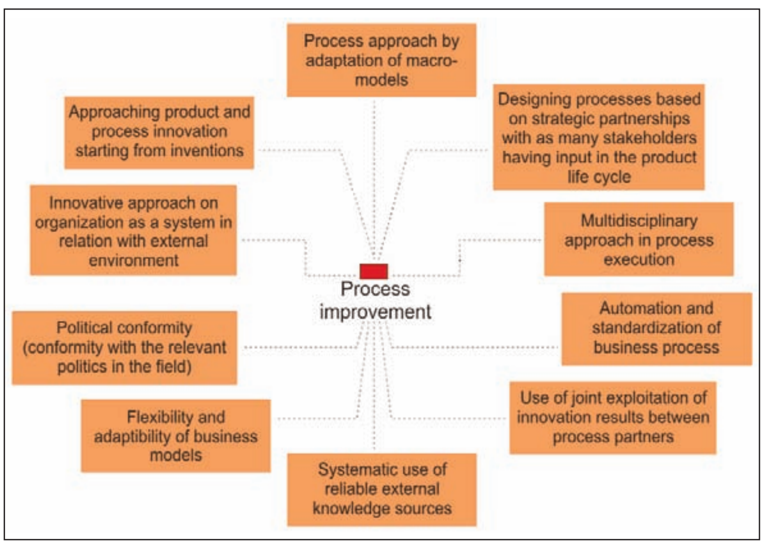

Fig. 2. Process improvement criteria proposed to organizations performing in the T&C sector

implementing this principle refer to the possibility of increasing process monitoring by having a complementary know how team handling it.

– ***Automation and standardization of business process***; It requires the use of Business Process Management software instruments and of standard languages such as Business Process Model and Notation (BPMN) to allow for analysis, simulation and evaluation of processes. The key benefits when implementing this principle refer to the possibility of increasing the effectiveness and efficiency of processes, the possibility of having process transparency and increasing the confidence of business partners on how the process is being handled. Process standardization can also constitute a key benefit of this principle. The T&C sector is based on processes having clear and specific flow charts; as such, process modeling (the Business Process Modeling perspective) should allow for improvement of process cycle time, process costs, process documentation, analysis and evaluation. An example of T&C specific process designed using the standard language BPMN 2.0 is presented in figure 3. As such, a static flow chart is converted into a dynamic flow of activities when modeled employing BPMN. ADOXX platform was used for this purpose. Organization performing in T&C sector should explore the benefits of using Business Process Modeling.

– ***Use of joint exploitation of innovation results between process partners***; It requires the identification and/or development of new instruments for exploring intellectual property in the case of process and/or product innovation starting from inventions and of new relationship marketing instruments that should allow for partnership creation for joint exploitation of process results. The key benefits when implementing this principle refer to the possibility of increasing the predictability of process results exploitation and of product life cycle control.

– ***Systematic use of reliable external knowledge sources***; It requires the identification of reliable external knowledge sources that allow for the creation and systematic update of internal databases for process support. It also requires creating strategies for the identification, evaluation and selection of reliable external knowledge sources that are relevant for a particular process. The key benefits when implementing this principle refer to the possibility of increasing process effectiveness and the possibility of aligning process results with the state of the art.

– ***Flexibility of business models***; It requires identifying and/or designing business models that allow the organization to adapt to the complexity of certain undertaken processes, especially when several partners are involved. As such, establishing the basic elements of a business process must be guided by the organization's capacity to exploit the interdependency between the internal and external environment. This allows for developing policies and strategies. The key benefits when implementing this principle refer to the possibility of increasing the effectiveness and efficiency of undertaken processes and the possibility of increasing the sustainability of process results.

– ***Political conformity (conformity with relevant politics in the field)***; It requires being familiar with all policies concerning specific process that an organization is undertaking. The purpose is to ensure conformity with the relevant policies. The key benefits when implementing this principle refer to the possibility of aligning the organization's objectives and establishing the conformity of objectives, ideas for development and process results with the relevant policies in the field of interest, both at national and international level, thus facilitating the organization's access to necessary resources and increasing exploitation potential of results.

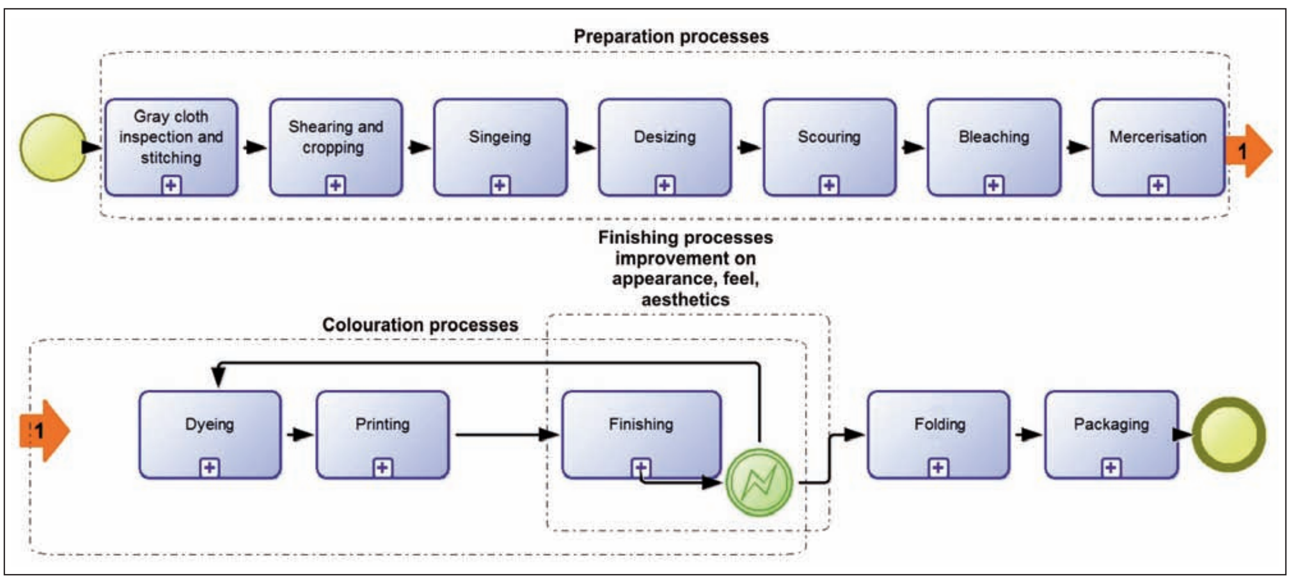

Fig. 3. Fabric wet processing [10] static flow chart converted into a dynamic flow of activities with the help of BPMN and Business Process Management instruments

CONCLUSIONS

The afore-defined principles are designed as criteria for process improvement and proposed to organizations in the T&C sector that strive to better perform in an open innovation framework, thus requiring to achieve efficiency and effectiveness of all their processes. The mentioned criteria should facilitate designing new innovation orientated business models which are the key for innovation market uptake and sustainable change. In order to support the increasing trend towards higher value-added products, the T&C sector should improve its business processes by applying improvement criteria deriving from open innovation processes.

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