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Sumar

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Analysis of cotton ring spun yarn diameter using regression and artificial neural network

PELIN GURKAN UNAL NILGUN ÖZDIL

REZUMAT – ABSTRACT

Analiza diametrului firului de bumbac filat cu inele folosind regresia și rețelele neuronale artificiale

Diametrul firului reprezinta una dintre cele mai importante proprietăți, care influențează caracteristicile produselor finite, cum ar fi factorul de acoperire, aspectul și tușeul țesăturilor. În cadrul acestui studiu, a fost propusă analizarea diametrului firelor de bumbac filate pe mașina de filat cu inele, din punct de vedere al proprietățile fibrelor de bumbac, utilizând regresia și modelele rețelelor neuronale artificiale. Ecuațiile și rețelele obținute au fost, de asemenea, comparate cu diametrul firelor de bumbac filate cu inele, obținut prin metoda dezvoltată de Peirce (1937). Rezultatele arată că ecuația de regresie obținută oferă o bună estimare a diametrului firelor, comparativ cu ecuația lui Peirce.

Cuvinte-cheie: fire de bumbac filate cu inele, diametrul firului, regresie, rețea neuronală artificială

Analysis of cotton ring spun yarn diameter using regression and artificial neural network

Yarn diameter is one of the most important properties that influence several properties of end products like cover factor, appearance and handle properties of the fabrics. In this study, it was aimed to analyse yarn diameter of cotton ring spun yarns with regard to the cotton fibre properties by using regression and artificial neural network models. Obtained equations and networks also compared with the yarn diameter of cotton ring spun yarns, which was developed by Peirce (1937). The results show that obtained regression equation gives good estimation of yarn diameter compared to Peirce's equation.

Keywords: cotton ring spun yarns, yarn diameter, regression, artificial neural network

Cotton fibre still remains the most desired fibre in the textile industry. It is suitable for making end products from knitted to woven fabrics, from towels to sheets and from carpets to industrial fabrics. The physical properties of the yarns strongly affect the performance of the process and the end products. There are several important properties of cotton spun yarns, which affect the properties of the end products. For instance, the cotton yarn's tensile property is very important during weaving stages, since warp yarns have to be enough strong to resist static and dynamic forces on the weaving machines. These properties of cotton spun yarns were investigated with regard to the cotton fibre properties by several researchers [1–7]. In addition to the cotton yarn's tensile properties, unevenness and hairiness properties were also investigated with regard to the cotton fibre properties by several researchers with various statistical methods [5], [7–8].

Yarn diameter of the cotton ring spun yarns is also important, hence this property is used to estimate fabric structural parameters such as width, and cover factor. As thousands of ends or wales are presented side-by-side in the woven or in the knitted fabrics, a slight change in yarn diameter can result in a substantial change in the overall cover factor of fabric. The factors, which affect the yarn diameter, also have an effect on the yarn density and fibre compactness. The properties of the cotton fibres such as fibre fineness, fibre stiffness, fibre length, and fibre crimp also affect the yarn diameter of the cotton ring spun yarns. In general, coarse and stiff fibres will result in bulkier or thicker yarn than fine and flexible fibres [9]. As the fibre becomes coarser, yarn density becomes smaller, leading to an increase in yarn diameter, although the linear density (yarn count) of yarn remains unchanged.

This study is aimed to analyse the yarn diameter of cotton ring spun yarns with regard to the cotton fibre properties by using regression and artificial neural network models. The equations and networks obtained were also compared with the model of yarn diameter of cotton ring spun yarns, which was developed by Peirce [10].

EXPERIMENTAL

In this study, a total of 8 different cotton blends in the form of roving, were used to produce 100 % cotton ring spun yarns. Five of these blends were combed and the rest of three blends were carded. Cotton ring spun yarns were produced in three yarn counts of Ne 20, Ne 30 and Ne 40 in three different twist factors of αe 3.8–4.2 and 4.6. As a result, a total of 72 different yarns were produced.

In order to eliminate the effect of machine variations on the ring spun yarns, the aforementioned yarns

Table 1

FIBRE SPECIFICATIONS OF THE MEASURED ROVINGS				
	Abbreviation	**Unit**	**Min**	**Max**
AFIS N Module	Neps/gr	Cnt/gr	3	47
	Neps Size	µm	0.70	0.78
AFIS L&M Module	L(w)	mm/inch	24.8	29.7
	L(w) %CV	%	30.1	35.3
	UQL (w)	mm/inch	30.6	39.3
	SFC (w) (n)	mm/inch	0.4	9.3
	D(n)	mm	12.1	14.1
AFIS T Module	Dust	Cnt/gr	17	105
	Dust Size	µm	134	254
	Trash	Cnt/gr	0	8
	VFM	%	0.000	0.155

were produced on the same spindles on Rieter G 30 ring spinning machine. The machine settings used within the study were as follows; spindle revolutions was 14.000 rpm, type of ring was orbit and had the diameter of 42 mm, cop length was 210 mm, the distance between the spindles was 70 mm.

As the purpose of the study was to estimate the diameter of the cotton ring spun yarns by using fibre properties, Advanced Fibre Information System (AFIS) was used to determine the properties of cotton blends in the form of roving. With different modulus of AFIS, it is possible to measure neps, length, trash and dust properties of the fibres. The measured properties of the rovings are given in table 1.

For the determination of yarn properties, the yarns were conditioned for 24 hours under the laboratory conditions. The yarn count test was performed according to the TS 244 EN ISO 2060 standard. 15 trials were carried out for yarn count and yarn twist from each yarn sample.

Yarn diameter was determined by using the diameter measurement module of Constant Tension Tester (CTT). For every yarn sample, 10 trials were carried out in order to get an average diameter. As a result, 720 trials were performed.

STATISTICAL PROCEDURES

Multiple Regression Method

Linear multiple regression analysis has been used to establish a quantitative relationship of yarn diameter with respect to fibre properties, yarn count and yarn twist. Stepwise procedure was selected for the estimation of the yarn diameter in linear regression analysis. Analyses were performed using Minitab software. Also simplified yarn diameter equation consists of only yarn count and yarn twist was developed by using power regression models.

Artificial Neural Networks

A multilayer feed forward network with one hidden layer trained by back propagation algorithm was used to predict the yarn diameter of cotton ring spun yarns. After several trials, the optimum learning rate of 0.01 and momentum coefficient of 0.3 were determined. As activation functions, hyperbolic function was used in the hidden layer and linear functions were used in the input and output layers. Of the 72 yarn samples, 54 were chosen as the training set at random, while 18 samples (25 % percent) were the testing set.

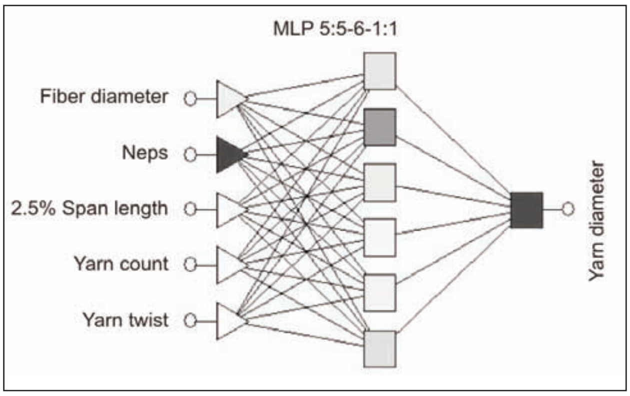

Fig. 1. ANN network model for the prediction of yarn diameter

Figure 1 presents the network model used in this study. In the model there is one hidden layer, one input layer and one output layer. Five parameters were selected for the prediction of yarn diameter in the input layer. Neural network with six hidden neurons for yarn diameter analysis was found to give maximum correlation coefficient and minimum mean absolute error. Statistica 7 software was used to develop ANN models.

RESULTS AND DISCUSSION

Linear multiple regression equation for the prediction of yarn diameter is given below:

$$d_{yarn}\,(\text{mm}) = 0.258 + (5.56 \times 10^{-3}\, D_n) + \\ + 0.173 \times VFM - (1.28 \times 10^{-4} \times Total\ Trash) - \\ - 2.59 \times 10^{-3} \times Ne - 3.04 \times 10^{-3} \times T/'' \qquad (1)$$

Table 2

REGRESSION SUMMARY STATISTICS OF THE MODELS FOR THE PREDICTION OF YARN DIAMETER					
	R	R^2	Adj.R^2	F	Sig. (p)
Peirce's Model	0.950	0.904	0.903	662.57	0.000*
Regression (Linear)	0.980	0.961	0.961	1740.74	0.000*
Regression (Power)	0.967	0.935	0.934	1005.12	0.000*
ANN (Overall)	0.990	0.982	0.981	3737.92	0.000*
ANN (Training)	0.992	0.986	0.986	3679.10	0.000*
ANN (Testing)	0.982	0.964	0.962	431.29	0.000*

* means statistically significant according to α = 0.05

where: D_n is the fiber fineness, *VFM* is the visible foreign material, *Total Trash* is the total dust, *Ne* is the yarn count and *T/"* is the twists per inch.

As known, the most important factors, which affect the yarn diameter, are yarn count and yarn twist. Also the fibre properties such as fibre diameter and fibre length have an effect on the yarn diameter value. But practically, the use of above equation for the prediction of the cotton ring spun yarns is difficult. First of all, to be able to estimate yarn diameter, one has to know the properties of the cotton fibre and then can estimate the yarn diameter value. In order to overcome this problem, the above equation was simplified. Therefore, a new simplified model including only yarn count and yarn twist was developed via using regression analysis to predict the yarn diameter. This simplified equation of yarn diameter is as follows:

$$d_{yarn}\ (\text{mm}) = \frac{2.4572}{\sqrt[0.4046]{Ne \times T/''}} \qquad (2)$$

This simplified yarn diameter equation was compared with Peirce's model for predicting the diameter of cotton ring spun yarns. The common yarn diameter equation which was developed by Peirce is insufficient to predict the diameter of the yarns that have same yarn count but different yarn twists. Peirce's equation for the diameter of ring spun yarns is as follows:

$$d_{yarn}\ (\text{inch}) = \frac{1}{28 \times \sqrt{Ne}} \qquad (3)$$

For the prediction of yarn diameter, artificial neural networks method was also analysed. Table 2 shows the regression summary statistics of all the models for yarn diameter.

In linear regression, as it is seen from the equation, the only parameters which are sufficient to predict the yarn diameter are fibre diameter, visible foreign material, total trash, yarn count and yarn twist. In ANN model, fibre diameter, neps, % 2.5 fibre span length, yarn count and yarn twist are necessary for the prediction of yarn diameter. All of the other parameters which were obtained from AFIS tests were included in the models of regression and ANN one by one; however, all these parameters did not improve the prediction power of the models considerably.

Table 3 presents descriptive statistics of the models. Comparison of ANN and regression models in predicting the yarn diameter shows that the ANN models are also powerful similar to the regression models with regard to the mean square error, root mean square error, mean absolute error, mean absolute percentage error. All these statistical criteria are the same with regression models. Although ANN is more powerful in predicting the nonlinear relations between dependent and independent variables, for the estimation of yarn diameter, nonlinear regression method is also sufficiently practicable.

In order to validate the models, five different yarns from the same blend, which were not used to construct the models, were used to test these models. In table 4 and table 5, regression summary and descriptive statistics of all the models for the validation of yarn diameter are given, respectively.

Table 3

DESCRIPTIVE STATISTICS OF ALL MODELS FOR PREDICTION OF YARN DIAMETER				
	Peirce's Model	Regression (Linear)	Regression (Power)	ANN (Overall)
Data Standard Deviation	0.025	0.031	0.032	0.033
Mean Square Error (MSE)	0.000	0.000	0.000	0.000
Root Mean Square Error (RMSE)	0.018	0.011	0.010	0.007
Mean Absolute Error (MAE)	0.014	0.008	0.007	0.004
Mean Absolute Error (%) (MAPE)	0.073	0.047	0.039	0.022

Table 4

REGRESSION SUMMARY STATISTICS OF THE MODELS FOR THE VALIDATION					
	R	R^2	Adj.R^2	F	*Sig. (p)*
Peirce's Model	0.978	0.957	0.946	89.18	*0.001**
Regression (Linear)	0.934	0.876	0.845	28.17	*0.006**
Regression (Power)	0.978	0.957	0.946	88.58	*0.001**
ANN (Overall)	0.834	0.695	0.619	9.12	*0.039**

* means statistically significant according to α = 0.05

Table 5

DESCRIPTIVE STATISTICS OF ALL MODELS FOR THE VALIDATION OF YARN DIAMETER				
	Peirce's Model	Regression (Linear)	Regression (Power)	ANN (Overall)
Data Standard Deviation	0.025	0.030	0.038	0.005
Mean Square Error (MSE)	0.000	0.000	0.000	0.001
Root Mean Square Error (RMSE)	0.013	0.005	0.007	0.025
Mean Absolute Error (MAE)	0.003	0.001	0.001	0.007
Mean Absolute Error (%) (MAPE)	0.015	0.005	0.007	0.030

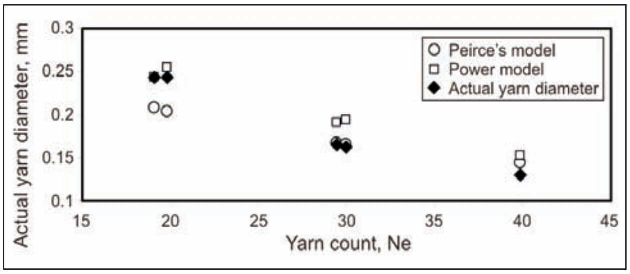

Fig. 2. Comparison of different models with the actual yarn diameter

In figure 2, comparison of Peirce's model, the power model which was developed in this work and actual yarn diameter is given. While in coarser yarns the power model developed in this work gives better results as compared to the Peirce's model, on the contrary, in finer yarns, the Peirce's model gives more accurate results to the actual yarn diameter. But it can easily be seen that this difference in finer yarns is much less than the difference in coarser yarns.

CONCLUSIONS

In this study, for the prediction of ring spun yarns diameter, different statistical methods were used to estimate this property, and these methods were compared with each other as well as with Peirce's yarn diameter model. In recent years, ANN models for the estimation of the yarn properties have been formed to be a popular approach, since ANN is a powerful statistical method, especially for the nonlinear relationship between the dependent and independent variables.

As a result of this study, it can be stated that the important parameters which have an effect on the yarn diameter are fibre fineness, yarn count and yarn twist. In the multiple linear regression analysis, the fibre length was not found to have an effect on the yarn diameter, although all of the blends have different values of fibre length; these blends belong to the same group according to the fibre length. Thus, to investigate the effect of fibre length on the yarn diameter, it is advisable to choose a wide range of the blends' properties. Fibre fineness has an effect on the yarn diameter. Increase in fibre fineness causes the yarn density become smaller, leading to an increase in yarn diameter, even if the yarn count remains the same. This is because coarser fibres are more resistant to bending than the finer fibres, thus twisting of the coarser fibres increases the bulkiness of the yarn.

For the simplified equation of the yarn diameter, it can be seen that the results are the same as compared to those of the Peirce's model (table 4). Since this equation also included the yarn twist, it is more effective to predict the diameter of yarns that have the same count and twist. Peirce's equation is insufficient to predict diameter of the yarns which have the different yarn twists but have same yarn counts.

The most important parameters that control yarn diameter are the yarn count, yarn twist and yarn spinning method. All these models are developed for the same yarn spinning method which is the conventional ring spinning method. Simplified yarn diameter equation can be used to predict the yarn diameter of the cotton ring spun yarns.

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Textile magnetic yarns – research and simulation

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REZUMAT – ABSTRACT

Fire textile magnetice – cercetare şi simulare

Această lucrare prezintă o metodă de realizare a firelor textile magnetice utilizând o tehnică de acoperire a firelor răsucite cu soluţii magnetice care conţin particule ferimagnetice, agenți de legare şi aditivi. Firele acoperite au fost analizate din punctul de vedere al caracteristicilor fizice (gradul de uniformitate a stării de suprafaţă, diametrul) şi magnetice (magnetizaţia de saturaţie masică, magnetizaţia remanentă masică, câmpul coercitiv). Această lucrare descrie, de asemenea, un model linear al unei bobine magnetice textile. Miezul acestei bobine este format dintr-un mănunchi de fire textile magnetice. Rezultatele simulării sunt oferite sub forma de distribuţie a unei bobine de inducţie magnetică într-un material textil magnetic.

Cuvinte-cheie: soluţii magnetice, acoperire, elemente textile magnetice, măsurători magnetice, simulare

Textile magnetic yarns – research and simulation

In this paper, we present a new method for obtaining magnetic yarns using a coating technique with magnetic solutions of hard ferrimagnetic grains, binders and additives. The physical (uniformity of the coated surface and yarn diameter) and the magnetic characteristics (mass saturation magnetization, mass residual magnetization and coercive field) of the coated yarns were analyzed. We also introduce a linear model of a textile magnetic coil in which the core of the coil consists of a bundle of magnetic yarns. Simulation results of the distribution of the magnetic field inside the coil are also provided.

Keywords: magnetic solutions, coating, magnetic textile elements, magnetic measurements, simulation

Textiles of today are materials with applications in almost all human activities and we are surrounded by textiles in almost all environments. The integration of multifunctional values in such a common material has become a special area of interest in recent years and an important platform for high-tech innovations [1]. Fiber yarns, fabrics and other structures with added functional value, known as smart textiles, have been developed for a range of applications (e.g. sensors and actuators [2]), with interdisciplinary implication between textile design, chemistry, physics, material science, computer science and technology.

Smart textiles can be grouped according to their capabilities: property change capabilities, energy exchange capabilities and reversibility. Property change materials undergo changes in property/or properties – chemical, thermal, mechanical, magnetic, optical or electrical as response to changes in the environment [3]. Development of textile materials engineering contributed to the production of multifunctional textiles [4].

Magnetic textiles are based on magnetic fibers [5, 6], yarns [7, 8] and fabrics [9]. Textiles are used for building textronics elements [10–12], magnetic devices such as sensors, actuators, marker of detection [13] and others. The basic elements of sensors or actuators are textiles with magnetic cores. Depending on the type of sensor or actuator, the coil may have various shapes such as linear, toroid, rectangular. The magnetic yarns represent a new direction of research and development with complex applications in the fields of medical and electronic textiles.

In this work were studied two magnetic yarns obtained by employing a coating technique in which two different magnetic solutions are used for coating. The magnetic yarns obtained in this way are composite yarns in which the matrix acting as magnetic filler forms with the diamagnetic fibers, acting as reinforcing element, a discontinuous phase. The textile fibers of the composite yarns may be selected from conventional textile fibers such as synthetic fibers (e.g. polyester, polyamide, polypropylene, etc), artificial fibers (e.g. viscose or rayon) and natural fibers such as cotton, wool. The textile fibers may be filaments or staple fibers.

EXPERIMENTAL PART

Equipment and yarn functionalization method

Magnetic solutions

A 100% carded twisted cotton yarn (Y), fineness Nm 100/3 (30 tex) has been selected on the basis of several criteria such as the content of cellulose at the yarn surface which is important for fixing and stabilizing the binder, minimum deformation (elongation), hygroscopicity and a higher degree of retention of aqueous substances. Two magnetic solutions with different composition and magnetic powder content were prepared. The first magnetic solution (S_1) was

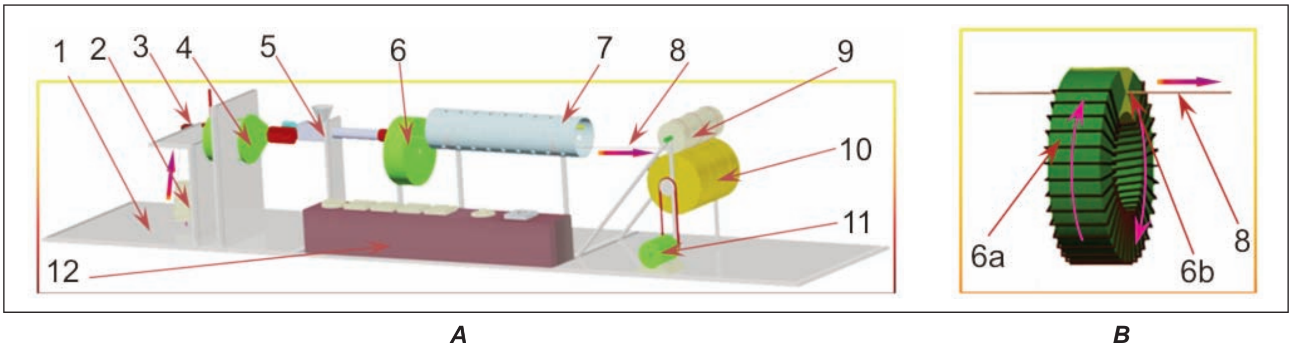


Fig. 1. Front view (A) of the yarn coating equipment and detailed view (B) of the air gap induction electromagnet: *1* – framework support, *2* – bobbin yarn, *3* – guiding yarn and tensioning device, *4* – feed drive with gear train, *5* – coating chamber with spinneret, *6* – air gap induction electromagnet, *7* – drying chamber, *8* – coated yarn, *9* – winding reel of coated yarn, *10* – grooving cylinder, *11* – winding drive, *12* – electrical control unit.

prepared by mixing 45 wt% barium hexaferrite (BF), 52 wt% polyvinyl acetate (PVA) and 3 wt% glycerol (GLYC). The second solution (S_2) was prepared by mixing 33 wt% barium hexaferrite (BF), 66 wt% polyvinyl acetate (PVA) and 1 wt% glycerol (GLYC). Coating with the two magnetic solutions S_1 and S_2 lead to two composite yarns CY_1 and CY_2, respectively.

The isotropic barium hexaferrite ($BaFe_{12}O_{19}$), which we will abbreviate as BF, is a ferrimagnetic material obtained from iron oxide (Fe_2O_3) and barium carbonate ($BaCO_3$). The magnetic characteristics of BF measured at room temperature were saturation magnetization (M_s) about 54 emu/g, residual magnetization (M_r) about 31 emu/g, and coercive field (H_c) about 100 kA/m. The Curie temperature (T_c) of BF does not exceed 450°C. BF is especially used in permanent magnets, microwave absorber devices and recording media.

The polyvinyl acetate ($(C_4H_6O_2)n$), abbreviated as PVA, is a rubbery thermoplastic synthetic polymer which can be used as adhesive, and often used in the textile industry for sizing of warp yarns. Its advantage over other resinous adhesives in that it is available in emulsion form that can be readily diluted with water for easy application. It is also safe because it does not contain any flammable solvents.

Glycerol ($C_3H_8O_3$), abbreviated as GLYC, is a trihydric alcohol widely used in the food, cosmetics and pharmaceutical industries because it can serve many functions such as a humectant (moisture absorber), plasticizer (softening agent), bodying agent, flavoring, denaturant, emollient (smoothing), antimicrobial, thickener and solvent. In this work, GLYC was used as plasticizer for magnetic solutions [7].

Coating laboratory equipment

The coated magnetic yarns were obtained through surface deposition of a thin magnetic film by employing in-house developed equipment (figure 1) which exhibits several innovative elements which are subject to a pending patent application [7].

A yarn is supplied from bobbin *2* and is passed through the leader yarn and tensioning device *3* which can be adjustable. Then, the yarn enters the coating chamber with spinneret *5* through the channels on gear wheel driven by the gear drive *4*. The magnetic solution is gravitationally supplied through the hopper into the coating chamber where the supplied solution is pushed to a heat conveyor being forced to adhere to yarn surface. The excess is calibrated by a spinneret *12*. In the end of this process, the yarn is covered with a continuous and homogenous coating layer (figure 2).

The ferromagnetic grains from the coating solution are placed onto the yarn surface into an oriented electromagnetic field generated by an air gap variable induction electromagnet *6* (figure 1B). The magnetic coating layer adheres to the surface of the yarn by solvent evaporation while the yarn is passing through the drying chamber *7*. The drying chamber has an adjustable temperature provided by a halogen linear lamp located eccentrically in an aluminum reflective tube. The guidance system of the yarn is placed at a distance of 1 cm from the heat source. During the drying process, vapors are released through some holes in the tube wall. The coated dried yarn *8* is wound on a loop cylindrical support *9* by friction using a grooved cylinder *10* that is driven by a variable speed stepper winding drive *11*. The components of the setup are controlled by an electrical control block *12*. All the component parts of the installation are fixed on a framework support *1*.

The advantages of this in-house developed equipment are the following:

- the possibility of using different types of yarns with a wide range of fineness.
- the possibility of using soluble binders in aqueous solutions or other solvents together with certain plasticizers at room temperature;
- uniform coverage of the yarns with different types of miscible products.

The process parameters are: yarn tension; diameter and type of the ferromagnetic grains; spinneret type, electromagnetic field strength; halogen lamp temperature; winding speed correlated to drying temperature. The surface of a coated yarn obtained through this process is shown in figure 2.

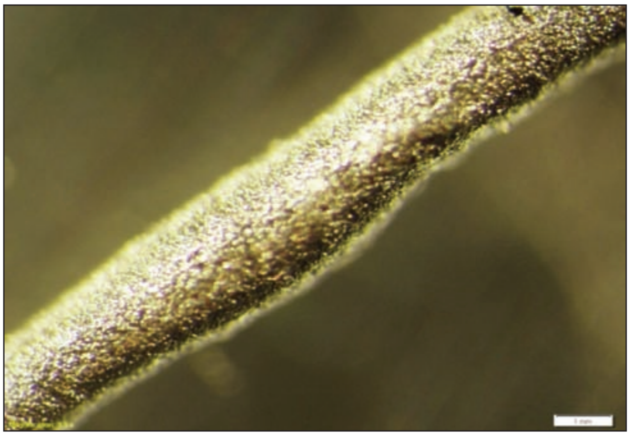


Fig. 2. Optical microscope image of a magnetic coated yarn

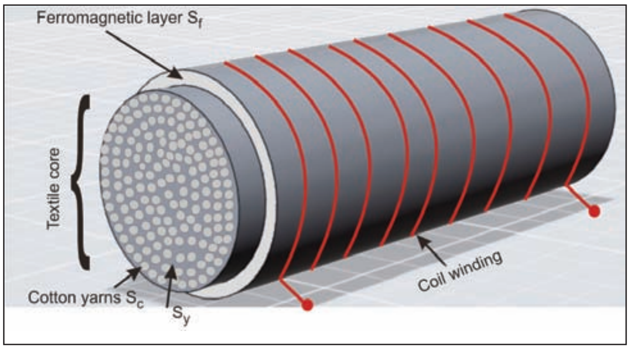


Fig. 3. Schematic view of the textile coil considered in the simulations

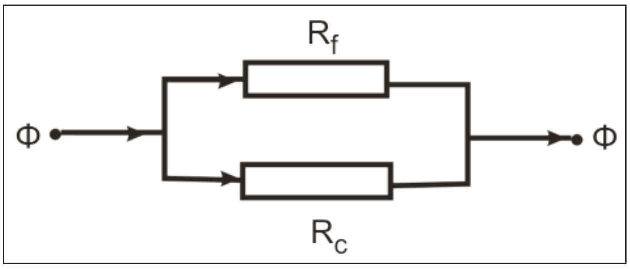


Fig. 4. Equivalent circuit diagram of the textile coil

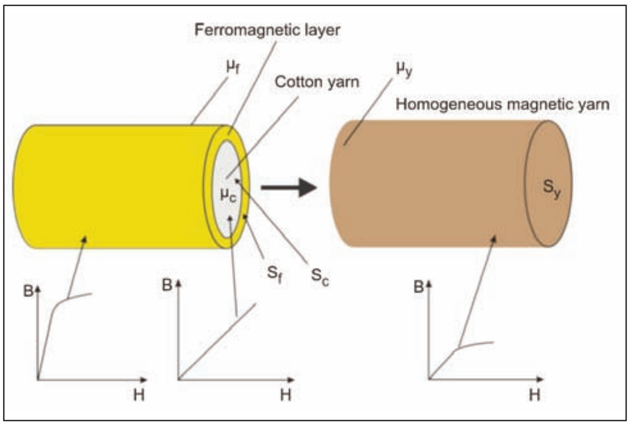


Fig. 5. Equivalent homogenous magnetic yarn having the same relative permeability as the composite on [8]

Simulation of a textile magnetic coil

Application – magnetic coil construction

The magnetic coil with a core made of coated yarns, which acts as a ferrimagnetic core, is shown in fig. 3. An electroconductive yarn is wound around the core of the coil.

A reluctance coil consists of two reluctances (see equation 1). One is the reluctance of the cotton core R_c and the another one is the reluctance R_f of the ferrimagnetic layer. A magnetic flux penetrates only through the ferrimagnetic layer because the reluctance of the cotton is very high. The equivalent circuit of such a magnetic circuit is presented in figure 4.

$$R_c = \frac{l_c}{\mu_c \cdot S_c}, \qquad R_f = \frac{l_f}{\mu_f \cdot S_f} \tag{1}$$

because $l_f = l_c = l_y$

$$R_y = R_c \parallel R_f = \frac{l_y}{\mu_c S_c + \mu_f S_f} \tag{2}$$

The equivalent permeability of a homogenous magnetic yarn μ_y (3)

$$\mu_y = \frac{\mu_c S_c + \mu_f S_f}{S_c + S_f} \tag{3}$$

where:

F – magnetic flux,
R_c – reluctance of cotton,
l_c – length of yarn (cotton),
μ_c – permeability of cotton,
S_c – area of yarn (cotton) cross-section,
S_f – area of layer ferrimagnetic cross-section,
R_f – reluctance of ferrimagnetic material,
l_f – length of yarn,
μ_f – permeability of ferrimagnetic material,
μ_y – permeability of magnetic yarn,
S_y – area of yarn (coating) cross-section.

Modeling and simulation of the magnetic core

Magnetic textile simulations are the first step in designing the magnetic core for a specific application. Numerical calculations are a versatile method for the analysis of phenomena occurring in the magnetic core.

One is the cotton yarn with magnetic permeability μ_c while the second one is the coating of ferrimagnetic layer which has the diamagnetic relative permeability μ_f. The equivalent magnetic permeability of a homogenous magnetic yarn which exhibits the same magnetic properties as the composite yarn is denoted by μ_y (figure 5). The simulation model is a textile induction coil which consists of bundles of fibers which form the magnetic core which is placed in a carcass. A copper wire or an electro conductive yarn with high conductivity is wound on the carcass. By employing the homogenization process we can replace the relative permeability of the textile magnetic core can be appointed for different layer thickness (figure 10). Simulations of the magneto static model coil were done with the software Package

CAD for Electromagnetic FLUX v. 10.3 [16]. The phenomena related to permanent magnetic fields are described by the Gauss law:

Gauss's Law for magneto static

Phenomena related to the permanent magnetic fields are described by the Gauss's law (4):

$$0 = \nabla \cdot \vec{B} \qquad (4)$$

after transformation (5):

$$0 = \nabla \cdot [\mu_0(\vec{H} + \vec{M})] \qquad (5)$$

where:

B – flux density,

H – field strength,

μ_0 – permeability of free space,

M – mass magnetization.

RESULTS AND DISCUSSIONS

Structural properties of the magnetic yarns

The magnetic composite yarns were subjected to a macroscopic analysis of their structural properties by employing a Olympus SZX 10 microscope equipped with Olympus DF PL 1,5 X-4 and Olympus DF PLAPO 1 X -4 lenses, and the Olympus Soft Motion Solutions, 1.5.1 (Build 8521) software. The apparent diameter was measured using an IOR-ML-4M microscope. Each sample was analyzed along a 10 cm length by performing 100 random measurements with a step of 1 mm.

The apparent diameter was measured using a IOR-ML-4M microscope.

Depending on the magnetic grains content in the coating solution, the surface of coated yarn has various shades of brown, *i.e.* from light brown in figure 6a to dark brown figure 6b, and a varnished brick aspect (figure 2). The fineness of the CY_1 and CY_2 samples was determined to be 134 tex and 88 tex, respectively. Figure 6 shows that small cracks varying between 11.16 μm and 14.57 μm can be observed on the yarn surface after the magnetic coating has dried. These lead to a variation of the yarn diameter along the fiber, variation which appears to be different for the two samples. The minimum, maximum, mean and standard deviation values of diameter are given in table 1 for the cotton yarn Y and coated yarns CY_1 and CY_2.

It can be observed from table 1 that also the diameter of the coated yarns CY_1 and CY_2 depends on the amount of magnetic powder in the coating solution. A 12% decrease in magnetic powder content, i.e. 45 wt% as compared to 33 wt% for CY_1 and CY_2, respectively, is resulting in a 59.91 μm decrease of the mean yarn diameter. However, the evenness of coated yarns increases with the decrease of magnetic powder content from 7.78% to 5.88%.

Based on the above, we can conclude that properties of the composite structure depend on the type of the magnetic coating solution and that the quality of covering process depends on the amount of magnetic particles in the mixture and the type and percentage of the binder.

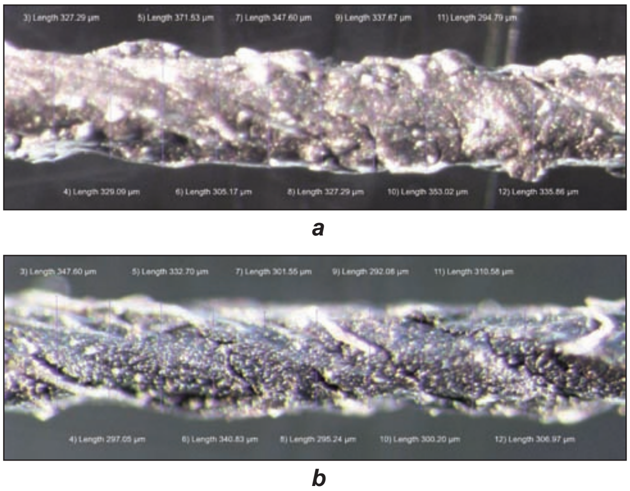


Fig. 6. Magnified view of CY1 (a) and CY2 (b)

Table 1

STATISTICAL ANALYSIS OF THE YARNS DIAMETER VALUES

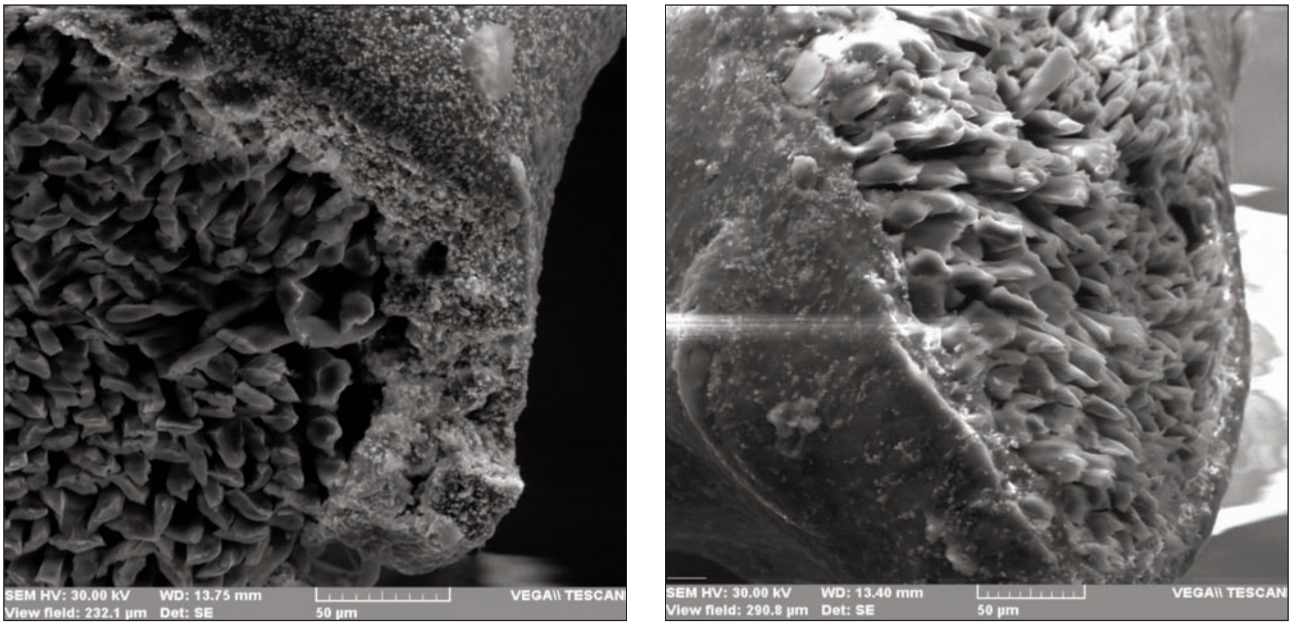
Statistical parameters	Y	CY1	CY2
Mean, μm	256.54	359.36	299.45
Minimum, μm	227.33	300.10	260.00
Maximum, μm	284.66	420.50	340.56
Dispersion (D^2), μm^2	213.90	800.10	310.20
Standard deviation, μm	14.62	28.29	17.61
Coefficient of variation, %	5.71	7.78	5.88

SEM characterization of the magnetic coating

The SEM images indicate the presence of different percentages of ferrite grains in the coating (figure 7). The coating layer of CY_1 (BF 45wt%) is seen to be thicker than the coating layer of CY_2 (BF 33wt%). At the same time, the uniformity of the magnetic layer increases with the percentage of magnetic grains in the coating solution due to the different distance between two adjacent magnetic grains which is smaller for S_1 than S_2.

It is worth noting, that the amount of 45 wt% of magnetic grains in the coating solution is the maximum amount used for coating when employing the method described in this work. Exceeding this amount of magnetic filler turned out to have various implications on the final characteristics of the composite yarns:

- decreased fluidity of the coating solution and poor adherence on the yarn surface;
- increased number of cracks at the surface of the magnetic layer;
- increased the rigidity of the composite yarns;
- improved residual magnetization of the composite yarn which reached values close to the residual magnetization of the coating solution and the one of the bulk magnetic filler;
- increased unevenness (coefficient of variation) on yarn surface.



A ***B***

Fig. 7. SEM view of CY1 (A) and CY2 (B)

Magnetic characterization of the composite yarns

The magnetic properties of bulk BF, coating magnetic solutions (S_1 and S_2) and composite yarns CY_1 and CY_2 have been determined with a VSM Lake Shore 7300 magnetometer having a maximum magnetic induction of 2T, in the temperature range of 4–1300 K. The magnetic measurements have been done according to ASTM A894/A894M-00(2011)e1, „Standard Test Method for Saturation Magnetization or Induction of Nonmetallic Magnetic Materials“.

The mass saturation magnetization (M_s) and mass residual magnetization (M_r) of the bulk BF at a maximum applied field of 580.43 kA/m are 49.59 emu/g and 32.69 emu/g, respectively. These values are higher than the ones of the magnetic solutions S_1 and S_2. In the case of S_1, M_s and M_r at a maximum applied field of 591.88 kA/m are 39.88 emu/g and 23.51 emu/g, respectively. In the case of S_2, M_s and M_r at a maximum applied field of 588.08 kA/m are 29.43 emu/g and 18.32 emu/g, respectively. The magnetic yarns have even lower M_s and M_r values than the coating solutions because only a small percentage of the solution magnetic grains is included in their composition. The higher charging degree, the higher are the values of M_s and M_r due to a higher magnetic grains content. For example, a 8.79% increase of the charging degree from 66.67% for CY_2 to 75.46% for CY_1 is resulting in an increase of M_s and M_r values from 13.78 emu/g and 6.22 emu/g to 25.28 emu/g and 13,78 emu/g, respectively. The maximum applied field was 592.37 kA/m for CY_1 and 584.93 kA/m for CY_2. The values dependence of the saturation and residual magnetization on the charging degree is presented in the figure 8. It can be seen that the magnetization value decreases with the charging degree.

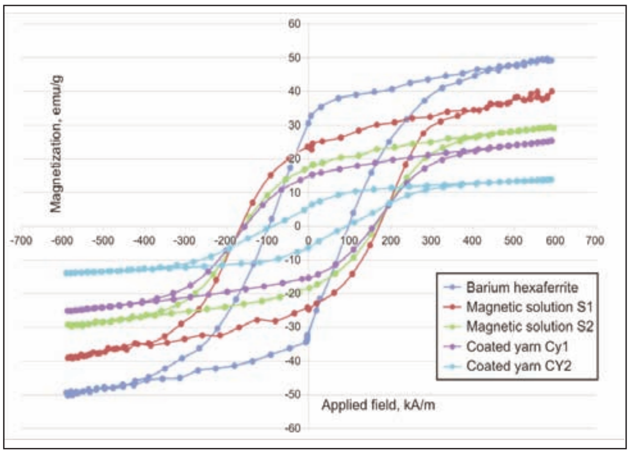


Fig. 8. Magnetic characteristics of bulk FB grains, coating solutions S_1, S_2 and yarns CY_1 and CY_2

Simulation results

As outlined above, the model is a textile magnetic coil with a magnetic core made of magnetic yarns and winding made of a metallic wire or an electroconductive yarn. The mesh structure of the yarn is shown in the cross section in figure 9. A grid structure specially concentrated on the border between the layers of

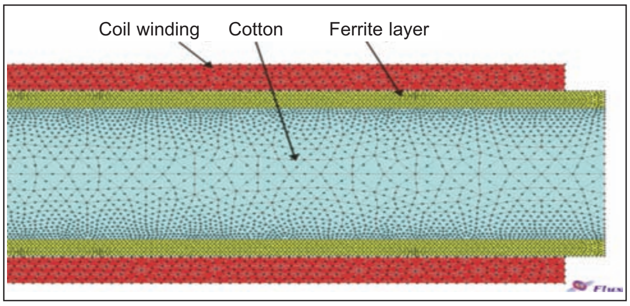


Fig. 9. Detailed mesh for 2D-view magnetic

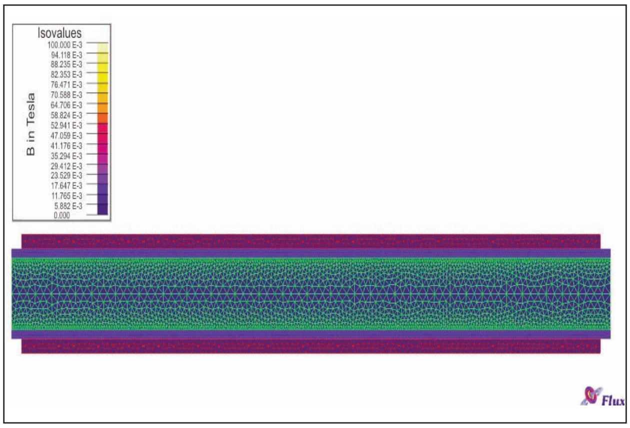


Fig. 10. Distribution of the induction of the magnetic yarn

textile magnetic composite. This procedure was performed in order to improve the accuracy and accelerating of numerical calculations. This treatment will not affect on the quality of the calculation due to the set the alternative magnetic permeability coefficients of composite fabric components.

The distribution of the magnetic induction B was simulated and is presented in figure 10. The distribution of magnetic induction, in this ideal case is homogeneous. In reality, it looks different and depends on the technological process of manufacturing the magnetic fibers. The value of the coil magnetic composite induction is almost two times larger than the earth induction. These properties even though not huge, are permanent. This allows the use of such products in various applications.

DISCUSSIONS AND CONCLUSIONS

Production of new textile yarns with magnetic properties can find their way in many new practical applications for example in the medical field. Such materials can be also used as electromagnetic shielding materials in wallpaper. The current challenge is to obtain magnetic yarns with good, i.e. high, magnetic properties and also mechanical properties. According to our results, the size of the magnetic grains must be optimized such as to achieve a balance between good mechanical and magnetic properties.

In this paper, we demonstrate the production of magnetic yarns by coating a ferrimagnetic solution containing micrometric grains of barium hexaferrite on a cotton yarn. As expected, increasing of the magnetic parameters values depends on the percentage of hard ferrimagnetic grains in the magnetic solution. The maximum experimentally-determined percentage of magnetic grains which could be included in coating magnetic solution was 45 wt%. Exceeding this amount of magnetic filler in the solution impends negatively on the final characteristics of the composite yarn due to decreased fluidity of the coating solution and also decreased adherence to the yarn surface. Consequently, the obtained magnetic coating is uneven and exhibits cracks. The diameter of the coated yarns depends on the amount of magnetic powder which adheres from the solutions. The diameter evenness increases with the decrease of magnetic powder.

The higher charging degree, the higher are the values of M_s and M_r due to a higher content of magnetic powder from the coating solution. Therefore, the magnetic properties of the yarns depend on the mass percentage of magnetic grains contented in the coating layer. Modeling of the magnetic yarn enables the magnetic circuits analysis of the phenomena which occur in them.

ACKNOWLEDGEMENT

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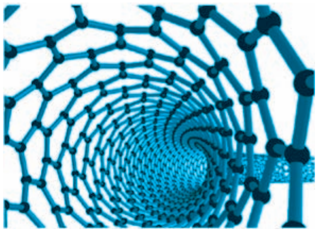

The thinness degree study of wool yarns of different origins using the Uster machine

DORINA OANA
IOAN PAVEL OANA
MARIUS ȘUTEU

REZUMAT – ABSTRACT

Studiul gradului de subțirime a firelor de lână de proveniență diferită cu ajutorul aparatului Uster

Gradul de subțirime este un parametru de bază al firelor care influențează finețea firelor de lână având efecte asupra calității tricoturilor și țesăturilor din lână și totodată cu efecte asupra proprietăților fizico-mecanice și estetico-funcționale ale acestora.
Scopul studiului este compararea gradelor de subțirime a firelor de lână provenite din zone geografice și climaterice diferite, în vederea stabilirii firelor cu uniformitatea cea mai bună din punct de vedere al fineții lor, pentru obținerea de structuri textile de calitate superioară. Analizele comparative s-au realizat pe fire de 100% lână, de proveniență diferită dar cu aceiași finețe Nm 40/1 și torsiunea de 620 tors/m. Studiul s-a realizat în condiții standard de temperatură și umiditate cu ajutorul aparatului USTER® TESTER 5-S800 R 5.7.
În urma prelucrării statistico-matematice a rezultatelor obținute la analizarea acestor fire, a fost identificat furnizorul firelor de lână de calitate superioară din punct de vedere al gradului de neuniformitate al fineții firelor și dispersia gradului de subțirime a acestora astfel s-a stabilit zona geo-climaterică favorabilă obținerii de lână de calitate superioară.

Cuvinte-cheie: grosimea firelor, Uster tester R, neregularitate, finețea firelor, torsiune, grad de subțirime

The thinness degree study of wool yarns of different origins using the Uster machine

The thinness degree is a basic parameter of woollen yarns, which are influencing the fineness of woollen yarns with effects on the quality of knitted fabrics and woollen fabrics and also with effects on their physical, mechanical and functional-aesthetic properties.
The purpose of the study was to compare the degrees of woollen yarns thinness from different geographic and climatic zones, in order to establish the best uniformity of yarns with regard to their fineness, in order to obtain high quality textile structures. The comparative analysis was performed on 100% wool yarns, from different backgrounds but with the same fineness Nm 40/1 and torsion 620 twists/m. The study was conducted under standard conditions of temperature and humidity using the machine TESTER 5-S800 USTER® R 5.7.
After processing the statistical and mathematical results obtained when analysing these yarns we identified the high quality wool yarns supplier in terms of the unevenness of yarns fineness and the dispersion degree of their thinness we established the favourable geo-climatic area for obtaining high quality wool.

Keywords: yarns thickness, Uster Tester R, irregularity, yarn fineness, torsion, thinness degree

INTRODUCTION

Global population growth has caused an increase in consumption of textile and clothing and the improvements in living standards brought back wool fabrics and knits on fashion designers agenda. According to the International Wool Textile Organisation – IWTO the wool industry is producing around 2.1 million tons of wool per year of wich 60% is used for apparel. [1] Natural fibers are particularly important in the field of high added value fabric production, but the studies related to these fibers, especially wool, are limited.

MODELING METHOD

This paper is part of a series of works regarding the identification of some woollen yarns quality, with recommendations on the choice of the raw material supplier for woven and knitted structures. The woollen yarns analysis was performed at SILVANIA SPINNING SRL using the machine USTER® TESTER 5-S800, which has the following features computer software: the USTER® TESTER 5-S800 is a menu driven design that allows quick access and selection of testing, setup, calibration and data management. These features include: windows operating system with icon-based software, simple user interface, error messages for troubleshooting, network capabilities.
Computer hardware: industrial computer system with dual core 2.5 GHz processor and 4GB RAM.
Mass and yarn count variations, thin places, thick places and neps can influence the quality and the sales price of the yarn enormously. With the USTER® TESTER 5-S800, these quality parameters can be determined with an incredible test speed of 800 m/min. The optoelectronic sensors of the USTER® TESTER 5-S800 give additional quality-relevant information. One innovation, exclusive to USTER, is having foreign fiber measurements integrated into the USTER® TESTER 5-S800. With the new Fancy Yarn Profile feature, the S800 offers all the benefits of precise quality control. Only USTER's unique sensor technology guarantees a hitherto

Fig. 1. USTER® TESTER 5-S800 [3]

unobtainable degree of precision – and the measuring accuracy which is the benchmark for the textile industry.

The transversal dimension of textile yarns is one of the most important parameters for assessing the quality of yarns batches, which largely influences the manufacturing processes and knitted and woven product quality. [2]

This parameter is taken into account in designing yarns when establishing the destination of yarns batches, the yarns assortment to be achieved, and the corresponding spinning technology. [3]

The fineness of the yarns that can be spun out of a given yarns is conditioned by a minimum number of yarns in the cross section. For the same yarn fineness, the higher the fineness of yarns, the higher the number of yarns in cross section, the frictional forces between the yarns will be higher, leading to a higher resistance of the yarn. The uniformity and stability of the yarns structure are influenced by the cross-sectional dimension, or the degree of thinness of the yarns. [4]

The degree of thinness of yarns determines a number of characteristics of the finished products (woven and knitted): the feel, its shine, flexibility, resistance to repeated bending, thermal insulation capacity. Unlike other materials, all kinds of yarns have two particular features:

– they have a certain non-uniformity both in the cross-sectional shape and the dispersion degree of thinness.
– they have a certain deformability on the transversal direction, a particularity which from a technologic point of view is an advantage, because it allows the fixation of yarns between the yarns structure. [5]

This deformability does not allow the use of flexible systems and devices for measuring the transversal dimension and requires the introduction of special techniques for assessing the degree of yarns thinness, such as the machine USTER® TESTER 5-S800.

The comparative analysis of optical non-uniformity, optical defects of the yarns: thinning, thickening, naps and hairiness, was performed using USTER® TESTER 5-S800 device simultaneously with determining the thinness of wool yarns of different origins. [6] These characteristics directly affect the quality of woollen yarns.

To perform the study were taken three batches of 100% woollen yarn of different origin, being taken in each batch ten samples for determining the yarns thinness degree using USTER® TESTER 5-S800 device. [1] It was performed the statistical and mathematical processing of the data obtained, after performing study tests and also the dispersion degree of thinness.

The first batch taken for analysis was woollen yarns from Asia (Batch 1). [7]

Table 1 presents the statistical and mathematical processing, the degree of thinness analyzed for the

Table 1

STATISTICAL AND MATHEMATICAL PROCESSING OF THE YARNS THINNESS DEGREE – BATCH 1

No.	CVm %	CVm 10m %	Thin –40% /km	Thin –50% /km	Thick +35% /km	Thick +50% /km	Neps +140% /km	Neps +200% /km	Index	Count	Rel. Cnt ± %	H	sh
1	15.95	3.08	362.5	35.0	150.0	15.0	2.5	0.0	1.05		–1.3	3.13	0.97
2	15.75	2.53	387.5	52.5	140.0	7.5	5.0	0.0	1.04		–0.2	3.24	0.98
3	16.14	2.46	470.0	37.5	182.5	17.5	5.0	0.0	1.07		–2.2	3.16	0.96
4	15.54	2.14	397.5	65.0	170.0	12.5	0.0	0.0	1.03		1.1	3.12	0.94
5	15.55	2.44	350.0	27.5	147.5	2.5	0.0	0.0	1.03		0.1	3.10	0.92
6	15.98	2.32	475.0	55.0	185.0	2.5	7.5	0.0	1.06		–0.3	3.20	0.99
7	15.78	3.10	380.0	60.0	162.5	10.0	2.5	0.0	1.04		0.7	3.14	0.97
8	15.71	2.65	325.0	35.0	160.0	5.0	7.5	0.0	1.04		0.9	3.16	0.99
9	16.18	2.50	465.0	60.0	207.5	5.0	2.5	0.0	1.07		1.8	3.23	0.99
10	16.30	2.60	457.5	62.5	150.0	5.0	10.0	5.0	1.08		–0.8	3.07	0.92
Mean	15.89	2.58	407.0	49.0	165.5	8.3	4.3	0.5	1.05		–0.0	3.16	0.96
CV	1.7	11.7	13.6	28.2	12.7	64.0	78.7	316.2	1.7		1.2	1.8	2.9
Q 95	0.19	0.22	39.7	9.9	15.0	3.8	2.4	1.1	0.01		0.9	0.04	0.02
Max	16.30	3.10	475.0	65.0	207.5	17.5	10.0	5.0	1.08		1.8	3.24	0.99
Min	15.54	2.14	325.0	27.5	140.0	2.5	0.0	0.0	1.03		–2.2	3.07	0.92

10 samples of woollen yarns from batch 1 obtaining: CV-average measured over 400 m for 1 minute, CV-intermediate measured on 10m, variation Nm, H-hairiness, SH-variation hairiness variation, NEPS-neps, Index - the value given by the tested yarn diameter, mean-average value obtained that relates to reference values, Q-95 permissible deviation from the standard value, Thin-thinness, Thick-thickening.

Next are represented the dispersion diagrams of the irregularity degree of thinness and also the irregularity spectrograms of the degree of thinness obtained, based on the mathematical and statistical processing, of the ten yarns from Batch 1.

In figure 2 is shown the dispersion diagram of the irregularity degree of thinness for the ten samples of woollen yarns, analyzed using USTER® TESTER 5-S800 device from Batch 1.

Figure 3 present the spectrogram of irregularity of the thinness degree for the ten samples of wool yarn, analyzed using USTER® TESTER 5-S800 device from Batch 1.

The second batch analyzed is the woollen yarns from South Africa (Batch 2).

Table 2 presents the statistical and mathematical processing, the degree of thinness analyzed for the 10 samples of woollen yarns from batch 2 obtaining: CV-average measured over 400 m for 1 minute, CV-intermediate measured on 10m, variation Nm, H-hairiness, SH-variation hairiness variation, NEPS-neps, Index - the value given by the tested yarn diameter, mean-average value obtained that relates to reference values, Q-95 permissible deviation from the standard value, Thin-thinness, Thick-thickening.

Next are represented the dispersion diagrams of the irregularity degree of thinness and also the irregularity spectrograms of the degree of thinness obtained, based on the mathematical and statistical processing, of the ten yarns from Batch 2.

The dispersion diagram of the irregularity degree of thinness for the ten samples of woollen yarns, analyzed using USTER® TESTER 5-S800 device from Batch 2 is presented in figure 4.

Figure 5 illustrates the spectrogram of irregularity degree of thinness for the ten samples of woollen yarns, analyzed using USTER® TESTER 5-S800 device from Batch 2.

The third batch taken for analysis represents the woollen yarns from England (Batch 3).

Table 3 presents the statistical and mathematical processing, the degree of thinness analyzed for the 10 samples of woollen yarns from batch 3 obtaining: CV-average measured over 400m for 1 minute, CV-intermediate measured on 10m, variation Nm, H-hairiness, SH-variation hairiness variation, NEPS-neps, Index - the value given by the tested yarn diameter, mean-average value obtained that relates to reference values, Q-95 permissible deviation from the standard value, Thin-thinness, Thick-thickening.

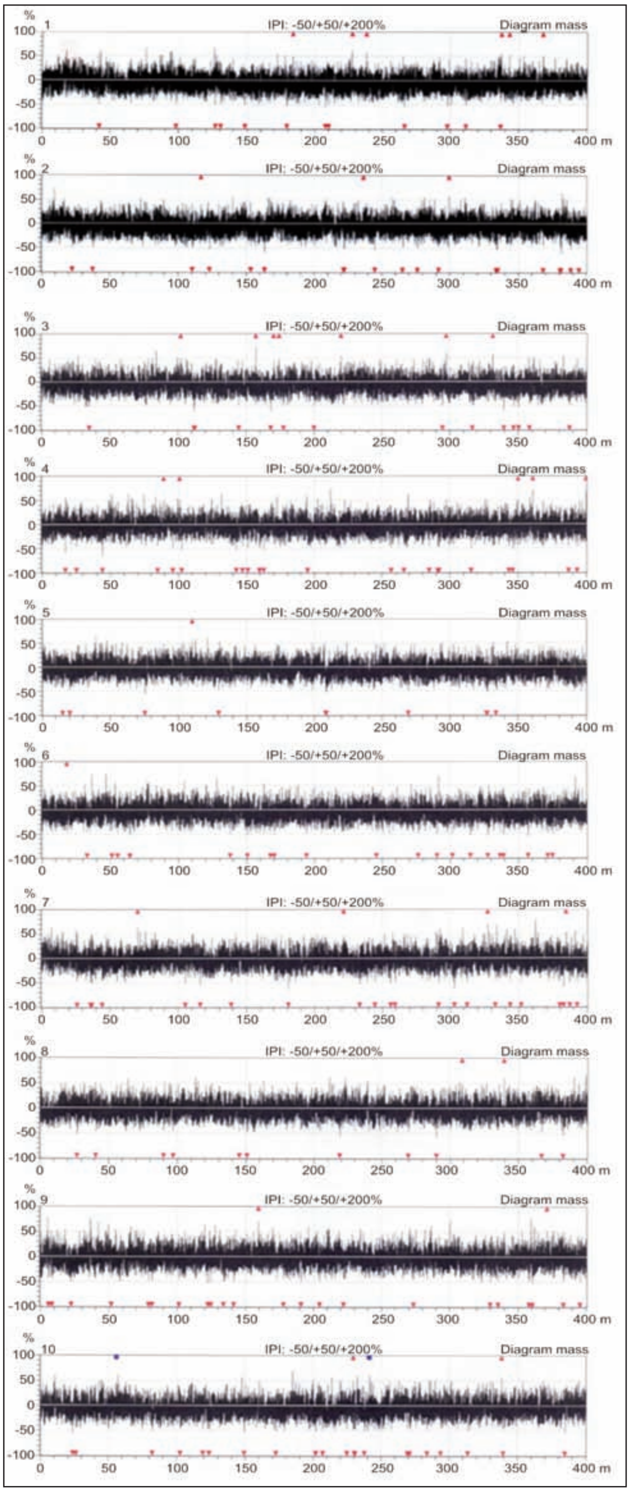

Fig. 2. Diagram of dispersion of the irregularity degree of thinness of yarns from Batch 1

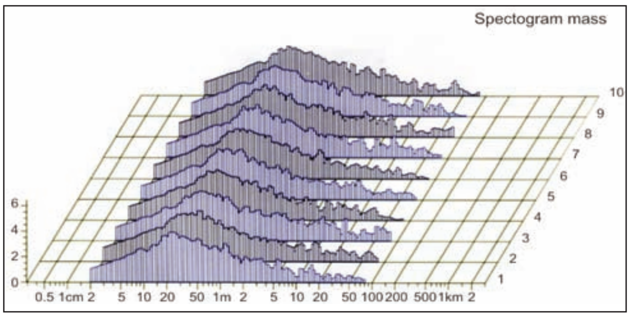

Fig. 3. Spectrogram of thinness degree irregularity yarns from Batch 1

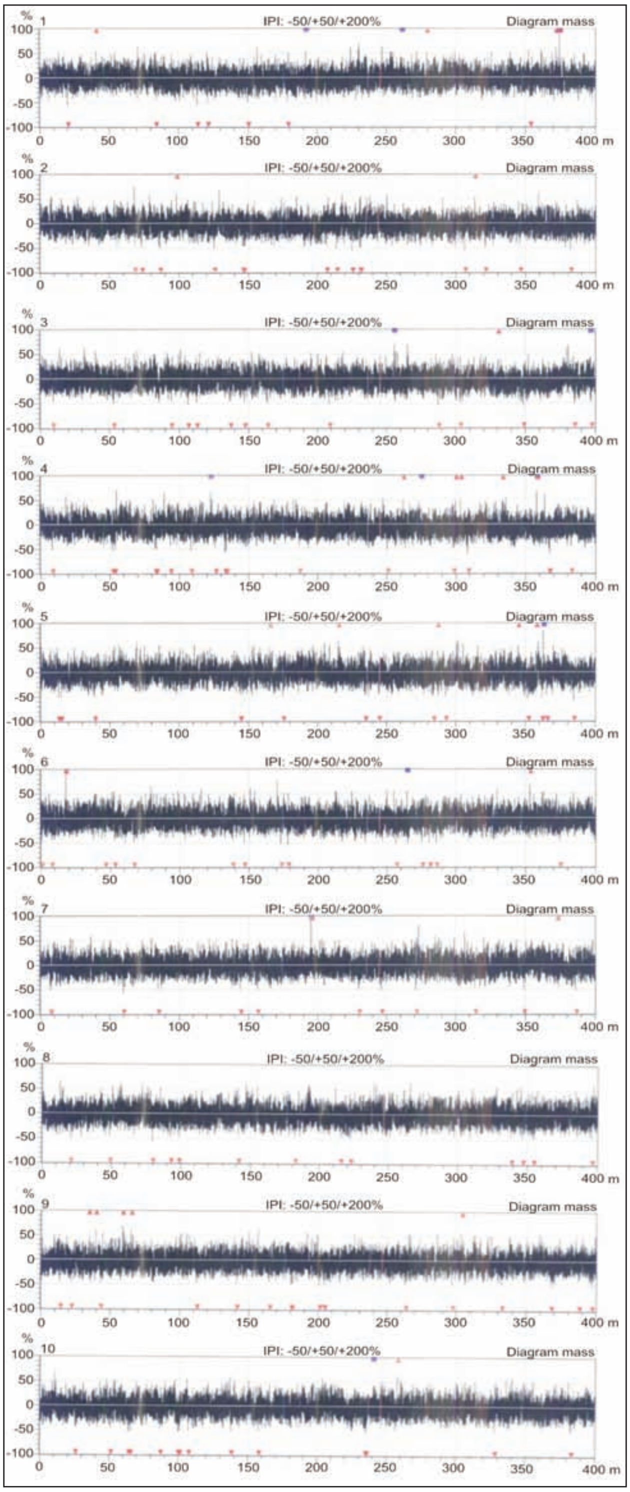

Fig. 4. Dispersion diagram of the irregularity thinness degree of yarns from Batch 2

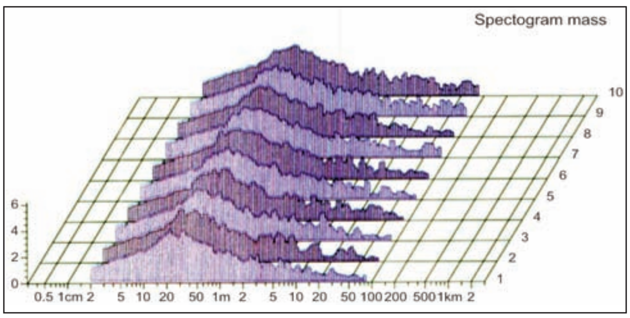

Fig. 5. Spectrogram of irregularity thinness degree of yarns from Batch 2

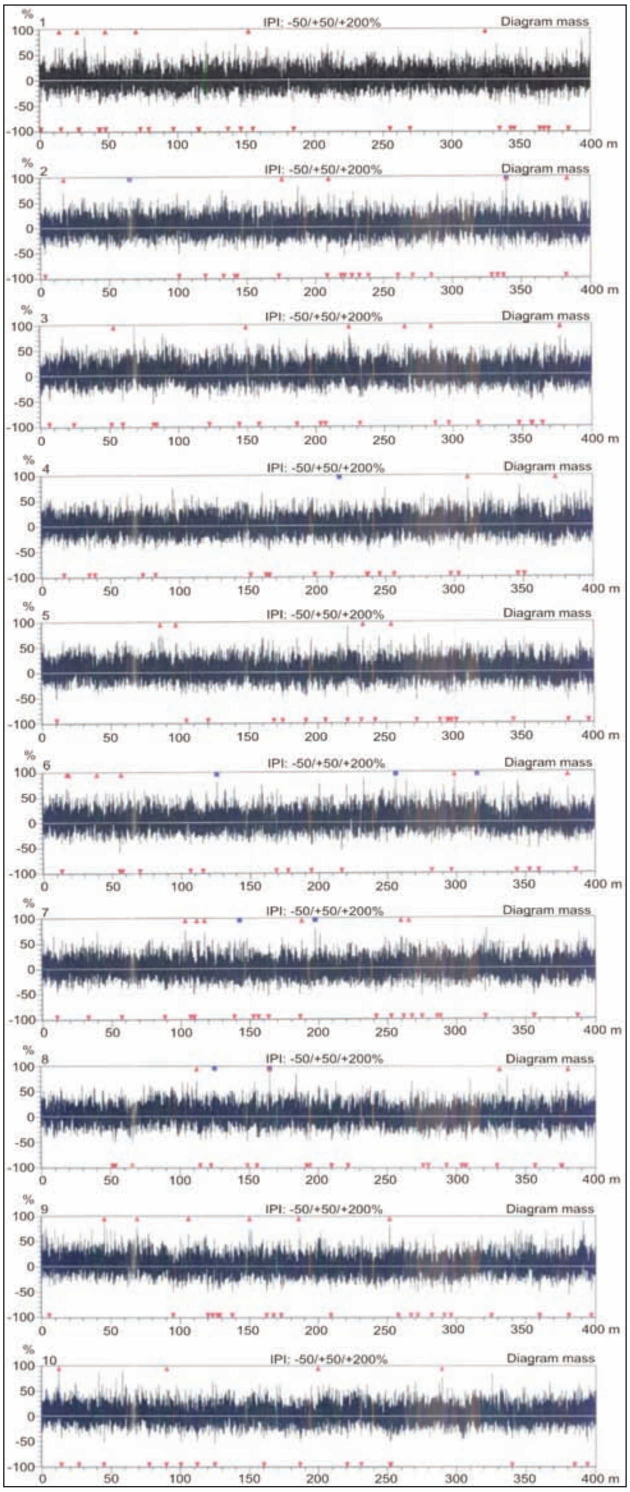

Fig. 6. Dispersion diagram of the thinness degree irregularity of yarns from Batch 3

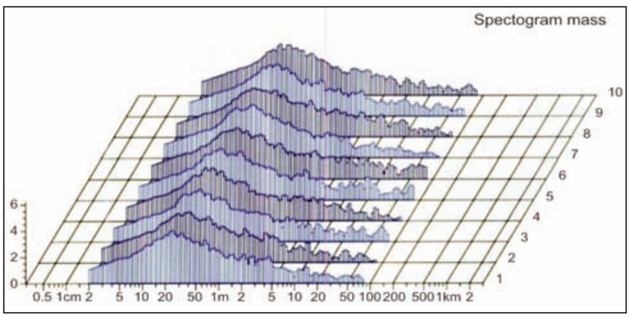

Fig. 7. Spectrogram of irregularity degree of thinness of yarns from Batch 3

Table 2

STATISTICAL AND MATHEMATICAL PROCESSING OF THE YARNS THINNESS DEGREE – BATCH 2													
No.	**CVm %**	**CVm 10m %**	**Thin –40% /km**	**Thin –50% /km**	**Thick +35% /km**	**Thick +50% /km**	**Neps +140% /km**	**Neps +200% /km**	**Index**	**Count**	**Rel. Cnt ± %**	**H**	**sh**
1	15.21	2.66	282.5	17.5	145.0	10.0	7.5	7.5	1.04		0.4	5.66	1.56
2	15.09	2.36	305.0	37.5	92.5	5.0	2.5	0.0	1.04		–0.1	5.46	1.42
3	15.21	2.43	345.0	40.0	97.5	2.5	10.0	5.0	1.04		–0.4	5.43	1.47
4	15.68	2.76	305.0	47.5	140.0	12.5	10.0	7.5	1.08		–2.3	5.61	1.49
5	15.60	2.80	342.5	40.0	147.5	12.5	10.0	2.5	1.07		–0.2	5.57	1.52
6	15.70	2.49	352.5	42.5	140.0	5.0	15.0	5.0	1.08		0.7	5.72	1.53
7	15.29	2.22	322.5	32.5	120.0	5.0	10.0	2.5	1.05		1.4	5.77	1.55
8	15.41	2.46	350.0	35.0	122.5	0.0	5.0	0.0	1.06		0.7	5.67	1.55
9	15.32	2.03	345.0	40.0	117.5	12.5	2.5	0.0	1.05		–0.5	5.48	1.48
10	15.65	2.22	382.5	37.5	122.5	2.5	5.0	2.5	1.07		0.2	5.72	1.54
Mean	15.42	2.44	333.3	37.0	124.5	6.8	7.8	3.3	1.06		0.0	5.61	1.51
CV	1.5	10.1	8.8	21.6	15.3	69.9	51.5	89.2	1.5		1.0	2.1	3.0
Q 95	0.16	0.18	21.0	5.7	13.6	3.4	2.9	2.1	0.01		0.7	0.09	0.03
Max	15.70	2.80	382.5	47.5	147.5	12.5	15.0	7.5	1.08		1.4	5.77	1.56
Min	15.09	2.03	282.5	17.5	92.5	0.0	2.5	0.0	1.04		–2.3	5.43	1.42

Table 3

STATISTICAL AND MATHEMATICAL PROCESSING OF THINNESS THE DEGREE OF THE YARNS - BATCH 3													
No.	**CVm %**	**CVm 10m %**	**Thin –40% /km**	**Thin –50% /km**	**Thick +35% /km**	**Thick +50% /km**	**Neps +140% /km**	**Neps +200% /km**	**Index**	**Count**	**Rel. Cnt ± %**	**H**	**sh**
1	16.00	2.51	490.0	85.0	137.5	15.0	0.0	0.0	1.10		–0.9	5.75	1.47
2	15.74	2.36	435.0	55.0	187.5	12.5	10.0	5.0	1.08		–0.4	5.65	1.44
3	15.96	2.90	415.0	52.5	200.0	15.0	10.0	0.0	1.10		1.8	5.72	1.47
4	15.92	2.58	452.5	50.0	160.0	5.0	5.0	2.5	1.09		–1.4	5.75	1.43
5	15.66	2.93	417.5	52.5	175.0	10.0	10.0	0.0	1.08		1.1	5.62	1.40
6	15.70	2.65	377.5	42.5	172.5	15.0	12.5	7.5	1.08		1.6	5.76	1.52
7	15.89	2.45	427.5	62.5	182.5	15.0	7.5	5.0	1.09		–2.1	5.59	1.45
8	15.80	2.80	407.5	60.0	185.0	10.0	10.0	5.0	1.08		0.2	5.52	1.39
9	16.01	3.46	420.0	60.0	187.5	15.0	5.0	0.0	1.10		0.2	5.76	1.47
10	15.88	2.67	400.0	45.0	195.0	10.0	0.0	0.0	1.09		–0.1	5.65	1.44
Mean	15.86	2.73	424.3	56.5	178.3	12.3	7.0	2.5	1.09		0.0	5.66	1.45
CV	0.8	11.6	7.2	21.1	10.3	28.0	62.5	115.5	0.8		1.3	1.5	2.6
Q 95	0.09	0.23	21.9	8.5	13.1	2.5	3.1	2.1	0.01		0.9	0.06	0.03
Max	16.01	3.46	490.0	85.0	200.0	15.0	12.5	7.5	1.10		1.8	5.76	1.52
Min	15.66	2.36	377.5	42.5	137.5	5.0	0.0	0.0	1.08		–2.1	5.52	1.39

Next are represented the dispersion diagrams of the irregularity degree of thinness and also the irregularity spectrograms of the degree of thinness obtained, based on the mathematical and statistical processing, of the ten yarns from Batch 3.

The dispersion diagram of the irregularity degree of thinness for the ten samples of woollen yarns, analyzed using USTER®TESTER 5-S800 device from Batch 3 is illustrated in figure 6.

Figure 7 show the spectrogram of irregularity degree of thinness for the ten samples of woollen yarns, analyzed using USTER® TESTER 5-S800 device from Batch 3.

RESULTS AND DISCUSSIONS

As a result of the comparative analysis of average variation coefficient values for the three batches of woollen yarns of different origins: CVm = 1.7; CVm = = 1.5; CVm = 0.8. Authors found that CVm = 0.8 has the lowest value, it results that the woollen yarns from England have the slightest non-uniformity in terms of their fineness, being the yarns with the highest quality and uniformity between the three groups analyzed.

CONCLUSIONS

As a result of the study conducted on three batches of wool yarns from different geo-climatic zones with the help of USTER® R5.7 TESTER 5-S800 device, were analyzed the non-uniformity properties, optical defects of the yarns: thinning, thickening, neps and hairiness on which we can determine the analyzed quality. Based on this was achieved the dispersion degree of yarns thinness and statistical and mathematical processing of data obtained from ten samples of woollen yarns from the three batches: CV-average measured over 400m for 1 minute, CV-intermediate measured on 10m, variation Nm, H-hairiness, SH-variation hairiness variation, NEPS-neps, Index - the value given by the tested yarn diameter, mean-average value obtained that relates to reference values, Q-95 permissible deviation from the standard value, Thin-thinness, Thick-thickening.

After analyzing these data it has resulted that the wool coming from England is superior in quality compared to the wool coming from South Africa and Asia, which have an increased hairiness.

The woollen yarns from England have an non-uniformity degree and CV-lowest, in terms of the thinness degree of the analyzed, due to the specific temperature and humidity from England.

ACKNOWLEDGEMENTS

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Optimization of the slub yarn tensile strength with Taguchi techniques

SEVDA ALTAŞ BANU ÖZGEN

REZUMAT – ABSTRACT

Optimizarea rezistenței la tracțiune a firelor cu flameuri folosind tehnici Taguchi

Rezistența firului reprezintă unul dintre parametrii calitativi cei mai semnificativi care urmează a fi controlați în timpul procesului de filare. În cadrul acestui studiu s-a dorit obținerea unei rezistențe la tracțiune maxime a firelor cu flameuri, folosind un proces de optimizare a factorilor de control selectați, și anume: lungimea nopeului, distanța între nopeuri, grosimea nopeului și finețea firului. În acest scop au fost folosite tehnica de design experimental Taguchi, analiza variației (ANOVA) și raportul semnal zgomot (S/N). În loc de 81 (3^4) de configurații diferite de fire cu flameuri (designul complet), au fost filate și folosite doar 9 configurații care au ținut cont de designul ortogonal Taguchi L_9. Ca urmare a experimentărilor au fost determinați parametri optimi ai firelor cu flameuri, ceea ce a condus la o îmbunătățire considerabilă a rezistenței la tracțiune.

Cuvinte-cheie: design Taguchi, optimizare, rezistență la tracțiune, fir cu flameuri

Optimization of the slub yarn tensile strength with Taguchi techniques

Yarn strength is one of the most significant quality parameters to be controlled during the yarn spinning process. In this study, it was aimed to achieve maximum slub yarn tensile strength with an optimization process on selected control factors that were slub length, slub distance, slub thickness and yarn count. For this purpose, the Taguchi experimental design technique, analysis of variance (ANOVA), and signal-to-noise (S/N) ratio were used. Instead of 81 (3^4) different slub yarn configuration (full factorial design), only nine yarn configurations with respect to Taguchi's L_9 orthogonal design were spun and tested. As a result of these experiments, the optimum slub yarn parameters, which made a considerable improvement on yarn tensile strength, were determined.

Keywords: Taguchi design, optimization, tensile strength, slub yarn

The fancy yarns add value to the end-product by improving the appearance, giving it a more attractive and natural look. For several years fancy yarns have been essential components of modern fashion and have been gaining more importance in the clothing sector, especially denim, and in furnishing and draperies [1].

A variety of methods are available for producing slub yarns and each offering its own benefits and challenges. The finer slubs can be used simply to introduce a subtle variation in the surface of plain fabric; on the other hand the heavier slub can be used as a design element [2].

The higher strength of slub yarns is required in terms of both the performance in production and the end use of the fabric. Therefore, the weak points in slub yarn are not desired; they especially occur at the beginning and end of the slubs due to change of roller speed in the production of slub yarn. It is known that the main descriptive parameters of slub yarn (slub length, slub distance, slub multiplier, base yarn count, twist level etc.) have an effect on the strength and elongation performance of the yarn. These parameters highly affect the yarn physical properties [3, 4].

Breaking strength of the slub-yarn is stronger than that of the classic ring spun yarn yarn with the same twist design. It is believed that base parts in slub-yarn acquire more twists than the classic ring spun yarn, and before reaching the critical twists, the increased twists lead to the high breaking strength. Slub length is the key factor that affects the twist level in the base yarn, and the increase of the slub length increase the twist of the base yarn. It is necessary to adjust the slub length to avoid basic yarn twist exceeding critical twist. Slub multiplier is another key factor thus the increase in the slub multiplier decreases the twist in the slub sections [5]. The twist of the slubs are lower than the basic yarn twist, as a result of this in the slub part of the yarn, the fibre to fibre interaction are less than the basic yarn. For this reason with the increase of the slub length, the increase of slub thickness and the increase of slub frequencies, the yarn strength values decreases [6].

The experiments were designed according to Taguchi's orthogonal array (OA) technique which is a powerful tool for improving quality and simultaneously reducing development time [7]. Experimental design refers to the determination of the experimental conditions run in order to decide design parameters or manufacturing conditions for stable quality. Traditional experimental design is mainly used to improve the average level of a process. In modern quality engineering, experimental design is used to come up with robust designs for quality improvement [8].

Taguchi's methodology for optimization can be divided into four phases, namely, planning, conducting, analysis and validation. Each phase has a separate objective and individually contributes to the overall optimization process. The method uses a special design of OAs in order to study the entire parameter space with a small number of experiments. The experimental results are then transformed into an S/N (signal to noise) Ratio. Optimization is conducted through the comparison of S/N Ratios for each level [9].

The present study focused on optimizing the slub yarn properties affecting the yarn tensile strength. Yarns were produced according to Taguchi L_9 layout and yarn strength values were tested and analyzed. A confirmation experiment was carried out to verify the optimum conditions suggested by S/N Ratios and ANOVA analyses.

DETERMINATION OF CONTROL FACTORS

A simple slub yarn structure is composed of two parts, the base part and the slub part. The appearance of slub yarn is influenced by the length and linear density of each constituent part. Slub distance, slub length, amplitude of slub and yarn count are the basic variables in slub yarn production. Thus they were selected as control factors in this study. Each control factor was evaluated with three levels. The control factors, their designations and levels were given in table 1.

Table 1

CONTROL FACTORS AND THEIR LEVELS

Factor	Designation	Levels		
		1	2	3
Slub distance (mm)	A	100	200	300
Slub length (mm)	B	50	75	100
Amplitude of slub	C	1.5	2	2.5
Yarn count (Ne)	D	8	14	20

MATERIALS AND METHODS

In the experimental part of the study 100 % combed, 738 tex cotton rovings with 48 T/m twist were provided from a yarn spinning mill. The average values for the cotton fibre length, fineness and tenacity values were; 29.80 mm, 4.32 micronaire and 30.7 cN/tex, respectively. Basic slub yarns were produced with Merlin spinning frame. In order to achieve the slub effect, the intermittent acceleration of the middle and back feeding rollers was applied to obtain the varying degrees of draft in yarn spinning. The spindle speed was constant at 8000 r.p.m. Basic slub yarn linear densities were chosen as; tex 73.85 (Ne 8), tex 42.19 (Ne 14) and tex 29.53 (Ne 20) having the same twist coefficient; α_{tex} =114 (α_e = 3.8).

The layout of the experimental design, which was obtained by assigning the selected factors and their levels to appropriate columns of L_9 orthogonal array, was shown in table 2. This array has 9 rows and 4 columns and each row represents a trial condition while each column has a specific process parameter. Selection of control factors and their levels were made on the basis of literature review.

Table 2

EXPERIMENTAL LAYOUT USING ORTOGONAL ARRAY (L_9) FOR SAMPLE PRODUCTION

Sample No	Slub distance	Slub length	Slub thickness	Basic slub yarn linear density
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

S/N Ratio analysis and the analysis of variance (ANOVA) were utilized with QT-4 to find the optimal slub parameters and yarn linear density. Furthermore, multiple regressions were fitted to figure out the effect of slub yarn production parameters; slub distance, slub length, slub thickness and yarn linear density on the tensile property of yarns by the help of SPSS 18.0 statistical pocket program.

RESULTS AND DISCUSSION

All the measurements and tensile tests were performed under standard atmospheric conditions (temperature 20 ± 2 °C, 65 ± 2% Rh). Before the tensile tests, the dimensional parameters of the slub yarn samples were measured i.e. lengths (slub lengths, slub distance) and slub thickness with Uster Tester 5 slub yarn evaluation tool at 400 m/min test speed. The yarn tensile strength values were measured with Uster Tensojet with a test speed of 400 m/min. The measured dimensional parameters and tensile strength properties of slub yarns were given in table 3 and table 4, respectively.

S/N Ratio Analysis

The experimental results of yarn tensile strength were then transformed into S/N Ratios. The S/N Ratio is used to measure quality in terms of the reciprocal of variability per unit. Regardless of the category of quality characteristic, a greater S/N Ratio corresponds to better quality characteristic. The method of calculating the S/N Ratio depends on whether the quality characteristic is smaller-the-better, larger-the-better or nominal-the-best. The yarn tensile strength is a larger-the-better quality characteristic wherein it is desirable that these characteristics be as high as possible.

Table 3

THE MEASURED DIMENSIONAL PARAMETERS OF SLUB YARNS			
Sample No	**Slub distance (cm)**	**Slub length (cm)**	**Slub thickness (% mass increase)**
1	9.30	5.14	43.4
2	11.06	7.55	84.4
3	11.52	10.22	137.6
4	19.80	6.21	93.6
5	20.35	7.63	138.2
6	22.74	8.86	39.0
7	29.78	5.72	138.0
8	31.43	7.88	52.4
9	30.08	9.90	92.4

Table 4

AVERAGE YARN TENSILE STRENGTH VALUES AND S/N RATIOS OF YARN TENSILE STRENGTH RESULTS						
Sample No	**A**	**B**	**C**	**D**	**Average yarn tensile strength (cN/tex)**	**S/N ratio (dB)**
1	1	1	1	1	15.61	25.36
2	1	2	2	2	11.35	24.10
3	1	3	3	3	10.78	21.81
4	2	1	2	3	13.24	23.56
5	2	2	3	1	15.89	25.07
6	2	3	1	2	16.54	25.41
7	3	1	3	2	15.71	24.84
8	3	2	1	3	14.41	23.89
9	3	3	2	1	16.00	24.73

For larger-the-better characteristics, the S/N Ratio in decibel units is calculated as

$$S/N = -10 \log\left[\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right] \qquad (1)$$

where n is the repeat number of the experiments in the OA and y_i is the value from the experimental observations. Average yarn tensile strength values and S/N Ratios calculated with equation 1 were given in table 4.

For each control factor, average effect of each factor on the yarn tensile strength at different levels was determined (table 5). This is equal to the sum of all S/N Ratios corresponding to a factor at a particular level divided by the number of repetitions of each factor level. The delta value was calculated by subtracting the highest value from the lowest in each row. A higher delta value means that the level change of this factor has an impact on the yarn tensile strength. As shown in table 5, yarn count had greater effect than the other control factors.

Table 5

RESPONSE TABLE FOR S/N RATIOS				
Factor	**Average S/N ratios (dB)**			
	Level 1	**Level 2**	**Level 3**	**Delta**
Slub distance	23.76	24.68*	24.48	0.92
Slub length	24.59*	24.35	23.98	0.61
Amplitude of slub	24.89*	24.13	23.91	0.98
Yarn count	25.06*	24.78	23.09	1.97

** Optimum factor level*

The factor level corresponding to the maximum average effect of each factor was selected as the optimum level. As seen in figure 1 the highest S/N Ratio

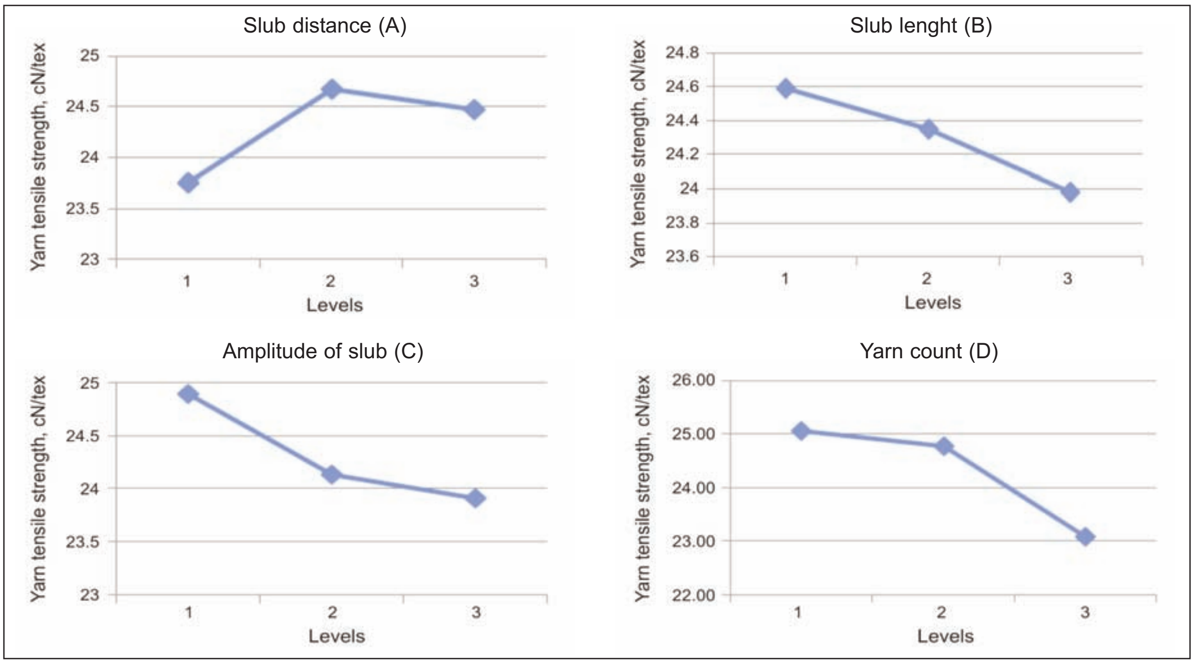

Fig. 1. Average effect plots of control factors for S/N Ratios

Table 6

OPTIMUM FACTOR LEVELS	
Factor (level)	**Level type**
A 2	200 mm
B 1	50 mm
C 1	1.5
D 1	Ne 8

for each factor was determined as A2B1C1D1. The corresponding factor levels for the optimum yarn tensile strength were given in table 6.

ANOVA Analysis

ANOVA is a one of the most frequently used statistical methods to measure the influence of individual factors and to determine the relative importance of various parameters. In order to understand the relationship between observed parameters and yarn tensile property, regression analyses were used. The results of ANOVA and regression analysis results were given in table 7 and table 8, respectively.
According to the statistical analysis, all control factors has significant effect on yarn tensile strength. Yarn count had the most significant effect with 59.43 % contribution percentage. The increase of yarn linear density decreased yarn strength. Slub distance had the contribution percentage of 10.81 % and it can be concluded from the positivity of coefficient value of this parameter in the regression analysis that the increase of the slub distance increased the yarn strength. Slub length had a minor influence on yarn strength results with the contribution percentages of 2.54 %. It can be seen that slub length had negative coefficient which indicated a decrease in the yarn strength values. Furthermore, slub thickness affected yarn strength results in a similar way the slub length did with the contribution percentage of 12.52 %. Thus the increase of slub thickness decreased the yarn tenacity.

Confirmation experiment

A confirmation experiment is the final step in the design of an experiment. The confirmation experiment is performed by conducting a test with optimum settings of the factors and the levels previously evaluated. The predicted value of S/N Ratio at optimum factor levels n_0 is calculated as

$$n_0 = \eta_m + \sum_{i=1}^{j}(\eta_i - \eta_m) \qquad (2)$$

where j is the number of factors, η_m is the mean value of multiple S/N Ratios in all experiments and η_i are the multiple S/N Ratios corresponding to optimum factor levels. According to the equation 2, the predicted S/N Ratio of the optimum yarn was calculated as 26.28 and when this value was substituted in equation 1, the yarn tensile strength value was obtained 20.60 cN/tex.
In addition to the theoretical calculations, the slub yarn was produced according to the optimum design (A2B1C1D1). Dimensional properties and yarn tensile strength values were also measured. Results of these tests were given in table 9.

Table 7

ANOVA ANALYSIS RESULTS FOR YARN TENSILE STRENGTH

Factor	Degree of freedom (n)	Sum of squares (S)	Variance (V)	F-Ratio (F)	Sig.	Percentage (%)
Slub distance	2	21.58	10.79	17.21	.000*	10.81
Slub length	2	6.05	3.01	4.81	.014*	2.54
Slub thickness	2	24.79	12.39	19.77	.000*	12.52
Yarn linear density	2	112.96	56.48	90.09	.000*	59.43

** Statistically significant at 0.05 level*

Table 8

REGRESSION ANALYSIS RESULT

Factor	Coefficient	t	Sig.
Constant	24.2987	19.889	0.000
Slub distance	0.0061	2.947	0.005
Slub length	–0.0179	–2.174	0.036
Slub thickness	–1.6733	–4.058	0.000
Yarn linear density	–0.3025	–8.803	0.000

**Statistically significant at 0.05 level*

Table 9

RESULTS OF OPTIMUM DESIGN

Design	Slub distance (cm)	Slub length (cm)	Slub thickness (% mass increase)	Yarn strength (cN/tex)
A2B1C1D1	40.40	5.18	41.1	18.92

The tensile strength of the optimum yarn was measured as 18.92 cN/tex. This result is very close to the result estimated by Taguchi design (20.60 cN/tex). Taking the lowest yarn tensile value (10.78 cN/tex) determined with the initial experiments, the increase in the value of yarn tensile strength using Taguchi design can be observed clearly.

CONCLUSIONS

As a result of the evaluations, yarn linear density, slub thickness and slub distance were designated as the important factors affecting the yarn tensile strength. Based on the Anova results for the S/N ratios, yarn linear density was the most important parameter for yarn tensile property. The increase of the fibre in the cross section unsurprisingly increased the strength property of yarn. Comparing three descriptive slub yarn parameters; slub thickness was the most important parameter affecting the strength property of the yarns. Yarn tenacity decreased with the increase of the slub thickness. This result was also proved with previous researches [3–6]; with the increase of the slub thickness, twist of the slub decreased, the number of uncontrolled fibres increased and as a result of this yarn strength decreased. In addition to this, slub distance had lower impact on tensile property. The slubs are the weakest part of the yarns. As a result of this, the increase of the slub distance decreased the number of weakest points and increased strength value of yarns. Slub length found as the least effective parameter on strength value comparing to the other parameters. With the increase in the slub length yarn tenacity decreased. This could be explained with the selection of high slub lengths in the experimental part of the study and the excessive increase of the basic yarn twist [5].

It can be concluded from this study that using the Taguchi method, the optimum factors for maximizing yarn tensile strength can be determined from few experiments with low cost. Taguchi's approach provides a systematic, simple and efficient methodology for the optimization of design parameters with only a few well-defined experimental sets and helps determine the main parameters that affect the process. The optimum factor levels were found as A2B1C1D1; this corresponds to Ne 8 yarn with 200 mm slub distance, 50 mm slub length and 1.5 slub amplitude. The yarn tensile strength was improved considerably with the determined optimum levels.

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An kinetic study for wool fabrics chromium dyeing using the PEK Model

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REZUMAT – ABSTRACT

Studiu cinetic al vopsirii cu crom a țesăturilor din lână utilizând modelul PEK

În cadrul acestui studiu a fost studiată cinetica vopsirii cu crom a țesăturilor din lână, utilizând modelul PEK. Adsorbția colorantului pe țesăturile de lână a fost analizată prin corelarea datelor experimentale utilizând modelul PEK. Experimentele de vopsire au fost efectuate utilizând raportul flotă/materiale de 25:1 într-o baie de vopsire etanșă, din oțel inoxidabil. Modelul PEK a fost propus deoarece descriere epuizarea colorantului la diferite momente. În ultima perioadă de timp, ecuația matematică a modelului PEK este folosită pentru interpretarea datelor experimentale din punct de vedere al parametrilor cinetici ai moleculelor de colorant. Cu modelul PEK, cinetica de adsorbție este compusă din doi termeni exponențiali care reprezintă procese rapide și lente, cu propriul lor timp caracteristic și soluția conținutului colorantului. Rezultatele arată că estimările teoretice sunt în concordanță cu datele experimentale având coeficienți de regresie medii mai mari.

Cuvinte-cheie: fibre din lână, model PEK, adsorbție, vopea crom, vopsire

An kinetic study for wool fabrics chromium dyeing using the PEK model

Chromium dyeing kinetic on wool fabrics using the PEK model has been studied. The adsorption of the dye on to wool fabric was analysed by fitting the experimental data by means of the PEK model. The dyeing experiments are carried out using liquor-to materials ratio of 25:1 in a sealed stainless steel dyebath housed. PEK model is proposed that describes the dye exhaustion at different time. Recently, the mathematical equation of the PEK model is used to interpret the experimental data in terms of kinetic parameters of the dye molecules. With the PEK model, the adsorption kinetics is composed of two exponential terms which represent fast and slow processes, with their own characteristic times and solution of dye contents. The results show that the theoretical estimates are in reasonable agreement with experimental data with higher average regression coefficients.

Keywords: wool fibres, PEK model, adsorption, chromium dye, dyeing

INTRODUCTION

Although sheep were domesticated 9 to 11 thousand years ago, archaeological evidence from statuary found at sites in Iran suggests selection for woolly sheep may have begun around 6000 BC [1–2], with the earliest woven wool garments having only been dated to two to three thousand years later. Wool is the textile fiber obtained from sheep and certain other animals, including cashmere from goats, mohair from goats, qiviut from muskoxen, angora from rabbits, and other types of wool from camelids [3]. Wool has several qualities that distinguish it from hair or fur: it is crimped, it iselastic, and it grows in staples (clusters). Wool fibers readily absorb moisture, but are not hollow. Wool can absorb almost one-third of its own weight in water [3]. Wool absorbs sound like many other fabrics. It is generally a creamy white color, although some breeds of sheep produce natural colors, such as black, brown, silver, and random mixes. Wool ignites at a higher temperature than cotton and some synthetic fibers. It has a lower rate of flame spread, a lower rate of heat release, a lower heat of combustion, and does not melt or drip; it forms a char which is insulating and self-extinguishing, and it contributes less to toxic gases and smoke than other flooring products when used in carpets [4]. Wool carpets are specified for high safety environments, such as trains and aircraft. Wool is usually specified for garments for firefighters, soldiers, and others in occupations where they are exposed to the likelihood of fire [5].

There are more than 10,000 different synthetic dyes widwly used in the textile, paper, cosmetics, food and pharmaceutical industries. It is estimated that 10 to 35% of the dye is lost in textile effluents during the dyeing process [6]. Tar chromium dyes is one of the popular dye classes used for the dyeing of wool fibres. The most attractive feature of the use of these dyes is essential simplicity of the dyeing process, and the higher wet fastness properties of the dyed materials. However, the use of these dyes caused certain problems, including the use of high temperature, the long process time and discharge of coloured effluent leads to pollution environmental such as other textile dyes. Hence, the main aim of this present work is dyeing of wool fabric with Tar - chromium dyes. More specifically, the objectives of this study are to identify the PEK model and type of the slow, and the fast adsorption process.

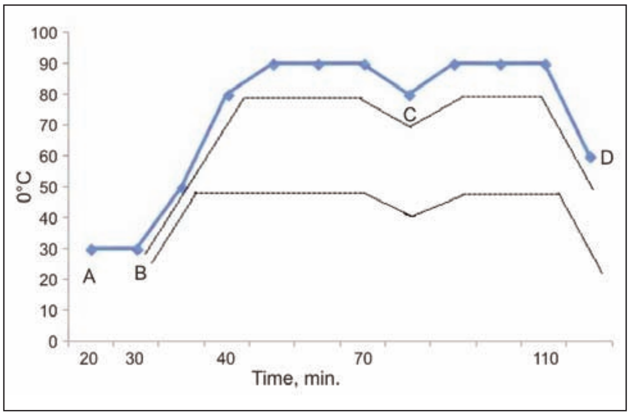

Fig. 1. Dyeing procedure (A–D are process steps): A – the amount of salt, B – the amount of dye and acetic acid, C – sodium bicarbonate, D – the cooling

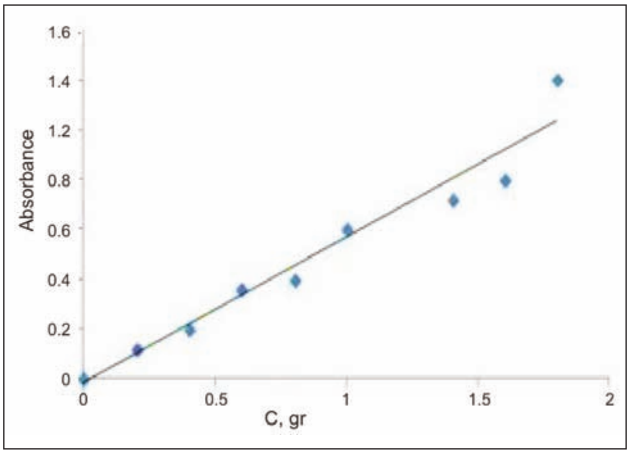

Fig. 2. Calibration curve of Tar-chromium Red dye at the wavelength of 530 nm

EXPERIMENTAL WORK

Materials and methods

The fabric used was 100% wool; step twill weave; fabric weight, 225g/m^2, 26 ends/cm; and 21 picks/cm. The fabric was mill-scoured, rinsed and dried at room temperature.

Dyeing process

The dye used was Tar-Chromium Red and this was obtained from Van textile factory. A dye concentration of 1 % owf was used, together with 2.5% owf sodium sulphate. The material-to-liquor ratio of 1/25 and the pH was adjusted to 4.5 with acetic acid. The dyeing processes were carried out according to the manufacturer's instructions. The dyeing process was carried out in a laboratory dyeing machine at a liquor ratio of 25:1 under at P^H 5.0. The dye absorption at each dyeing time was determined using a Cintra 202 Duble Beam UV-vis spectrophotometer.

The UV-visible absorption spectrum in water of this dye was recorded using Cintra 202 Duble Beam UV-vis spectrophotometer. Its absorption spectrum showed that the maximum absorption wawelength was 530 nm.

Determination of dye concentration

The concentration of dye were determined using UV-visible absorption spectrophotometer at the characterictic maximum wavelength. The main principle in the quantitative Uv-visible technique is the linear relation between absorbance at the maximum wavelength and concentration, as given by the Beer-Lambert Law. The dye in the exhaused dye bath was estimated by evaluating the extinction value at maximum absorbance (λ_{max}) with UV-vis spectrophotometer (Cintra 202 Duble Beam).

The wavelength of maximum adsorbance (λ_{max}) is 530 nm. The standart working curve of curcumin dye is shown in fig. 2. The linear regression calibration equation was obtained by computer fitting, and according to eqs. (1), $A = 8.235C$, $R^2 = 0.9595$, where A is the absorbance at a specific wavelength; C, the concentration of dyeing solution (g/L), l, the path length, ε the extinction coefficient and R^2 the linear relative coeffcient. It is found that the relationship between absorbance and concentration of dye solution is linear

$$A = \varepsilon l C \qquad (1)$$

Determination of dye exhaustion

After dyeing the per cent dye exhaustion (E %) values were determined by calculating the dye concentration before adding fabric into the dyebath (C_0) and after dyeing (C_f) according to eq. (2), as given below:

$$E\% = \frac{C_0 - C_f}{C_0} \times 100 \qquad (2)$$

where, E is the dye exhaustion, C_0, the initial concentration of dye and C_f, the concentration of dye after dyeing.

RESULTS

Experimental Data treatment

The exhaustion of the Tar-chromium red dye with time (t) has been discussed. The dyeing process was carried out according to the procedure outlined in figure 1. As seen in figure 1, the percentage of the dye molecules adsorbed on the wool fabric increases rapidly during 15 to 20 minutes. The dyebath exhaustion at the end of this phase is called the primary exhaustion. When temperature increases of the dyebath to more dye is absorbed from the bath the exhaustion continues to increase slowly until the equilibrium state is reached approximately at 55–60 min. The exhaustion of dyebath at the end of the second process is called the secondary exhaustion.

The result indicates that the evolution of the tar chromium red dye exhaustion as a function of time can be modeled by two parallel independent processes. The first one is the rapid phase and the second one is slow phase.

Table 1

PEK PARAMETERS					
Temperature (°C)	**$E_{1\infty}$ (%)**	**$E_{2\infty}$ (%)**	**K_1 (1/min.)**	**K_2 (1/min.)**	**R^2**
50	43.27	20.35	0.609	0.0245	0.9183
70	43.45	22.51	0.760	0.0112	0.9273
90	43.57	23.63	0.875	0.0351	0.9471

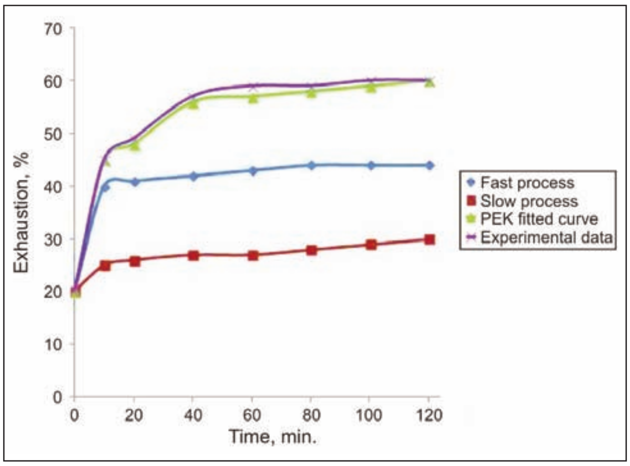

Fig. 3. PEK fitted curves of exhaustion Tar-chromium red dye bath at 90 °C

PEK Model (Parallel Exponential Kinetics)

The PEK model was used to examine the sorption kinetics. The PEK model deconvolutes the sorption kinetics curve into two exponential kinetics processes (fast and slow) were obtained from nonlinear curve fitting of eq. (3) [7–8–9]. To summarize, the PEK equation has the form:

$$E_t = E_{1\infty}\,[1-\exp(-K_1 t)] + E_{2\infty}\,[1-\exp(-K_2 t)] \quad (3)$$

where E_t is the exhaustion of the dyebath at time t. $E_{1\infty}$ and $E_{2\infty}$ are the exhaustion of the dyebath at an infinite time associated respectively with the fast and slow sorption process (fig. 3). K_1 and K_2 are the adsorption kinetic of dye molecules respectively at the fast and slow processes [9]. The model proposed to describe the dye uptake is tested by comparing the theoretical curves with the experimental one. As can be seen from the figure 3, the PEK curves gave excellent fits with the experimental data. On the other hand, the value of correlation coefficient (R^2) 0.9895 shows the the experimental data are good the PEK model. The equilibrium exhaustion associated with the fast and slow processes are 43.57% and 23.63% respectively. It was observed that the first 15 to 20 minutes of dyeing the dye exhaustion was quite increased but at higher time of dyeing the exhaustion was exactly increased. Similar kinetics results have been recorded a new kinetic for cotton reactive dyeing at different temperature [9, 10]. The K_1 and K_2 rate of constant of the fast and slow process was found to be 0.875 min^{-1} and 0.0351 min^{-1} respectively. The $K_1 >> K_2$ which means that the rapid process can be assumed tobe negligible on the overall adsorption kinetics and very short [9]. Table 1 presents the PEK Parameters.

Effect of temperature on adsorption

The effect of temperature on the exhaustion of dyebath and the adsorption kinetics were studied in the range of temperature between 50, 70 and 90 °C for initial dye concentration at P^H 5.0 and liquor ratio of 25:1. The obtained results are shown in table 1. The results of table 1 demonstrated that the PEK model provided the best correlation (R^2) with experimental results. This fact indicates that the experimental data well fitted to the PEK model and also, it can be showned higher diffusion rate could be obtained in a short time and that 43.57% of amount initially dye in dyebath was adsorbed at 15–20 minutes. Then, 23% of the initial dye amount used in the dyebath needs more than 120 minutes to be exactly exhausted.

It is clear from table 1 that the effects of temperature is positive for dyebath exhaustion and kinetic parameters of PEK model, but the more important dyebath exhaustion was attained at 90 °C and the adsorption kinetic of the dye molecules associated with the fast process was more important at 90 °C.

Analysis of adsorption kinetics was conducted using the parallel exponential kinetics model with well fits to the experimental data obtained. The results fitted well to the PEK model. The dyes adsorption on to wool fabric increased with the increase of the temperature. The adsorption kinetics is fast with 15–20 minutes, and it was found that more than 43% of dye amount initially used in the dyebath was holding onto wool fabric for a short time. Then, 23% of the initial dye amount used in the dyebath needs more than 120 minutes to be exactly exhausted. For each temperature, the adsorption kinetic coefficients K_1 and K_2 have been calculated, and K_1 is higher than K_2, This can be explained by fast process can be assumed to be very sort and negligible on the overall adsorption kinetics.

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The wetting and moisture transmission properties of woven shirting fabrics

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REZUMAT – ABSTRACT

Proprietățile de udare și de transfer al umidității ale țesăturilor destinate confecțiilor pentru cămăși

În cadrul acestui studiu s-a urmărit investigarea proprietăților de udare și de transfer al umidității ale țesăturilor utilizate la confecționarea cămășilor, țesături produse din diverse materii prime, cu diferite tipuri de legături și compacticitate în vederea determinării celor mai avantajoase tipuri de țesături în ceea ce privește comfortul la umiditate al angajaților care își desfășoară activitatea la birou. Au fost realizate optsprezece tipuri de țesături pentru cămăși și au fost analizate proprietățile de management al umidității al acestora, absorbția apei, timpul de scufundare și comportamentul la uscare. Rezultatele au arătat că, o creștere a impermeabilității țesăturii a determinat o diminuare a capacității de control a managementului umidității și ale proprietăților de absorbție ale țesăturilor. De asemenea s-a constatat că, în comparație cu legătura de tip pânză, legătura de tip diagonal a determinat creșterea capacității de absorbție a acestor țesături. Țesăturile din bambus regenerat au prezentat proprietăți de absorbție mare a apei, capacitate scăzută de uscare, performanțe scăzute ale managementului umidității, astfel încât nu sunt potrivite pentru confecționarea cămășilor. Dealtfel, țesăturile realizate din amestec de fibre de bumbac și poliester cu legătură diagonal mediu și țesăturile din amestec de bumbac și poliester cu legătură slabă tip pânză, având bune proprietăți de transmitere a umidității pot fi folosite pentru confecționarea cămășilor, în vederea creșterii comfortului acestora.

Cuvinte-cheie: capacitate de absorbție, confort, capacitate de uscare, transmiterea umidității, materiale pentru cămăși

The wetting and moisture transmission properties of woven shirting fabrics

In this study, it is aimed to investigate the wetting and moisture transmission properties of woven shirting fabrics, which have different raw materials, weave types and fabric tightnesses, and to determine the advantageous fabric types in terms of wetness comfort of the office workers. Eighteen woven shirting fabrics were produced systematically, and their moisture management properties, water absorbency, sinking time, and drying behaviour pertaining to comfort of fabrics, were measured. The findings indicated that the increase in the fabric tightness generally caused a worsening of the moisture management and absorbency properties of the fabrics. It was also determined that, compared to the plain weave, the twill weave enhanced the water absorbency of the fabrics. Regenerated bamboo fabrics had high water absorbency, low drying ability, and low moisture management performance, and therefore they may not be suitable for the shirts worn by office workers. Besides, the cotton/polyester-twill-medium and the cotton/polyester-plain-loose fabrics with good moisture transmission properties can be used for shirting production in an attempt to increase the clothing wetness comfort.

Keywords: absorbency, comfort, drying ability, moisture transmission, shirting

INTRODUCTION

Skin is the first barrier between the environment and the organism, and a substantial organ, which controls fluid and heat flow occurring from external environment to body, and vice versa. It also includes complex vascular systems and sweat glands. Thanks to these systems, skin can respond to thermoregulatory demands of the body [1]. Vapour/liquid sweat transmission through textiles is important to determine comfort and performance of clothing systems [2]. Therefore, textiles should have two key features to ease sweat transmission from the skin surface. On the one hand, clothing should allow evaporation of sweat from the skin during activities. On the other hand, the moisture in the clothing layer should be removed quickly after the activity [3, 4].

In the literature, various researchers have evaluated wetting performance and moisture transmission for sportswear, which contains a large amount of perspiration depending on the activity level [5–7]. Even if these studies have emphasized the importance of wetness comfort for sportswear, it is an incontrovertible fact that the wetness comfort is also crucial for the clothing of office workers. If the secreted sweat could not be removed from the skin and clothing throughout the day, the mental performance and work efficiency of the office workers might decrease [8]. The comfortable business attires can be produced by changing yarn and fabric structural properties, and by applying special finishing processes. Nayak *et al.* [9] have investigated the effect of weave type, pick density and polyester content on thermal comfort and tactile properties of polyester/viscose blended suiting fabrics, and concluded that water vapour transfer has decreased with the rise of polyester content. It has also been observed that water vapour transfer of twill fabrics has been lower than that of plain fabrics. Das *et al.* [10] have examined the hydrophilicity of plain woven fabrics produced from polyester/viscose blended yarns. The analyses have indicated that as viscose content has increased, absorbency of the fabrics has enhanced. On the other hand, sinking time and wicking have decreased with the increase of viscose content of the fabrics. Tyagi et al. [11] have measured the comfort properties of bamboo/cotton blended plain woven fabrics produced taking into account three variables, i.e., the yarn count, the fibre composition and the yarn production method. They have reported that the fabrics produced from ring yarns have had higher wickability as compared to Murata Jet Spinning (MJS) yarn fabrics. Also, it has been observed that the increase of cotton proportion and the decrease of yarn linear density have been increased the absorbency. The research of the effects of raw material in the weft direction and washing treatments on the moisture management properties of denim fabrics have been conducted by Mangat et al. [12]. As far as the raw material has been concerned, the utilization of polypropylene weft yarn has been improved the properties; whereas the samples with cotton weft yarn have had low moisture transmission. Saricam and Kalaoglu [13] have investigated the wicking and drying ability of polyester woven fabrics. The fabrics have been produced by altering yarn structure, weft density and weave type. The results have showed that the fabrics with texturised yarns have been better vertical wicking height than the filament yarn fabrics.

The main objective of the study is to determine the factors affecting the wetness comfort of the shirts worn by the office workers, and to establish the outstanding commercial shirt fabrics, which is suitable for office environment from the point of wetness comfort. The fabrics used in this study were produced by varying raw material, weave type and fabric tightness. Thus, the effects of these variables on the wetting and moisture transmission properties of the fabrics were investigated. The findings will contribute to minimizing discomfort wetness sensations in the office workers, and will also enlighten the consumers on the garment selection considering clothing comfort.

EXPERIMENTAL WORK

Materials

Eighteen types of commercially available shirting woven fabrics were produced according to three variables to examine the interactions of different variables (i.e. raw material, weave type and weft density) on wetting and moisture transmission properties of the fabrics. Plain and 3/1 twill were chosen as the weave type. The fabrics were produced with three different weft densities representing loose, medium and tight, and were woven from 14.8 tex cotton and regenerated bamboo, and 16.7 tex polyester staple yarns on a Vamatex 1001ES loom (Vamatex Co. Ltd., Italy). The ends/cm was kept constant at 45 for the fabrics. The constructional details of all samples are given in table 1.

Table 1

EXPERIMENTAL DESIGN OF THE FABRICS

Sample Code*	Raw Material		Weave Type	Weft Density (in loom) (picks/cm)
	Warp	Weft		
CPL	Cotton	Cotton	Plain	26
CPM				30
CPT				34
CTL			3/1 Twill	28
CTM				34
CTT				40
BPL	Regenerated Bamboo	Regenerated Bamboo	Plain	26
BPM				30
BPT				34
BTL			3/1 Twill	28
BTM				34
BTT				40
PPL	Cotton	Polyester	Plain	24
PPM				28
PPT				32
PTL			3/1 Twill	28
PTM				34
PTT				40

* **1st letter:** Raw material (C: Cotton, B: Bamboo, P: Cotton/Polyester);
2nd letter: Weave type (P: Plain, T: Twill);
3rd letter: Fabric tightness (L: Loose; M: Medium; T: Tight).

Greige fabrics were singed, washed at 70°C, and dried at 95 °C. After the processes, the fabrics were treated with micro silicone softener (30 g/L), and were dried at 140°C. For cotton/polyester fabrics, thermal fixation was done at 185°C for 48 seconds. Sanforization and calendaring treatments were applied to the cotton and bamboo fabrics; whilst the cotton/polyester fabrics were only sanforized.

Methods

All experiments of the fabrics were carried out in standard atmospheric conditions at 20±2°C and 65±2% relative humidity. The measured fabric structural properties were warp and weft density, mass per unit area, thickness, surface porosity, volume porosity and average pore radius (2D and 3D). Fabric physical and structural properties are shown in table 2.

Fabric density was measured using the counting glass according to ASTM D3775-12 [14]. Thickness and mass per unit area were measured as per ASTM D1777-96 e1 [15] and ASTM D3776/D3776M-09a [16] standards, respectively. Air permeability of the fabric was measured by using Textest FX-3300 Air Permeability Tester (Textest AG, Schwerzenbach, Switzerland) with air pressure of 100 Pa (20 cm² test area) according to ASTM D737-04 test standard [17]. An average of 10 repetitions was taken for each sample.

Table 2

PHYSICAL AND STRUCTURAL PROPERTIES OF THE FABRICS									
Sample Code*	**Weft Density (picks/cm)**	**Warp Density (ends/cm)**	**Mass per Unit Area (g/m²)**	**Fabric Thickness (mm)**	**P_S (%)**	**P_V (%)**	**R_{2D} (μm)**	**R_{3D} (μm)**	**Air Permeability (l/m²/s)**
CPL	28.40 (0.52)	49.10 (0.32)	122.80 (0.19)	0.26 (0.0055)	13.90	37.98	56.32	93.11	412.20 (17.94)
CPM	32.80 (0.42)	49.80 (0.42)	132.96 (0.99)	0.26 (0.0071)	11.70	34.32	47.75	81.78	246.20 (11.24)
CPT	38.70 (0.67)	49.00 (0.67)	143.73 (0.73)	0.25 (0.0045)	10.06	26.97	41.10	67.29	134.00 (9.18)
CTL	30.44 (0.53)	50.00 (0.47)	125.95 (1.46)	0.29 (0.0089)	12.39	47.29	50.90	105.79	334.30 (12.75)
CTM	37.80 (0.42)	50.40 (0.52)	139.29 (1.14)	0.29 (0.0122)	9.50	40.58	39.85	88.39	242.70 (7.48)
CTT	43.60 (0.84)	50.50 (0.85)	147.97 (0.80)	0.30 (0.0110)	7.44	39.57	32.79	81.11	219.40 (10.66)
BPL	28.80 (0.42)	50.70 (0.82)	134.39 (0.78)	0.27 (0.0045)	8.67	30.14	43.47	81.05	126.00 (4.76)
BPM	32.50 (0.53)	50.40 (0.52)	140.85 (0.92)	0.27 (0.0055)	7.89	24.13	39.17	68.48	90.00 (3.61)
BPT	37.80 (0.42)	50.30 (0.95)	147.97 (0.90)	0.27 (0.0045)	6.47	19.90	32.92	57.71	54.50 (3.07)
BTL	30.20 (0.42)	50.60 (0.84)	129.36 (1.82)	0.30 (0.0130)	8.37	38.53	41.76	97.15	172.10 (5.61)
BTM	37.20 (0.63)	51.10 (0.74)	142.51 (1.32)	0.30 (0.0164)	6.13	33.78	32.04	82.23	122.60 (4.09)
BTT	43.40 (0.84)	51.20 (0.42)	156.39 (1.65)	0.33 (0.0089)	4.47	35.54	25.30	77.12	105.21 (4.72)
PPL	24.90 (0.32)	48.40 (0.52)	122.04 (0.29)	0.26 (0.0084)	14.75	39.00	62.42	101.49	449.50 (18.28)
PPM	29.10 (0.32)	49.20 (0.42)	130.70 (0.87)	0.26 (0.0045)	12.29	34.35	52.27	87.39	251.10 (6.97)
PPT	34.00 (0.47)	49.50 (0.71)	142.29 (0.67)	0.27 (0.0084)	10.04	31.71	43.58	77.44	126.90 (6.15)
PTL	29.60 (0.52)	50.10 (0.57)	129.11 (0.97)	0.30 (0.0071)	11.40	44.87	49.46	104.61	431.30 (21.47)
PTM	36.00 (0.47)	49.70 (0.67)	142.54 (0.50)	0.30 (0.0055)	9.10	38.90	40.24	89.41	310.80 (15.82)
PTT	42.40 (0.84)	48.60 (0.52)	154.04 (1.26)	0.28 (0.0045)	6.97	29.95	32.81	74.58	226.60 (22.17)

(P_S: surface porosity; P_V: volume porosity; R_{2D}: average pore radius (two dimensional); R_{3D}: average pore radius (three dimensional))
* **1st letter:** Raw material (C: Cotton, B: Bamboo, P: Cotton/Polyester); **2nd letter:** Weave type (P: Plain, T: Twill); **3rd letter:** Fabric tightness (L: Loose; M: Medium; T: Tight).

Fabric porosity was theoretically calculated for the fabrics. Surface porosity (P_S), which is based on the fabric cover factor (*CF*), can be calculated according to following equations;

$$CF = D_{wr}\, d_{wr} + D_{we}\, d_{we} - D_{wr}\, d_{wr}\, D_{we}\, d_{we} \quad (1)$$

$$P_S = 1 - CF \quad (2)$$

where D_{wr} and D_{we} are the warp and weft density; d_{wr} and d_{we} are the diameter of the warp and weft yarn, respectively. Volume porosity (P_V) was calculated according to the intersection types of the warp and weft yarns with 3D pore unit cell models from following equation:

$$P_V = \frac{V_T - V_Y}{V_T} \times 100\ (\%) \quad (3)$$

where V_T *is the* whole accessible volume and V_Y *is the* volume covered by yarns. Besides, the average pore radii (2D and 3D) were calculated as per the formulas used in the research of Turan and Okur [18]. Multi-dimensional moisture management properties were determined using the Moisture Management Tester (MMT) (SDL Atlas LLC, Rockhill, SC, USA) as per AATCC 195 [19]. Accumulative one-way transport index (AOTI) and the overall moisture management capacity (OMMC) of the fabrics, which are two important measurement indexes of MMT, were assessed in this study.

Absorbency of textiles was measured in accordance with BS 3449 [20]. Samples were cut the dimension of 8 x 8 cm^2 at 45° to the warp direction. The samples were weighed in dry state. They were submerged in distilled water hold by a sinker for 20 minutes. After being removed from the container, excess water on the samples was removed by shaker, and they were weighed again. Absorption for each of the samples was calculated from following equation;

$$Absorption = \frac{Mass\ of\ water\ absorbed}{Dry\ mass} \times 100\ (\%) \quad (4)$$

To evaluate the sinking time of the fabrics, a fabric sample 2.5 x 2.5 cm^2 was dropped onto the surface of distilled water in a beaker, and the length of time to sink completely from the surface layer of water for the test sample was recorded as the sinking time [21].

Drying ability of the fabrics was determined according to FTTS-FA-004 standard [22]. Samples were prepared to the dimension of 5 x 5 cm². Each of the samples was weighed, and its dry weight was recorded as w_f (g). A volume of 0.2 ml distilled water was dripped above the centre of the test sample from a height of 1 cm using a micropipette, and then recorded as w_o (g). Changing weight of water was recorded with 10-minute intervals as w_i (g). The same process was repeated for 100 minutes (test period). Remained water ratio (RWR) at the 40^{th} minute (evaluation index) was calculated by the following equation;

$$RWR_{40} = \frac{(w_i - w_f)}{(w_o - w_f)} \times 100\ (\%) \quad (5)$$

Statistical analyses were performed by using software SPSS version 19.0 (IBM, Armonk, NY, USA). The effects of raw material, weave type and fabric tightness on the wetting and moisture transmission properties, and the effect sizes were determined with the univariate analysis of variance (ANOVA). To reveal whether the parameters were significant ($p < 0.05$) or not, the significant effects were examined.

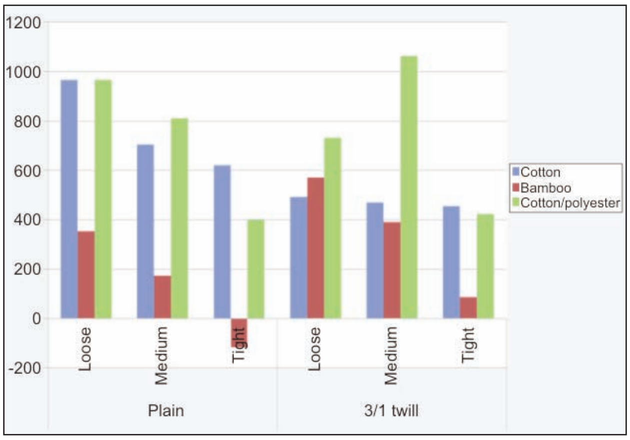
RESULTS AND DISCUSSION

Wetting and moisture transmission behaviour of woven fabrics was examined by measuring various properties such as the sinking time, water absorbency, drying time, and multi-dimensional liquid moisture management. All measurement results and statistical analyses of the fabrics are tabulated in table 3 and table 4, respectively.

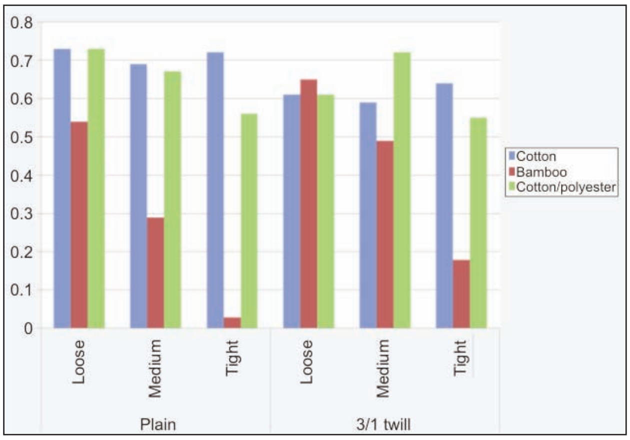
MMT results

The accumulative one-way transport index (AOTI) and the overall moisture management capacity (OMMC) measured by using the MMT provide an insight about the liquid moisture transmission performance of fabrics.

AOTI is the cumulative liquid moisture difference between two sides of the fabric. Positive and high AOTI value is a measure that moisture transmission from the skin to the environment occurs quickly. As it can be seen from fig. 1(a), the cotton/polyester-twill-medium fabric had the highest AOTI value, followed by cotton/polyester and cotton-plain-loose fabrics. AOTI values for bamboo fabrics generally were lower than those of the cotton and cotton/polyester fabrics. This might be due to the hairiness of bamboo yarns. The increase in hairiness causes low porosity and small pore size in fabrics, and hence it resists air and moisture flow, which is similar to research findings suggested by Mahish *et al.* [23]. As the tightness of the fabrics increased, AOTI values generally decreased. This is related to decreasing porosity, and it was observed the significant correlations between AOTI and pore parameters and air permeability (P_s: $r = 0.752$; R_{2D}: $r = 0.715$; Air permeability: $r = 0.804$). Moreover, in fig. 1(a), there was not a main effect for AOTI between the plain and the twill weave types, and no significant difference was also found statistically ($p<0.05$).



a



b

Fig. 1. Comparison of the (a) AOTI and (b) OMMC of the fabrics

Table 3

THE MEASUREMENT RESULTS OF WETTING AND MOISTURE TRANSMISSION PROPERTIES OF THE FABRICS

Sample Code*	AOTI (%)	OMMC	Sinking Time (sec)	Absorbency (%)	RWR_{40}** (%)	RWR_{100}** (%)
CPL	964.51 (128.19)	0.73 (0.03)	114.60 (20.08)	104.54 (5.05)	25.88 (4.06)	2.55 (0.25)
CPM	703.65 (60.18)	0.69 (0.05)	88.00 (23.95)	91.23 (4.93)	26.61 (3.45)	3.01 (0.45)
CPT	619.54 (79.60)	0.72 (0.03)	89.60 (13.63)	77.50 (3.09)	19.40 (1.75)	2.92 (0.24)
CTL	490.69 (98.76)	0.61 (0.05)	89.00 (28.74)	132.97 (7.28)	26.88 (4.73)	2.74 (0.15)
CTM	468.10 (123.31)	0.59 (0.07)	94.40 (19.36)	113.59 (4.44)	26.12 (2.77)	2.91 (0.27)
CTT	453.29 (85.64)	0.64 (0.11)	208.40 (39.88)	102.72 (4.85)	30.40 (4.97)	2.99 (0.10)
BPL	352.43 (29.43)	0.54 (0.05)	91.20 (16.53)	129.54 (4.45)	35.25 (4.81)	4.57 (0.19)
BPM	172.21 (63.70)	0.29 (0.07)	97.00 (10.51)	119.66 (7.16)	33.03 (5.05)	4.75 (0.54)
BPT	-117.45 (39.48)	0.03 (0.03)	150.00 (23.48)	114.89 (2.83)	33.83 (4.89)	4.15 (1.12)
BTL	571.10 (91.52)	0.65 (0.04)	115.60 (19.24)	187.80 (12.28)	21.73 (10.01)	3.65 (0.15)
BTM	391.21 (142.80)	0.49 (0.08)	113.20 (8.81)	153.72 (9.07)	32.12 (3.43)	4.33 (0.31)
BTT	85.61 (31.04)	0.18 (0.04)	134.80 (17.92)	153.54 (8.87)	43.85 (4.80)	5.46 (0.49)
PPL	966.52 (193.52)	0.73 (0.03)	***	81.57 (4.32)	10.36 (6.11)	1.50 (0.24)
PPM	809.48 (37.68)	0.67 (0.01)	***	68.01 (2.11)	26.38 (9.94)	1.44 (0.32)
PPT	397.27 (98.48)	0.56 (0.06)	***	54.61 (2.84)	11.71 (7.26)	1.44 (0.36)
PTL	731.0 (61.42)	0.61 (0.05)	***	99.23 (3.32)	32.61 (2.79)	0.97 (0.22)
PTM	1062.10 (46.68)	0.72 (0.04)	***	89.26 (3.46)	21.94 (5.46)	1.14 (0.13)
PTT	423.56 (81.35)	0.55 (0.07)	***	73.96 (1.24)	22.24 (5.96)	1.41 (0.30)

* **1st letter:** Raw material (C: Cotton, B: Bamboo, P: Cotton/Polyester); **2nd letter:** Weave type (P: Plain, T: Twill); **3rd letter:** Fabric tightness (L: Loose; M: Medium; T: Tight).
** RWR_{40}: Remained water ratio at the 40th minute; RWR_{100}: Remained water ratio at the 100th minute.
*** Test sample did not sink at the end of 10-minute period.

The OMMC refers to the ability of fabric to transfer liquid moisture. The higher the value is, the better the performance of the fabric is. The OMMC results were given in fig. 1(b). It was seen that regenerated bamboo fabrics generally had lower OMMC values than the other fabrics, similar to the findings in AOTI. Cotton/polyester and cotton fabrics had high and similar OMMC values. Cotton/polyester fabrics have more intense cotton yarns in their structures, and hydrophobic polyester fibres did not have important influence on the moisture management performance during the test period (120 s). This may be due to the short test period of the MMT. On the other hand, it was determined that there was no big change with the increasing tightness for cotton fabrics. However, OMMC values of the bamboo and cotton/polyester fabrics generally decreased with the increase of fabric tightness. There were good correlations between OMMC and pore parameters of fabrics (P_s: $r = 0.688$; R_{2D}: $r = 0.628$). As observed by Wardiningsih and Troynikov [24], OMMC decreased with the decrease of porosity (i.e. the increase in cover factor). Moreover, the change of weave type did not have a main effect on OMMC, and it can be seen from the results in table 4, the weave type did not have a statistically significant effect on OMMC values ($p<0.05$). Raw material, fabric tightness and raw material*fabric tightness had the highest effect sizes on OMMC.

Table 4

Source		Sig.	Effect size	Source		Sig.	Effect size
Raw Material	AOTI	0.000	0.857	Fabric Tightness	AOTI	0.000	0.777
	OMMC	0.000	0.885		OMMC	0.000	0.732
	Absorbency	0.000	0.966		Absorbency	0.000	0.826
	Sinking Time	0.599	-		Sinking Time	0.000	0.549
	RWR_{40}*	0.000	0.545		RWR_{40}*	0.490	-
	RWR_{100}*	0.000	0.930		RWR_{100}*	0.001	0.182
Weave Type	AOTI	0.293	-	Raw Material * Fabric Tightness	AOTI	0.000	0.509
	OMMC	0.484	-		OMMC	0.000	0.768
	Absorbency	0.000	0.896		Absorbency	0.033	0.173
	Sinking Time	0.001	0.223		Sinking Time	0.332	-
	RWR_{40}*	0.001	0.147		RWR_{40}*	0.000	0.244
	RWR_{100}*	0.234	-		RWR_{100}*	0.154	-
Raw Material * Weave Type	AOTI	0.000	0.599	Weave Type * Fabric Tightness	AOTI	0.000	0.269
	OMMC	0.000	0.536		OMMC	0.003	0.146
	Absorbency	0.000	0.515		Absorbency	0.025	0.128
	Sinking Time	0.032	0.092		Sinking Time	0.001	0.250
	RWR_{40}*	0.003	0.152		RWR_{40}*	0.000	0.195
	RWR_{100}*	0.200	-		RWR_{100}*	0.000	0.222
Raw Material * Weave Type * Fabric Tightness	AOTI	0.001	0.224				
	OMMC	0.313	-				
	Absorbency	0.016	0.198				
	Sinking Time	0.000	0.508				
	RWR_{40}*	0.000	0.308				
	RWR_{100}*	0.000	0.254				

THE EFFECTS OF RAW MATERIAL, FABRIC TIGHTNESS, WEAVE TYPE AND THEIR INTERACTIONS ON THE WETTING AND MOISTURE TRANSMISSION PROPERTIES OF THE FABRICS

* RWR_{40}: Remained water ratio at the 40^{th} minute; RWR_{100}: Remained water ratio at the 100^{th} minute.

Absorbency and sinking time

Absorbency is the ability of solid to take up and retain liquid under various conditions, and it is an indicator of the liquid sweat-holding capacity of the fabric. It depends upon the structure of the textile material, solid and liquid bulk properties, and the fabric thickness [25–27].

As it can be depicted from fig. 2(a), the highest water absorbency was measured for the regenerated bamboo fabrics, followed by the cotton and cotton/polyester fabrics. This can be explained by the fact that internal structure of bamboo fibres containing micro-gaps and micro-holes that provide an outstanding water absorption ability [28]. These results were also compatible with the findings of Gericke and Van der Pol [29]. The increase in fabric tightness caused a decrease of the water absorbency as can be seen in fig. 2(a). Since the absorbency is directly related to the air proportion presence within the fabric, the lower air proportion could be the reason for the lower water absorbency of the tight fabrics. This conclusion showed agreement with Behera et al., and Karahan and Eren [25, 30]. Additionally, the water absorbency of the twill fabrics was higher than that of the plain fabrics depending upon the fabric thickness. The effects of all parameters and their interactions on the water absorbency were statistically significant ($p<0.05$). Raw materials had the highest effect size on the water absorbency.

A liquid wicking into an immersed fabric displaces most of the air in the fibrous material, and then brings about it to submerge. For the solid to be immersed into the liquid, the solid surface must have adequate surface energy, which exceeds the free surface energy of the liquid [31]. Fig. 2(b) shows the sinking time of the cotton and bamboo fabrics submerged in the liquid at the end of 10-minute period. On the other hand, cotton/polyester fabrics did not sink within the time specified, and thus were not presented in fig. 2(b). The sinking time of the fabrics generally increased with the increase of the fabric tightness. The analysis of variance indicated that the weave type and the fabric tightness caused significant differences in the

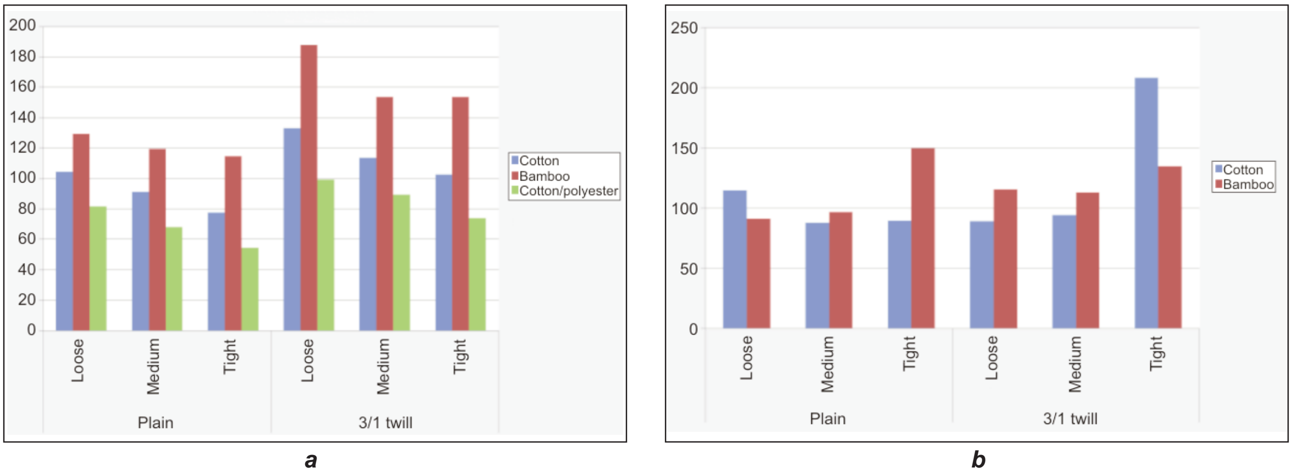


Fig. 2. Comparison of the (a) water absorbency and (b) sinking time of the fabrics

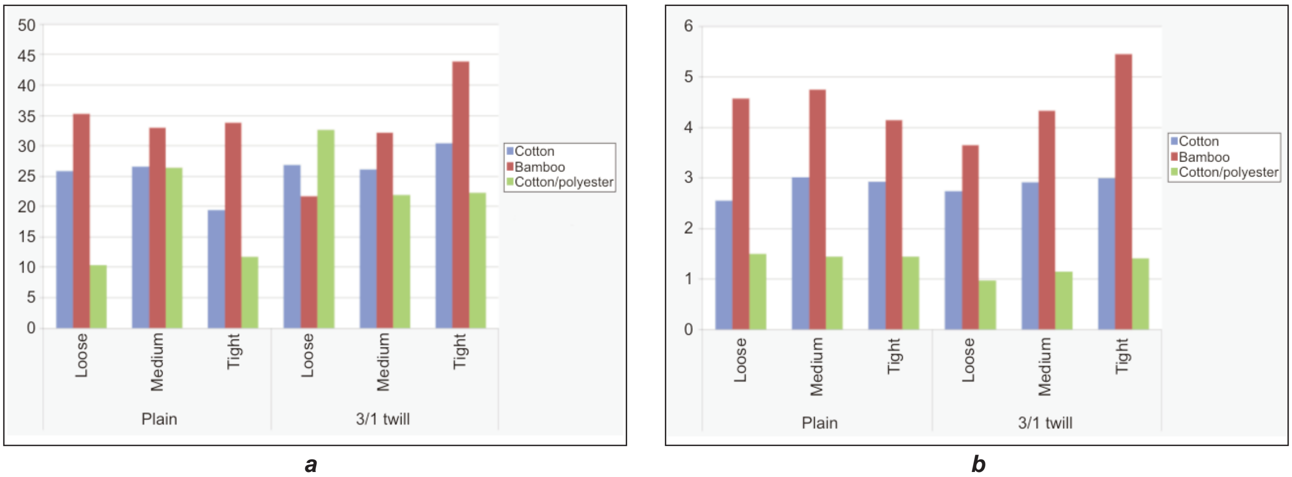


Fig. 3. Comparison of the (a) RWR_{40} and (b) RWR_{100} values of the fabrics used in the study

sinking time of the fabrics; whereas the raw material did not have statistically significant effect. Besides, there were generally significant effects of the interactions of the variables on the sinking time (p<0.05).

Drying behaviour

The ability of garments to quickly remove sweat from the skin is an important parameter to maintain the comfort of the body. The results of the remained water ratio at the end of the 40 and 100-minute (i.e., RWR_{40} and RWR_{100}) were illustrated in fig. 3.

As seen from fig. 3(a), the bamboo-twill-tight fabric had the worst drying ability. RWR_{40} values of the fabrics had significant correlations with the fabric thickness, the surface porosity and the average pore size (R_{2D}) (r=0.495; –0.570; –0.536, respectively), which is in agreement with findings presented by Sarıcam and Kalaoglu, and Prahsarn *et al.* [13, 32]. Moreover, it was found a significant negative correlation between RWR_{40} and OMMC (r = –0.626). As expected, liquid moisture management performances of the fabrics were poor owing to the fairly bad drying ability.

Within the scope of the results at the end of test period in fig. 3(b), the fabrics, which included the maximum amount of liquid moisture, were the bamboo fabrics, followed by cotton fabrics. Due to the fact that hydrophilic cotton and bamboo fibres hold a large amount of water, they do not remove the absorbed moisture quickly. Therefore, it is possible to say that the hydrophilic nature of the fibre affects the drying ability of fabrics. Similar findings were reported by Onofrei *et al.* and Fanguiero *et al.* [7, 33]. Raw material had statistically significant effects on RWR_{40} and RWR_{100}. On the other hand, there was not a significant effect of fabric tightness on RWR_{40}, and the effect of weave type on RWR_{100} (p<0.05).

CONCLUSIONS

The main aim of this research was to examine the effects of raw material, fabric tightness and weave type on the wetting and moisture transmission properties of the fabrics of shirts preferred by the office workers, and therefore to determine the advantageous woven fabric types from the point of wetness comfort.

The test results of regenerated bamboo fabrics indicated that these fabrics had good absorbency, low drying ability, and low moisture management performance. This means that the shirts produced from regenerated bamboo fibres can absorb water well; however, they do not immediately transfer sweat, and will cause wet and cold feel. Moreover, it was concluded that the cotton and cotton/polyester fabrics had similar moisture management properties and drying behaviour at the end of 40-minute. Hydrophobic polyester fibres used in cotton/polyester fabrics did not have an important influence during these test periods. However, it was observed that cotton/polyester fabrics had better drying behaviour at the end of 100-minute than that of cotton fabrics. Consequently, it can be said that cotton/polyester fabrics exhibit a similar moisture transmission behaviour with cotton fabrics in the beginning of the test; and afterwards, polyester fibres make a contribution to developing their moisture transmission properties. Furthermore, the change of fabric tightness affected the porosity of the fabrics. It was observed that as porosity of the fabrics increased, the wetting and moisture transmission properties of the fabrics enhanced. Weave types used in this study had either an insignificant influence or a weak effect size on the measured properties, except the absorbency. However, the interactions of weave type and other parameters had a more important effect on these properties. Based upon the results, the cotton/polyester-twill-medium and the cotton/polyester-plain-loose fabrics with good moisture transmission properties distinguished from the others, and these fabrics can be suitable for the shirts worn by office workers in terms of wetness comfort.

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Characterization of contemporary bast textiles and investigation of induced ageing effects for complex Cultural Heritage restoration of textile artifacts

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REZUMAT – ABSTRACT

Caracterizarea materialelor textile contemporane din fibre liberiene şi investigarea efectelor îmbătrânirii artificiale pentru restaurarea complexă a bunurilor culturale textile

Valoarea primară a unui bun de patrimoniu cultural este dată de dimensiunea sa temporală: un obiect creat acum sute de ani reprezintă o punte către un context cultural şi social, care sunt altfel inaccesibile. Factorul vârstă al unui bun de patrimoniu cultural poate genera două consecinţe: amplificarea valorii sale culturale, până la pragul unei valori inestimabile (aşa cum poate fi considerat Giulgiul din Torino), dar în acelaşi timp poate susţine procesul deteriorării bunului cultural, prin fragilizarea structurii interne a materialului, ca urmare a acţiunii factorilor de natură chimică şi biologică, astfel existând riscul piederii bunului cultural respectiv. În lucrarea de faţă sunt prezentate rezultatele obţinute la îmbătrânirea accelerată a unui material contemporan din fibră liberiană, indusă prin iradiere, folosind 3 regiuni spectrale în UV şi cicluri de temperatură şi umiditate. Modificările structurale ale fibrelor liberiene sunt evaluate prin colorimetrie şi FTIR.

Cuvinte-cheie: îmbătrânire artificială, colorimetrie, FTIR, patrimoniu cultural, fibre liberiene, in, Linum usitatissimum

Characterization of contemporary bast textiles and investigation of induced ageing effects for complex Cultural Heritage restoration of textile artifacts

The primary value of a heritage object is given by its temporal dimension: an object that was created centuries ago is the bridge to a cultural and social context that would otherwise be inaccessible. The age factor of an heritage object has two possible outcomes: it can amplify the cultural value of an object until it may become of inestimable value (a good example of which is the Torino Shroud) but also it can cause deterioration of the object by loosening the inner structure of the material and as a consequence opening it to chemical and biological attack, thus raising the possibility of losing the heritage object itself. In this paper there are presented the results obtained for accelerated ageing of hemp samples induced by irradiation using 3 UV spectral regions and a temperature and humidity cycle. The structural modification of the textile fibres after artificial ageing is measured by colorimetry and FTIR techniques.

Keywords: artificial ageing, colorimetry, FTIR, cultural heritage, bast fiber, flax, Linum usitatissimum

INTRODUCTION

The investigations and analyses comprised in the current paper are part of a complex national research project (MYTHOS) that is focused on development of new materials for conservation and restoration of bast European artifacts using biotechnological tools, namely – to produce textile reference materials that have the strongest biological and/or technical similarity with the Cultural Heritage objects. Three types of textile structures are investigated: the textile material which is part of the Cultural Heritage artifact, the textile material obtained from contemporary fibres and the new textile material obtained by biotechnology that has the same characteristics as the Cultural Heritage one.

The present paper is focused on the second type of textile structure – the contemporary ones, starting from their producing and characterization for raw, washed and bleached conditions, and ending up with artificial ageing and assessment of their behavior for different ageing protocols using FTIR and colorimetry investigations.

Within the field of material characterization, Fourier Transform Infrared Spectroscopy (FTIR) has proven to be one of the most reliable analytical techniques, with applications employed for the molecular study of virtually any type of material. Due to their heterogeneous nature, fibers derived from plant sources often appear as problematic materials, especially difficult to analyze when trying to distinguish between similar types of fibers within a certain group. Principally composed of cellulose ordered in various internal structures, the study of textile fibers is important not only for their identification, but also for an accurate assessment of their state of degradation, as well as to confirm a series of processing or dye treatments.

IR studies carried within the last decade on natural textile fibers [1] allowed an in depth characterization on regard to their structure, morphology and chemical composition – including hydrogen bonding, crystallinity measurement, compositional variation or physical organization at microscopic level. Under the cellulosic plant fibers of the bast group (flax, hemp, jute) peak intensities ratio techniques were able to differentiate fiber types on the basis of their relative lignin content with respect to other cellular components, while studies focused on degradation and ageing mechanisms [2] highlighted distinctive degradation products produced by oxidative processes and/or microorganism that can be further linked with characteristic changes of the fiber microstructure.

EXPERIMENTAL WORK

Materials and methods

Characterization of contemporary flax yarn and woven

For this study a flax yarn (*Linum usitatissimum*) was used to manufacture a woven fabric that was afterwards washed and bleached. The ageing protocols were applied on these three types of fabrics – raw, washed and bleached, in order to obtain comparative results of the ageing factors on textile materials which are in different stage of technological processing.

The flax yarn was acquired from Faltin S.A (Falticeni, Romania), as a 100% raw flax yarn processed on wet system and then it was weaved on a shuttle weaving machine, UNIREA AB120 type. The values for yarn characterization are presented in table 1.

Establishing the process flow in order to produce the current flax fabric was in agreement with the destination of the fabric – clothing products and with the properties of warp and weft yarns, flax yarns, sensitive to friction. The weaving included specific operations such as warping, shaft drawing-in, reed drawing-in, warp fitting, weaving machine adjustment. The weft yarns were used as coils in the shape of a truncated cone directly to the weaving machine.

The equipment and the parameters for each operation were:

- *Warping:* Warper: Textima ribbon warping; No. of ribbon yarns: 40; No. of warp yarns: 1600; Warp length: 50 m.
- *Drawing-in* was performed manually, both for the shaft drawing-in and the reed drawing-in: Type of drawing-in: straight, 8 shafts; Yarn distribution: 1 yarn in the heald, 1 yarn in reed box in the ground, 5 boxes, each containing 2 yarns in the box, each edge; Number of healds: 1600; Type of reed: conventional, reinforced with metal coils; Reed gauge: 80 boxes/10cm; Reed width: 100 cm.
- *Weaving* – it was performed on a shuttle weaving machine, type UNIREA AB120; Weave: plain; Speed: 160 rot/min; Weft density: 10 yarns/cm.

In figures 1 and 2 are presented different aspects of the warp flax yarns and of the woven during weaving. The raw flax woven obtained on classic technology as mentioned, was washed and bleached and the main parameters were analyzed. The values obtained are presented in tables 2 and 3. The washing process was done with cleaning agents, Kemapon PC/LF and anhydrous sodium carbonate. The bleaching process was done in the same facilities with hydrogen peroxide (H_2O_2) and anhydrous sodium carbonate (Na_2CO_3).

Artificial ageing

The artificial ageing protocols understudy are made for the determination of the long term effects of expected levels of stress ethnographic textile materials are subjected to, such as temperature, humidity

Table 1

CHARACTERIZATION OF CONTEMPORARY FLAX YARN

Bast yarn	Fineness Tex (Nm)	Breaking resistance (N)	Elongation at break (%)	Twist (t/m)	Twist sense	Apparent diameter (μm)
Raw	92,37x1 (10,83/1)	14.57	2.65	314.1	Z	409.2

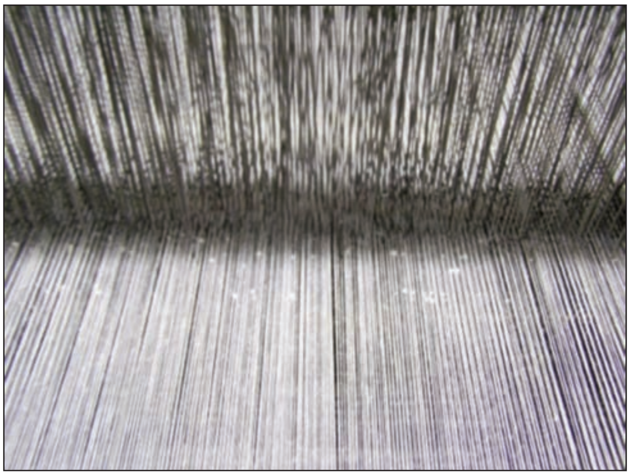

Fig. 1. Warp yarns

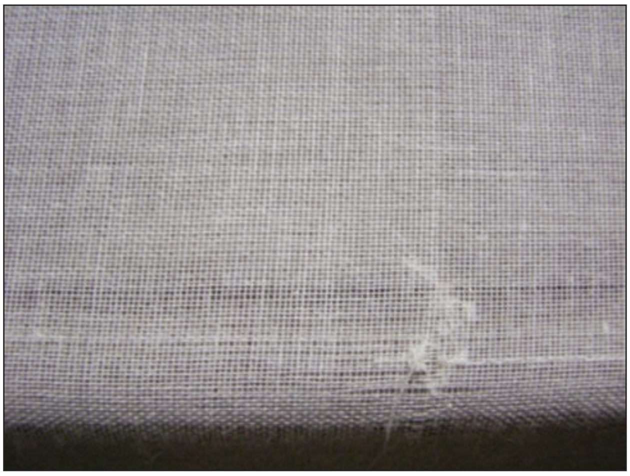

Fig. 2. Fabric during weaving

Table 2

CHARACTERIZATION OF THE WOVEN								
Woven	**Mass (g/m^2)**	**Density (threads/10 cm)**		**Breaking force (N)**		**Elongation at break (%)**		**Thickness (mm)**
		U	**B**	**U**	**B**	**U**	**B**	
raw	311	177	136	909	734	23.1	5.04	0.95
washed	321	190	136	1090	914	19.97	7.84	0.81
bleached	328	181	133	879	665	118.26	7.58	0.76

Table 3

CHARACTERIZATION OF THE WOVEN							
Woven	**Tearing force (N)**		**Permeability to air ($L/m^2/s$)**	**Abrasion (cycles)**	**Recovery from creasing (degrees)**		**Permeability to water (%)**
	U	**B**			**U** (face/verso)	**B** (face/verso)	
raw	123.1	128.8	754.6	9750	51/58	54/60	33.05
washed	121.1	111.9	524.2	14 180	54/69	59/56	29.1
bleached	88.6	89.5	568.3	9429	53/53	56/59	33

or exposure to UV light. The results will be used in assessment of the specific conservation protocols and studied on the basic processes of decay.

The raw, washed and bleached textile samples were subjected to 4 different induced ageing protocols, using the following equipment:

– UVA lamp: spectral region 315 – 380 nm, peak = 350 nm, power = 36 W
– UVB lamp: spectral region 305 – 315 nm, peak = 311 nm, power = 36 W
– UVC lamp: spectral region < 300 nm, peak = 253.7 nm, power: 55 W

Binder, type KBR climate chamber for temperature and humidity cycles: T_{min} = –3 °C, T_{max} = 65 °C, RH_{min} = 38 %, RH_{max} = 86%. One daily cycle is described in figure 3.

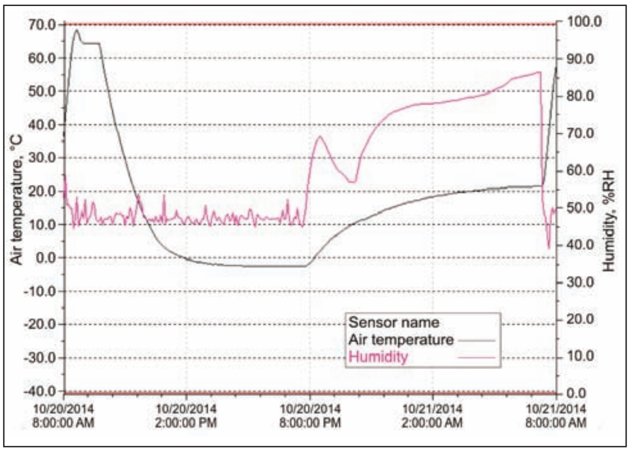

Fig. 3. The temperature and humidity cycle

RESULTS AND DISCUSSION

In terms of light induced effects, the textile samples (raw, washed and bleached) were exposed to fluorescent lamp radiation up to a number of 225 hours. No filters were applied as in order to produce more rapid changes within the tested materials. Taking into consideration the variations within the spectral signature and output power of selected light sources, the total exposure dose (time integral of irradiance) has to be considered for each specific wavelength range. Colorimetric and FTIR investigations were performed for each sample subjected to the ageing protocols, in order to assess the visual and chemical changes that the textile material undergoes.

Colorimetric analyses

The color changes were evaluated using a ColorEye XTH spectrometer with an illuminant D65/10° observer. The color parameters evaluated were L*, a*, b* and the ΔE (total color change) corresponding to CIE 1976 L*a*b* color system. The fluctuation of the color parameters are presented in table 4 for the raw samples, table 5 for the washed samples and table 6 for bleached samples.

The evaluation of the differences encountered in the color parameters was focused on the most important one: b*, which stands for the blue – yellow axis, and gives us details about the yellowing of the textile substrate – a major factor for the conservation of artworks. The Δb* values are presented in figure – for the raw samples, figure 5 – for the washed samples and figure 6 – for the bleached samples.

Analyzing the Δb* values it can be concluded that so far, at 225 hours of UV exposure, only UVC has made quite considerable jump into the yellow area of the b* axis for all three types of textile samples: raw, washed and bleached. Also, the colorimetric changes attributed to the climate chamber exposure are insignificant, being in the range of measurement

Table 4

COLOR DIFFERENCES FOR RAW SAMPLES FOR DIFFERENT AGEING PROTOCOLS							
Raw samples							
	ΔL*	Δa*	Δb*		ΔL*	Δa*	Δb*
UVA 75	1.025	0.002	–1.448	UVB 75	6.028	–0.818	–2.152
UVA 150	5.548	–0.437	–2.022	UVB 150	8.002	–1.040	–2.582
UVA 225	7.242	–0.595	–2.953	UVB 225	9.197	–1.018	–3.062
UVC 75	7.712	–1.230	–1.030	CC 75	–0.343	0.043	–0.627
UVC 150	8.640	–0.933	1.272	CC 150	–0.277	0.217	–0.247
UVC 225	8.358	–0.730	2.305				

Table 5

COLOR DIFFERENCES FOR WASHED SAMPLES FOR DIFFERENT AGEING PROTOCOLS							
Washed samples							
	ΔL*	Δa*	Δb*		ΔL*	Δa*	Δb*
UVA 75	2.665	–0.315	–2.023	UVB 75	2.932	–0.387	–1.715
UVA 150	4.183	–0.352	–2.008	UVB 150	4.375	–0.532	–1.947
UVA 225	4.822	–0.420	–2.458	UVB 225	5.602	–0.652	–2.650
UVC 75	2.815	–0.822	–0.360	CC 75	–0.057	0.130	–0.103
UVC 150	3.310	–0.550	2.368	CC 150	0.730	0.153	–0.237
UVC 225	2.965	–0.495	2.822				

Table 6

COLOR DIFFERENCES FOR BLEACHED SAMPLES FOR DIFFERENT AGEING PROTOCOLS							
Bleached samples							
	ΔL*	Δa*	Δb*		ΔL*	Δa*	Δb*
UVA 75	1.403	0.087	–2.107	UVB 75	0.948	0.098	–1.632
UVA 150	1.805	0.202	–0.935	UVB 150	1.813	0.028	–2.048
UVA 225	2.730	–0.033	–2.847	UVB 225	2.050	–0.197	–2.973
UVC 75	0.420	–0.067	0.025	CC 75	0.930	–0.100	–0.857
UVC 150	1.175	–0.057	1.740	CC 150	0.780	–0.017	–1.123
UVC 225	0.618	0.163	2.150				

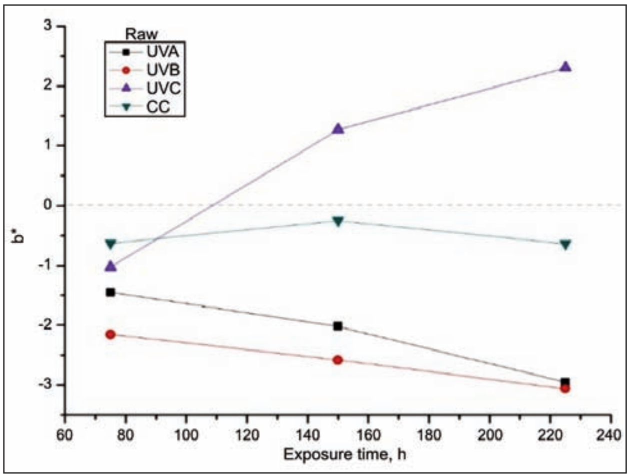

Fig. 4. Δb* fluctuations for the raw samples

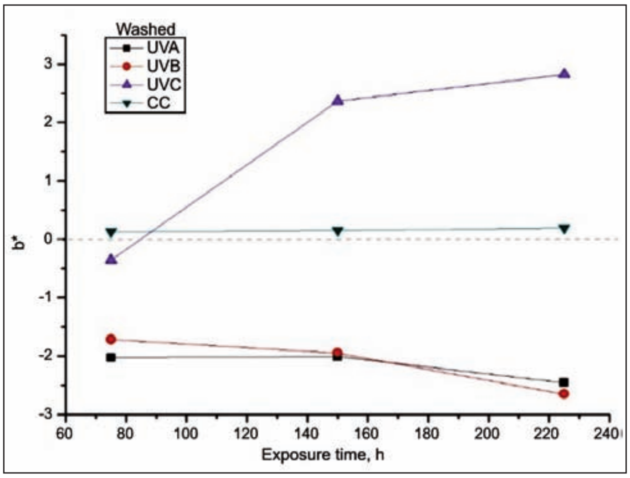

Fig. 5. Δb* fluctuations for the washed samples

Table 7

ΔE VALUES FOR RAW, WASHED AND BLEACHED SAMPLES FOR DIFFERENT AGEING PROTOCOLS							
ΔE	*raw*	*washed*	*bleached*	**ΔE**	*raw*	*washed*	*bleached*
UVA 75	1.774	3.361	2.533	UVB 75	6.453	3.418	1.890
UVA 150	5.921	4.654	2.043	UVB 150	8.472	4.818	2.736
UVA 225	7.843	5.428	3.944	UVB 225	9.746	6.231	3.617
UVC 75	7.877	2.954	0.426	CC 75	0.716	0.175	1.268
UVC 150	8.783	4.107	2.100	CC 150	0.429	0.783	1.368
UVC 225	8.701	4.123	2.243				

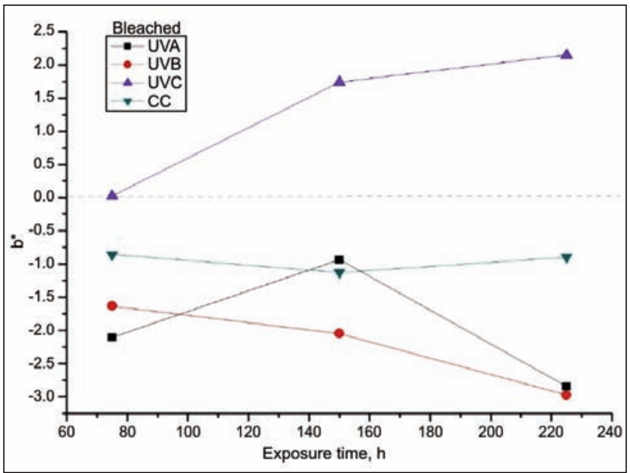

Fig. 6. Δb* fluctuations for the bleached samples

error for the raw and washed samples, but in the case of the bleached one there can be observed a slight color change.

The changes encountered in the total color index ΔE (see table 7) indicate modifications in the structural characteristics of the textile samples, for all the UV irradiated samples [3]. The ΔE values for the samples subjected to RH and T cycle are insignificant for the raw and washed samples, but closing up to the 1.5 threshold for the bleached samples, fact that indicates that structural modifications may occur at higher exposure times.

FTIR analyses

Attenuated Total Reflectance (ATR) – FTIR measurements were performed with a monolithic diamond crystal via a PerkinElmer Spectrum Two FITR spectrometer. Data were collected in the mid infrared range 4,000 – 450 cm^{-1} at a spectral resolution of 4 cm^{-1} by averaging 8 scans, with automatic background subtraction; no special sampling preparation was required. For each type of tested material measurements were carried in multiple points while in terms of data processing all spectra data presented here were baseline corrected and a smooth factor applied.

Artificially aged samples were examined and further compared with reference spectra collected on untreated selected material as in order to asses possible modifications induced via accelerated testing applied. Natural products, vegetal fibers are characterized by a cellular structure mainly composed of sugar based polymers – cellulose, hemicelluloses, combined with pectin and lignin, along a series of other minor components such as residual protein, waxes, oils or inorganics as well as structural water [4].

With intrinsic variations along the fiber length, FTIR studies following deterioration emphasize investigations within the regions characteristic of crystalline and amorphous cellulose, as the differences that may appear within these regions can be directly linked with changes in the fiber structure [5]. As already mentioned [6], environmental conditions, age or various degradation processes have a great influence on regard the physico-chemical properties of such fibers as they can directly affect not only the internal structure but the chemical composition as well.

Upon examination of the reference materials it could identify a series of absorption bands that can be assigned on the basis of their spectral signatures to specific components [7], with cellulose as the major constituent (see table 8 for exact band assignment). For all three series of analyzed hemp textiles – raw, washed and bleached, the ATR spectra obtained appears extremely similar with only minor differences on regard absorption bands corresponding to the C-H stretching vibration at 2900 cm^{-1} and 2850 cm^{-1}, 1734 cm^{-1} respectively due to the C=O ester band, from pectin (see figure 7).

This variations could be explained on one hand by the mechanical process involved during the washing and bleaching of the yarns as the above mentioned bands are directly related to the general organic material content of the fiber [8]. During this mechanical processing the cellulosic structure is affected, situation that can be translated at the physico-chemical fiber characteristics (cellulose crystallinity) as well as to the overall chemical composition, as upon washing and bleaching minor components are being removed. This fine structural molecular rearrange-ment generates a different signature in relation to the raw, unprocessed samples that can be further considered as a discriminatory factor within various studies.

On regard to the effects of the accelerated aging process, ATR data registered on UV exposed

Table 8

INFRARED BAND ASSIGNMENT	
Position / cm^{-1}	**Assignment**
~ 3336	ν(OH)
~ 2915	ν(C-H)
~ 2850	ν(CH_2) symmetrical stretching
~ 1734	ν(C=H) ester
~ 1640	adsorbed water
~ 1427	δ(C-H)
~ 1365	δ(C-H)
~ 1335	δ(CH_2) wagging
~ 1315	δ(C-H)
~ 1278	δ(CH_2)
~ 1248	δ(C-OH) out of plane
~ 1200	δ(C-OH); δ(C-CH)
~ 1155	ν(C-C) asymmetric
~ 1105	ν(C-O-C) glyosidic
~ 1052	ν(C-OH) 2° alcohol
~ 1029	ν(C-OH) 1° alcohol
~ 1002	ρ(-CH-)
~ 983	ρ(-CH-)
~ 895	ν(C-O-C) in plane, symmetric

(ν – stretching vibrations, δ – scissoring, ρ – rocking)

samples showed no significant modifications within the mid infrared range, overall slightly changes being assumed for minor components (see figure 8 details). The same absent response was seen on all level of exposure in spite the increased number of exposure hours and various levels of radiation energy. A similar response was seen on all series of tested textiles in terms of the microclimate variations as no changes were observed within IR absorptions bands.

We have to mention that this particular response upon artificial weathering has to be assessed within the frame of the mid-infrared region and thus seen as a fake apparent stability as colorimetric data registered on the aged samples indicates various level of yellowing (see the general color variation), and thus oxidation reaction within the cellulosic substrate. This suppositions seem to be confirmed as FTIR and NIR data found in literature highlights the presence of carbonyl and carboxyl molecular fragments in cellulose – corresponding to oxidation and acid promoted dehydration during ageing, with the need of an activation energy of 98 kJ/mol for cellulose oxidation to occur [9, 10].

The progressive changes within the band around 1630 cm^{-1} could be explained as a loss of structural water (with a note that the moisture content of the fibers is dependent on the content of non-crystalline part), while the slightly variations around 1734 cm^{-1}

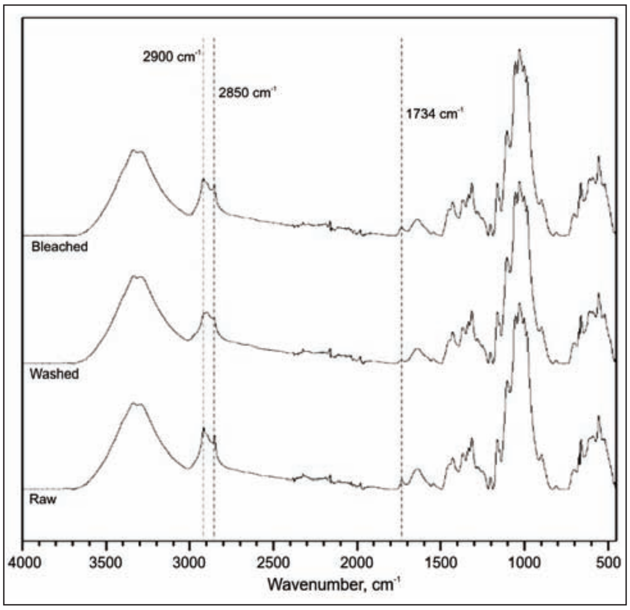

Fig. 7. ATR- FTIR spectra of reference samples with highlights on IR analytical band differences

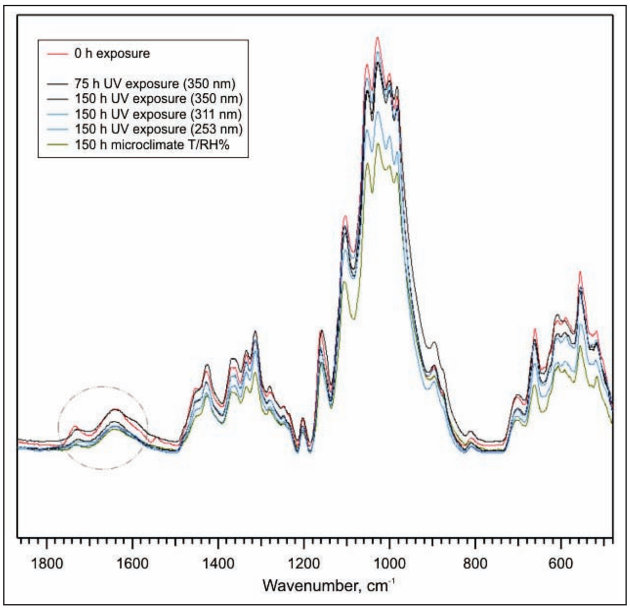

Fig. 8. Detail of ATR- FTIR spectra recorded on raw flax aged samples

corresponding to the lignin content would indicate a degradation within this minor constituent.

CONCLUSIONS

With extensive literature and large amount of data showing a relatively wide distribution within the chemical composition and structure of the same specimen, analysis of natural fiber properties and ageing characteristics proves problematic, experimental factors having to be carefully taken into account as in order to have a realistic evaluation of the measurements. In terms of the applied accelerated aging, with a focus on the light ageing regime, we have to mention that while radiant exposure is an important factor in understanding photochemical deterioration; this unit tells us only how much radiation has been deposited onto the surface of a material but not how much has been absorbed.

Chemical changes, and ultimately significant deterioration processes, have to be linked with a complex set of reactions in which the combined action of UV light and oxygen are considered predominant [11]; according to previous literature [12], the amount of energy absorbed by a molecule must exceed the energy bond that holds the molecular structure together as in order to initiate degradation. With this into account, the colorimetric and spectroscopic data obtained on the artificially aged hemp samples could indicate a mismatch in terms of energy when comparing the internal bond strengths of the fibers and selected wavelengths of radiation, as only minor variations could be measured at molecular level. The existence of an induction period, seen as the extent of degradation as a function of wavelength, and thus the necessity of longer exposure hours have to be considered, along with the optimization of monitoring techniques.

Acknowledgements

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Life cycle assessment for medical textiles treated with plasma

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REZUMAT – ABSTRACT

Evaluarea ciclului de viață pentru textile medicale tratate în mediu de plasmă

Tratamentul ecologic de finisare a materialelor textile este o prioritate în secolul 21. Tratamentul clasic al materialelor textile este un proces cu un consum ridicat de apă, coloranți și energie. Tratamentul în mediu de plasmă are o eficiență sporită în ce privește consumul de materii prime, auxiliari si energie. Din acest motiv, s-au realizat studii de cercetare referitoare la tratamentul în plasmă al materialelor textile, cu obiectivul de a demonstra reducerea impactului asupra mediului. Un studiu LCA cuprinzător a fost efectuat în acest sens: programul software utilizat a fost Sima Pro 7. Rezultatele cercetării obținute au demonstrat faptul ca materialele textile tratate în mediu de plasmă prezintă proprietăți funcționale similare sau chiar îmbunătățite în comparație cu materialele textile tratate prin procedeul clasic. Mai mult, materialele textile tratate în plasmă au un impact asupra mediului semnificativ redus, în conformitate cu studiul LCA.

Cuvinte-cheie: plasmă, materiale textile, bumbac, studiu LCA

Life cycle assessment for medical textiles treated with plasma

Environmental friendly treatment of textile materials is a high priority in the 21st century. Classical treatment of textile materials is a manufacturing process, consuming a large amount of water, dyestuff and energy. The plasma treatment has a significant improved efficiency in the consumption of raw materials, auxiliaries and energy. Hence, studies regarding the plasma treatment on textile materials have been performed aiming to prove the reducing of the environmental impact. A comprehensive LCA study has been accomplished in this regard: the supporting software program used was Sima Pro 7. The research results obtained have shown that textile materials treated with plasma nanotechnology have similar or even improved functional properties compared to the textile materials treated with the classical process. Moreover, the plasma nanotechnology treated fabrics have a significantly reduced impact on the environment, accordingly to the LCA study.

Keywords: plasma, textiles, cotton, LCA study

INTRODUCTION

The aim of this paper is to demonstrate the environmentally friendly character of plasma treatment on textile materials, compared to the classical treatment within a preliminary process for finishing. The similarity of the functional properties as result of both types of treatment, gave the possibility of accomplishing this comparative LCA study [5–6].

As overall aim of the research activities, we envisaged to perform studies in the field of plasma treatment on textile materials, in order to underline its benefits and to disseminate the results to industrial multipliers – European textile SMEs. The multi-functionality of textile products based on plasma treatments brings competitive advantages to the European SMEs and makes possible the manufacturing of high added-value products.

INCDTP – Bucharest has certified laboratories for the investigation of textile materials (RENAR certified) and has also in its endowment a plasma treatment installation from Europlasma Belgium: the CD 400 Roll-to-roll low-pressure plasma installation (fig. 1).

In order to highlight the reason of the comparative LCA study, we would like to present an entire perspective of the performed research activities in the field of plasma treatments on textile materials:

– A deep research study in the field of plasma treatment on textiles was accomplished;
– The functional properties of textile materials were improved, as consequence of plasma treatment:

Fig. 1. Plasma treatment installation

hydrophobic functionality, hydrophilic functionality, anti-microbial functionality. A multitude of textile samples have been treated with the plasma installation: the functionality of the samples was given by the parameters of the plasma treatment:
  - Type of Gas; Type of frequency generator; Power; Treatment duration; Pressure; Temperature [3].
- The anti-microbial character of the medical articles treated in plasma [4] was demonstrated by means of anti-microbial investigation tests, accordingly to the Standard ISO 20743:2007. The plasma treated fabrics were finished with colloidal silver, chitosan and thyme oil. As final medical articles, there were envisaged: bandages, surgical gowns and bed linen for surgery rooms.

The novelty degree of the performed research studies consists in the improvement of the properties of textile materials, based on plasma treatment with various parameters. Hence, we obtained on fabrics a hydrophobic effect with Hexafluoropropane gas plasma treatment. We could also obtain a hydrophilic effect (wettability effect) with Oxygen plasma treatment, with subsequent application of colloidal silver, chitosan and thyme oil for an improved anti-microbial effect. The Turkish partner PLUS ELECTRONIC was able to manufacture an industrial plasma treatment installation and made possible the implementation of the performed laboratory experiments on industrial scale.

Nevertheless, one of the final activities was evidencing the environmentally friendly character of the plasma treatment compared to the classical treatment and this is the subject of the present paper.

EXPERIMENTAL

The research activities for plasma treatment on textile materials had good results in all the proposed research premises. These results were presented in several previous papers [11–16]. The aim of this paper is to present the environmental friendly character of the plasma treated fabrics in comparison with the classical treatment, having in view the preliminary finishing process of the cotton woven fabrics. The software program Sima Pro 7 was used for the accomplishing of the comparative LCA study [1–2]. Accordingly to the Standard 14040 and 14044, a LCA [7–8] study has four phases (fig. 2).

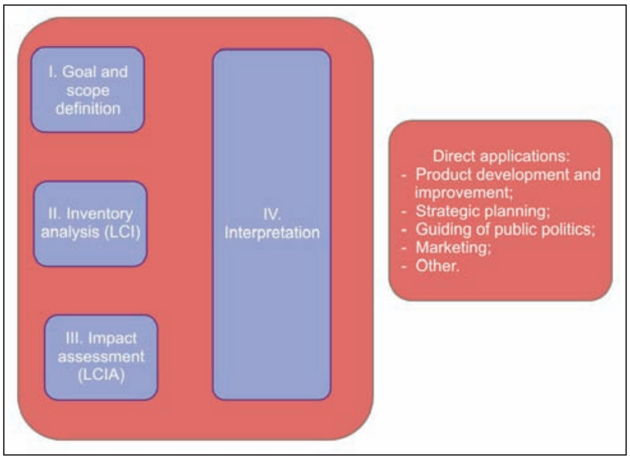

Fig. 2. The four phases of a LCA study accordingly to the Standard 14040

GOAL AND OBJECTIVES

The main objective of the LCA study was the accomplishing of a comparative study between two types of treatments:
- The cotton woven fabric (189 g/m^2) with classical treatment;
- The cotton woven fabric (189 g/m^2) with plasma treatment;

The LCA study is a cradle-to-gate study, studying the two methods of treatment of the woven cotton fabrics, in laboratory conditions, in the production stage. The functional properties of both fabric's treatment methods are similar, accordingly to the research results: an Oxygen gas plasma treatment was performed for the cleaning of the fabric surface, a process which replaces the preliminary classical finishing for the cotton fabric. Hence, a comparative LCA study [9–10] for the two treatment processes was possible. The functional unit for comparison is of 1 kg of finished woven cotton fabric. The reason of this LCA study is evidencing the environment friendly character of the plasma treatment for textile materials.

The system limitations were:

A. It was introduced in calculation:
   a. The consume of raw materials;
   b. The consume of natural resources;
   c. The consume of chemical auxiliary products;
   d. The consume of electrical energy for the treatment installations.

B. It was excluded from calculation:
   a. The consume of heating power (gas/coal), considered as equivalent in both methods;
   b. The transport of the materials, considered as not relevant in this case.

The used LCA method for this study was Eco-indicator 99 (E) version 2.08.

The dissemination public envisaged for this LCA study is the research and academia environment, as well as the industrial environment, represented by the textile SMEs in Romania and Europe.

RESULTS

Within the LCI study the inventory data of both treatment methods have been registered. Only the comparative data for the two methods have been evidenced in this study. This means that the data for manufacturing the raw cotton woven fabric was neglected.

The model for the calculation of the consume of electric energy of the installations used in the classical treatment of the cotton woven fabric, consists in the transformation of the processed quantity of woven fabric in linear meters. The specific weight being 189 g/m^2 and the width of the fabric 1,50 m, it results 283,5 g/lm. 100 kg of cotton fabric = 352,7 lm, and 1 lm = 0,2835 kg.

Table 1

ELECTRICAL ENERGY CONSOMPTION FOR THE CLASSICAL TREATMENT METHOD						
Operation	**Time duration (min.)**	**Time duration (h)**	**Power (kW)**	**Electrical energy consume (kWh)**	**Electrical energy consume (kWh/ml)**	**Electrical energy consume (kWh/kg fabric)**
A. Preliminary preparation						
a. Degreasing	45	0.75				
b. Alkaline cleaning	120	2				
c. Hot washing	30	0.5				
d. Warm washing	30	0.5				
e. Cold washing	30	0.5				
f. Neutralizing	30	0.5				
g. Cold washing	30	0.5				
Total preparation	**315**	**5,25**	**15**	**78.75**	**0.223**	**0.7875**
B. Dyeing	90	1.5	15	22.5	0.0637	0.225
Total dyeing	**90**	**1.5**	**15**	**22.5**	**0.0637**	**0.225**
C. Superior finishing						
a. Fireproofing: Drying stenter speed: 10 lm/min	35.3	0.59				
b. Hydrophobic effect: Drying stenter speed: 10 ml/min	35.3	0.59				
Total superior finishing	**70.6**	**1.18**	**58**	**68.44**	**0.1940**	**0.6844**
TOTAL general	**475.6**	**7.93**		**169.69**	**0.4807**	**1.6969**

The following formula has been applied: L = P t, where L = electrical energy consume; P = installation power; t = treatment duration. The subsequent table of consumes has been obtained (see table 1).

The model for the consume of chemical substances in the preliminary treatment of the cotton fabric, consists in the calculations for the exhaust treatment method: the exhaust ratio has a report of 1:3. This means that 100 kg of cotton woven fabric consume 300 l of exhaust bath. In the preliminary treatment is used for degreasing Kemapon with a concentration of 0,5 g/l. It results an exhaust bath of 300 l: 0,5 g/l × × 300 l = 150 g Kemapon. For 1 kg of finished cotton fabric we use: 150 g Kemapon/100 kg cotton = 1,5 g Kemapon/1 kg cotton. This model applies to the Preliminary preparation (A) and Dyeing processes (B), while we use another calculation model for padding in case of the Superior finishing (C).

The model for the consumption of the plasma installation treatment has to take into account the parameters of the plasma treatment:

- Oxygen gas; Generator frequency: kHz; Generator power: 50 W; Treatment duration: 120 s; Pressure: 20 mTorr; Temperature: 19,8°C.

The oxygen gas quantity was estimated by means of the law of ideal gases: p V = n R T at a total weight of 106 g O_2. For the electrical energy consumption we have L = P t, where P = 32 kW (from the machine data) and t = 120 s. It results a consumption of electrical energy of L_1 = 1.06 kWh. Thus results the table 3 with comparative life cycle inventory data.

Table 2

RECIPE FOR THE TECHNOLOGY PROCESS OF PRELIMINARY PREPARATION	
A. Preliminary preparation	**Recipe/Parameters**
1. Degreasing – washing	Temperature = 50 °C; Duration: 45 min Recipe: Kemapon PC/LF : 0,5 g/l
2. Alkaline classical finishing	Temperature = 98 °C; Duration: 120 min Recipe: NaOH: 8–20 g/l / Na_2CO_3: 1/3 from NaOH Kemapon PC/LF : 0,5 g/l Kemapon SR 40: 0.5 g/l (Concentration reducer: 1 – 2 g/l)
3. Hot washing	Temperature = 90 °C; Duration: 30 min
4. Warm washing	Temperature = 70 °C; Duration: 30 min
5. Cold washing	Temperature = 30 °C; Duration: 30 min
6. Neutralizing	Temperature = 40 °C; Duration: 30 min Acetic acid = 0.5g/l
7. Cold washing	Temperature = 30 °C; Duration: 30 min

Table 3

COMPARATIVE LIFE CYCLE INVENTORY DATA							
→ Functional unit = 1 kg finished woven fabric							
Classic treatment:				**Plasma treatment:**			
Process	Substances	Consume substances	Consume energy	**Process**	Substances	Consume substances	Consume energy
Preliminary preparation Exhaust rate 1:3	Kemapon PC/LF	15 g	0,7875 KWH	**Treatment in Oxygen plasma**	Oxygen	=> 106 g O_2	32 KWHx 2 min = 1.06 KWH
Alkaline cleaning: Exhaust rate 1:3	NaOH= 8–20 g/l	30 g					
	Na_2CO_3= 1/3 from NaOH	10 g					
	Kemapon PC/LF	1,5 g					
Neutralizing: Exhaust rate 1:3	Acid acetic:	1,5 g					

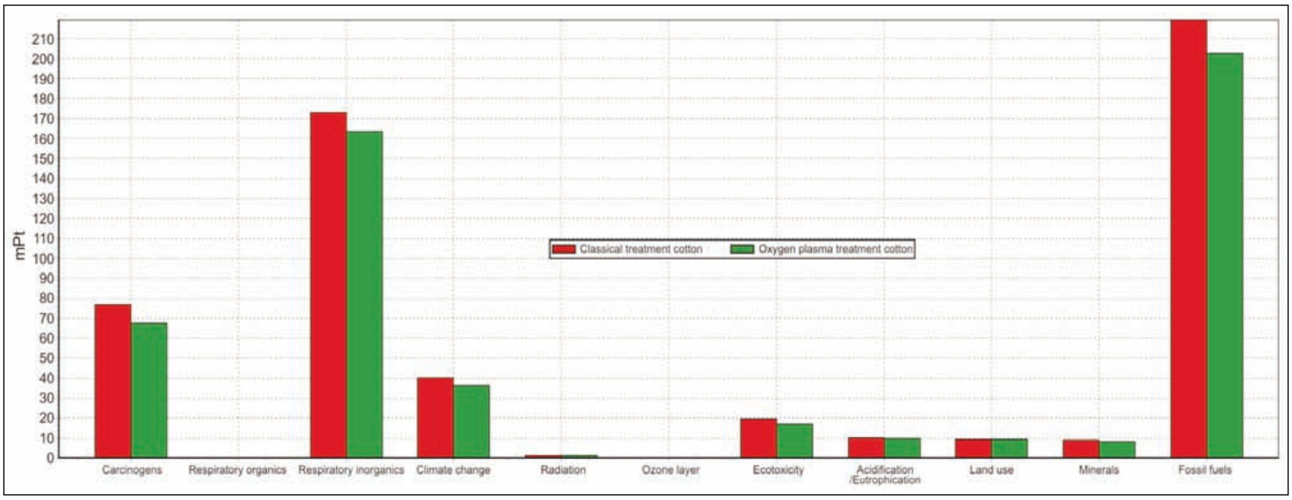

Fig. 3. Comparative results environmental impact assessment with weighting factor

DISCUSSION

LCIA study – The Life Cycle Inventory Assessment study shows some of the results obtained by processing the LCI data in the Sima Pro 7 software.

We will show as overall result the comparative diagram (figure 3) based on the weighting factor:

– The cotton woven fabric with classical treatment (with red color);

– The cotton woven fabric with plasma treatment (with green color).

As seen in figure 3 the impact categories of the assessment method Eco-indicator 99 (E). These impact categories are: carcinogens, respiratory organics, respiratory inorganics, climate change, radiation, ozone layer, toxicity, acidification/eutrophication, land use, minerals, fossil fuels. The weighting factor representation applied to this graphics is given by the multiplication of each impact category with a weighting factor, accordingly to the overall impact of this category on the environment.

As seen from the graphics, that plasma treatment is less environment polluting than classical treatment in impact categories, such as: carcinogens, respiratory inorganics, climate change and fossil fuels.

CONCLUSIONS

The interpretation of the LCA can be deduced from the figure 3. The classical treatment method shows a higher environmental impact in all the impact categories of the LCA method Eco-indicator 99 (E). Thus, we can conclude, that the plasma treatment method is a more environmentally friendly treatment method. The plasma treatment of textile materials is an efficient and modern method for the finishing of textile materials, which could be introduced at large scale in the European textile companies. The research results plead for the implementation of plasma treatment installations on industrial scale, as environmentally friendly treatment method of textile materials, providing specific functionalities and an improved efficiency.

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Optimization model for an assortment structure of textile confections

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REZUMAT – ABSTRACT

Model de optimizare a unei structuri sortimentale de confecţii textile

Corelarea proprietăţilor fiziologice ale confecţiilor textile trebuie adaptată diverselor cerinţe ţinându-se seama de caracteristicile materialelor, geometria produselor, mediul climatic în care produsul va fi purtat şi nu în ultimul rând, de activitatea pe care o depune purtătorul.
Prin această lucrare ne propunem ca, pe baza unui model matematic ce poate fi utilizat cu uşurinţă şi costuri minime de către producători, să determinăm o structură sortimentală optimă de confecţii textile, o structură echilibrată fiziologic.

Cuvinte-cheie: model matematic, gamă sortimentală, confecţii textile, proprietăţi fiziologice

Optimization model for an assortment structure of textile confections

The correlation of the physiological properties of the textile confections should be adapted to different requirements taking into account the characteristics of the materials, the geometry of the products, the climatic conditions in which the product will be worn, and, last, but not least, the activity carried out by the person wearing the clothes.
On the basis of a mathematical model that can be easily used and with minimal costs by producers, this paper proposes to determine an optimal assortment structure of textile confections, a physiologically balanced structure.

Keywords: mathematical model, assortment range, textile confections, physiological properties

INTRODUCTION

As in this paper we intend to analyze how mathematical modelling contributes to optimizing an assortment structure of textile confections, and based on the carried out study to build a possible model that meets this requirement, we consider necessary, for a start, to bring arguments in favour of our theme and its opportunity. The choice of this theme originates in objective rationales.

This paper is important due to the fact that it tries to answer the informational needs required by management. Obtaining this information requires efforts to create and develop their own informational systems characterized by elasticity, flexibility, precision and efficiency.

As for the opportunity, of course, the opinions can be different.

The issue of diversifying and optimizing an assortment structure of textile confections is far from being a low frequency one, having a small opportunity coefficient. And that is why it can not be categorized as such: the market competition expects manufacturers to have a rapid response enabling them to maintain and develop their acquired position. Then, we should take into account both the many fabrics that can be made into garments and the alternation of seasons which make practically inexistent the period of accommodation to certain temperatures, humidity, etc. This aspect is studied by the physiology of the clothing products. For an outfit to be physiologically balanced it is important and necessary that the physiological properties should be included in optimal proportions, so as to ensure physiological comfort [1].

In addition, using mathematical modelling, textile confections manufacturers can make their own assortment range according to the market requirements and their own capabilities.

Another advantage is the possibility of offering an operative analysis of the efficiency of the carried out activity, being also an instrument of investigation and forecast [2].

These are only some of the arguments supporting the appropriateness of our topic.

Globalization, as a determinant factor of the current economic environment determines a growing competition in all areas. Under these circumstances, for manufacturers to remain on the market, they must have the capacity for innovation [3]. An important aspect of this relates to the use of mathematical modelling based on the new software, the various activities and processes specific to the textile industry [4].

A further use relates to the technological process, i.e. to the achievement of optimal solutions regarding the reliability of the parameters and the dynamics of the production rate [5]. Also, mathematical modelling may be used to obtain some fabrics with certain characteristics [6] – [7].

The importance of how comfortable the clothing products are is also a subject of study for many researchers who have already highlighted the role of the physiological properties in determining the comfort [8] – [9].

THE OPTIMIZATION OF AN ASSORTMENT STRUCTURE OF TEXTILE CONFECTIONS

Model description

The main objective was the achievement of a possible optimized model of an assortment structure of textile confections using deterministic mathematical programming with multiple objective functions, such as [10]:

(1.1) $Ax \leq b$

(1.2) $x \geq 0$

(1.3) (optimum) $F = Cx$

where:

$A = ((a_{ij}))$, $i = 1, 2, ..., m$; $j = 1, 2, ..., n$ is a matrix $m \cdot n$;

$b = (b_1 ... b_m) \in R^m$ is a column vector, m-dimensional;

$x = (x_1 ... x_n) \in R^n$ is an unknown column vector, n-dimensional;

$F = (F_1 ... F_r)$ is a column vector with r components which represent the objective functions;

$C = ((c_{ij}))$, $i = 1, 2, ..., r$; $j = 1, 2, ..., n$ is a matrix $r \cdot n$.

We note: $D = \{x = (x_1 ... x_n), Ax \leq b, x \geq 0\}$ the set of admissible solutions to the problem (1.1) – (1.3).

To anchor the ideas we assume that all functions are at maximum. If this condition is not met, by transforming min. $F(x) = -$ max. $[-F(x)]$ we can make all the functions to be at maximum.

The problem is finding that vector $x^* = (x^*_1 ... x^*_n) \in D$ (or those vectors x^* able to respond to the system of restrictions 1.1, 1.2 and 1.3) to be 'best possible' in terms of the ensemble of the objective functions F_h ($h = 1...r$) [11].

Since the expression 'best possible' is not sufficiently clear and quantifiable, each of its mathematical formulation generated one point of view, and, therefore, one method of solving the problem with multiple criteria.

Since the vector space $V = \{(F_1(x), \ldots, F_r(x)), x \in D\}$ with its elements, having as components the values of the objective functions, is not totally ordered, it is usually difficult to find a point in the allowable solutions that optimizes simultaneously the ensemble of the objective functions.

If there are multiple objective functions, the optimal solution for a function is not optimal for the others, so we introduce the notion of a solution that does 'the best compromise', known as the non-dominant solution (an effective solution, the Pareto optimal).

Model implementation

We considered the following situation: a textile confections manufacturer wants to manufacture the article 'jacket for men', designed to be worn in the summer. This article is composed of three layers, namely: the front, the lining and the reinforcement. For this article the manufacturer can supply five fabrics for the front, three fabrics for the lining and two fabrics for the reinforcement, each of them having values for the hygienic property and a production costs presented in table 1.

According to [12]:

a) $Ra = \frac{\delta}{i}$

where:

Ra – air flow resistance;

δ – thickness of the material;

i – coefficient of permeability to air.

b) $Rv = \frac{\delta}{\mu}$

where:

Rv – vapour resistance;

δ – thickness of the material;

μ – coefficient of evaporation.

Table 1

TYPES AND CHARACTERISTICS OF THE FABRICS NEEDED FOR MAKING THE ARTICLE 'JACKET FOR MEN'

No.	Type of fabric	Air flow resistance ($m^2 \cdot h \cdot mm/kg$)	Vapour resistance ($mm \cdot h \cdot m^2/g$)	Thermal resistance ($m^2 \cdot h \cdot °C/Kcal$)	Production cost (lei)
			FRONT		
1.	A	0.0092	0.0539	0.0401	247.50
2.	B	0.0087	0.0270	0.0429	294.80
3.	C	0.0121	0.0484	0.0363	233.20
4.	D	0.0294	0.0396	0.0374	301.40
5.	E	0.0306	0.0508	0.0400	280.50
			REINFORCEMENT		
1.	M	0.0133	0.0150	0.0409	28.60
2.	N	0.0017	0.0506	0.0385	29.70
			LINING		
1.	P	0.0032	0.0266	0.0209	49.50
2.	Q	0.0029	0.0264	0.0165	50.60
3.	R	0.0028	0.0261	0.0187	47.30
Equivalent air layer		0.0325	0.0540	0.1490	

c) $Rt = \frac{\delta}{\lambda}$

where:

Rt – thermal resistance;

δ – thickness of the material;

λ – coefficient of permeability to air.

The obtained article ‘jacket for men’ must be physiologically balanced and, at the same time, also have an acceptable production cost, so that it can be sold.

We considered the following unit consumption for each of the three types of fabrics: α = 1.5 m for front, β = 1.45 m for lining and γ = 0.5 m for reinforcement.

We would like to mention that the fabrics for the front are made of wool and wool-like and those for the lining are made of viscose.

The physiological characteristics of the types of fabrics for the front, the linings and the reinforcements are based on the documentation from the Faculty of Textiles, Leather and Industrial Management, ‘Gheorghe Asachi’ Technical University of Iasi, but in this paper the values are hypothetical. Using programming with multiple objective functions, the situation considered by us can be transcribed mathematically, as follows:

Let’s consider x_i, i = 1...5 materials for the front, each having an air flow resistance (*Ra*), a vapour resistance (*Rv*), a thermal resistance (*Rt*) and a unit production cost (Cu_{xi}).

Let’s consider z_k, k = 1...2 materials for the reinforcement having *Ra*, *Rt*, *Rv* and Cu_{zk}.

Let’s consider *yj*, *y* = 1...3 materials for the lining, also having *Ra*, *Rt*, *Rv* and Cu_{yj}.

The first objective function is to achieve this article at an as lower production cost as possible, without affecting its quality negatively.

Mathematically, this function is written:

$$\text{Min } (\alpha\, Cu_{xi} + \beta\, Cu_{yj} + \gamma\, Cu_{zk}) \qquad (1)$$

Being a jacket designed to be worn in the summer, the values of the three properties should attempt to reach a minimum, so the other three objective functions will be written:

$$\text{Min } \textstyle\sum_{i=1}^{n} Ra \qquad (2)$$

where:

Ra – air flow resistance of the materials used to make the jacket.

$$\text{Min } (Rv_{\text{int}} + \textstyle\sum_{i=1}^{n} Rv_{\text{strat}} + Rv_{\text{ext}} + Rv_{\text{aer}}) \qquad (3)$$

where:

Rv_{int} – vapour resistance in underclothing microclimate (0,2 mm·h·m^2/g);

$\sum_{i=1}^{n} Rv_{\text{strat}}$ – the sum of the resistances of the materials that make up the jacket to the passage of vapours;

Rv_{ext} – resistance to the passage of vapours towards the exterior of the outfit (0.2 mm·h·m^2/g);

Rv_{aer} – resistance of the equivalent air layer to the passage of vapours.

$$\text{Min } (\textstyle\sum_{i=1}^{n} Rt_{\text{strat}} + Rt_{\text{aer}}) \qquad (4)$$

where:

$\sum_{i=1}^{n} Rt_{\text{strat}}$ – the sum of the thermal resistances of the materials that make up the jacket;

Rt_{aer} – thermal resistances of the equivalent air layer.

The working data were processed using a software package written in PHP. A set of auxiliary tables was used, namely: the thickness of the ensemble – to calculate the thickness of each possible combination; the permeability of the ensemble – to calculate the air permeability of each combination and their air permeability coefficient; the combined production cost – the cost resulting from the weighting according to specific component material consumption; the combined score – the weighted score obtained by each possible combination in relation to the specific resistances and the production cost; the air flow resistance, thermal resistance and resistance to the passage of vapours – each possible combination.

The tables contain a ‘scoring’ field that was obtained by applying the following working rule: ‘minimal resistance = maximum score’.

This data structure is flexible and supports a wide range of processing and subsequent extensions.

We used the following algorithm for solving it:

Step 1: we gave a code to each possible combination of the three types of materials (the fronts, the reinforcements, the linings) by joining their current numbers from table 1 (for example, code 513 – is a combination of the front having number 5, the reinforcement no. 1 and the lining with number 3). By combining all the materials shown in table 1 taken by threes, 30 possible variants resulted (5 × 2 × 3).

Step 2: with the help of the formulas in table 1 we determined the values of the characteristics of the fabrics necessary for making the article ‘jacket for men’ for all 30 combinations.

Step 3: as the article is designed to be worn in the summer, all the three resistances (*Ra*, *Rv* and *Rt*) should attempt to a minimum. Therefore, these resistances have been ranked in the ascending order of their value, considering that the best combination is the one that has the lowest values of these resistances. Each combination was given a score between 1 and 30 points, as follows: 30 points were awarded for the combination with the lowest value; then, decreasingly, down to the combination with the highest value, which has been awarded 1 point.

Step 4: for each combination we gathered the points obtained from each of the three resistances (*Ra*, *Rv* and *Rt*) that are to be weighted with their degree of importance in determining the physiological comfort (thus, 20% thermal resistance, resistance to and the passage of vapours and the air flow resistance with equal importance, i.e. 40% respectively [12]).

Table 2

Ranking by scores of the 30 combinations	
Ensemble code	**Ensemble score**
213	21
212	21
222	20
313	20
312	20
211	19
223	19
323	19
322	18
221	17
311	17
112	17
413	17
412	17
113	16
321	16
122	16
123	15
423	15
422	15
111	14
411	14
121	12
512	12
421	12
513	11
523	10
522	10
511	9
521	7

Table 3

Ranking by production cost of the 30 combinations	
Ensemble code	**Production cost ensemble**
313	432.69
323	433.24
311	435.88
321	436.43
312	437.47
322	438.02
113	454.14
123	454.69
111	457.33
121	457.88
112	458.92
122	459.47
513	503.64
523	504.19
511	506.83
521	507.38
512	508.42
522	508.97
213	525.09
223	525.64
211	528.28
221	528.83
212	529.87
222	530.42
413	534.99
423	535.54
411	538.18
421	538.73
412	539.77
422	540.32

Table 4

Ranking by cost/score ratio of the 30 combinations	
Ensemble code	**Cost/score ratio**
313	21.63
312	21.87
323	22.80
322	24.33
213	25.00
212	25.23
311	25.64
222	26.52
112	27.00
321	27.28
223	27.67
211	27.80
113	28.38
122	28.72
123	30.31
221	31.11
413	31.47
412	31.75
111	32.67
423	35.70
422	36.02
121	38.16
411	38.44
512	42.37
421	44.89
513	45.79
523	50.42
522	50.90
511	56.31
521	72.48

The results were ranked in a descending way regarding the points obtained, considering that the best combination is the one with the highest score (table 2).

Step 5: determining the cost of production for each of the 30 combinations according to the equation (1), considering the above mentioned unit consumptions (α, β, γ).

The 30 combinations are reordered in an ascending order, considering that the best combination is the one that has the lowest production cost (table 3).

RESULTS AND DISCUSSIONS

Analyzing the data from table 2, we find that if the confection manufacturer wants to have an assortment range of jackets physiologically balanced, the best combinations of materials are 213 and 212 that meet the maximum points.

Conversely, if the manufacturer wants to have an assortment range of jackets optimized from the production cost point of view, the best combination is 313 (table 3).

Regarding the structure of the production cost in general, herein specifically for the article 'jacket for men', we would like to mention that this is up to the manufacturers according to their informational needs and the specific of their business. Each structure has its advantages and its disadvantages. In order not to charge very much the volume of this paper, we would just like to recommend the use of the structure on items of calculation, which, in our opinion, greatly facilitates the calculation of costs and makes it less expensive.

However, for a confection manufacturer it is not sufficient to produce articles only physiologically balanced. We have to find the combination that best responds to both physiological requirements and to those related to the size of the production cost. For this we calculated, separately for each combination, the ratio of the production cost and the score obtained for the physiological properties (table 4).

The best combination, from this point of view, is the one whose ratio has the lowest value, i.e. the production cost tends to a minimum and the score to a maximum. This requirement is met by the combination 313 with the front made of material C, the reinforcement made of material M, and the lining made of material R.

CONCLUSIONS AND RECOMMENDATIONS

In order to have an outfit balanced from the physiological point of view, the manufacturer should start from choosing the materials/fabrics necessary for making the articles and take into account the separation of the expenses regarding the production activity from the expenses made for the rest of the activity carried out by the producers of textile confections.

For an outfit to be balanced from the physiological point of view it is imperative that the main physiological properties to be included in optimal proportions, so as to ensure physiological comfort.

Then, not following the recommendation regarding the separation of expenses entails the deviation of the costs from the reality and distorts the economic and financial situation. In addition, the action of determining the cost plays a special role because of the functions this economic indicator performs in order to optimize the decisions.

To achieve the objective of this paper, we used mathematical programming with multiple objective functions, which consisted in choosing the optimal alternative from a finite set, alternatives compared to each other in relation to a number of criteria. The result was a possible model that we recommend for optimizing any assortment structure of textile confections and not only.

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The contribution of clusters to increase the competitiveness of the textile and clothing industry. Cluster analysis using location quotient method

NICOLETA ASALOŞ MARIUS IORDĂNESCU

REZUMAT – ABSTRACT

Contribuția clusterelor la creşterea competitivitaţii industriei textile şi de confecţii. Analiza acestora prin metoda coeficientului de localizare

Sectorul industrial de textile-confecţii este o parte importantă a industriei europene, jucând un rol crucial în economie şi în bunăstarea socială a multor regiuni din Europa. A fi competitiv pe o piaţă specifică înseamnă practic a fi productiv, eficient, să obții produse de calitate, un management modern axat pe obiective și strategii. Creşterea competitivităţii în industria textilă şi cea de confecţii nu trebuie privită ca un proces ce exploatează avantajele pe termen scurt, ci ca un proces de creare a unei structuri economice bazate pe investiţii în capital şi cercetare-dezvoltare-inovare-procese. De aceea, lucrarea îşi propune să prezinte stadiul actual de dezvoltare al industriei textile şi de confecţii din Romania şi Europa, beneficiile clusterelor în stimularea printr-o politică strategică la nivel naţional a creşterii competitivităţii în industria textilă şi cea de confecţii, o analiză scurtă a clusterelor româneşti din industria textilă şi cea de confecţii şi propune un model de analiză pentru a identifica astfel de potențiale aglomerări economice şi pentru a evalua mărimea clusterelor funcţionale la nivel naţional în cadrul acestor industrii.

Cuvinte-cheie: clustere, competitivitatate, cercetare-dezvoltare-inovare, avantaj competitiv, metoda coeficientului de localizare

The contribution of clusters to increase the competitiveness of the textile and clothing industry. Cluster analysis using location quotient method

The textile and clothing sector is an important part of the European manufacturing industry, playing a crucial role in the economy and social well-being in many regions of Europe. Being competitive on a specific market is synonymous with being productive, efficient, obtaining quality products, a modern management focused on objectives and strategies. The increase of competitiveness in textile and clothing industry should not be regarded as a process of exploiting the advantages on a short term but as a process of creating an economic structure based on capital investments and research-development – innovation processes. Thus, this paper proposes to present the current stage of the development of the textile and clothing industry in Romania and Europe and to emphasize the benefits of stimulating clusters through a strategic policy at the national level, in order to increase competitiveness in textile and clothing industry, it also conducts a short analysis of the Romanian clusters in textile and clothing industry and proposes a model for the analysis in order to identify such potential economic agglomerations and also to evaluate the size of functional clusters at national level in these industries.

Keywords: clusters, competitiveness, research-development-innovation, competitive advantage, LQ method

INTRODUCTION

In the early years after 1989, developments in the textile industry were dominated by the collapse and closure of the production capacity in the textile industry, which led to a decrease in the economic share of this sub-sector.

The textile industry continues to have a significant role in the European economy and its decline will have a serious impact on the EU economy. The concern is caused by the production of textiles in Western Europe because it competes directly with the regions outside the EU, which have a cheaper labor force. Moreover, in terms of the environmental standards, these regions are more relaxed or, in some of them, these standards do not exist at all. Thus, EU producers should find alternative ways in order to survive. At the same time, the strong points held so far are not sufficient prerequisites for competitive advantage [1]. Clusters are a category of economic areas, as well as the main actors in the operation of their firms that are specialized in a field/industry in which innovation is the engine of competitiveness and the development of such companies [2]. The advantages offered by specialization, explained by the theories of absolute advantage [3] and of comparative advantage [4], and later by the theory of factor endowments, have been overtaken and adapted to the company level. The theory of absolute advantage brought for the first time to attention the possibility for a country to produce a certain product cheaper than another country. In this case, the countries' specialization in the production of goods with smaller costs and the trade of the production surplus was beneficial for both countries. Although it represented a major step in demonstrating the benefits of specialization, Adam Smith's theory could not offer the same perspectives for the countries that did not possess an absolute advantage for any category of products. From this situation, in 1817, David Ricardo demonstrated that specialization is possible and beneficial even when a country does not possess an absolute advantage in the production of any goods. Resources should be allotted to those goods whose production is cheaper and whose export can bring benefits to both countries. This was a major demonstration, which laid the basis for the theories developed later, regardless of the fact that they confirmed, enriched or contradicted the hypothesis of the comparative advantages theory. The first economist who described the clusters from the "chain of suppliers" perspective was Alfred Marshall who, analyzing the industrial agglomerations in England, found out that these geographical concentrations of enterprises from a specific sector create involuntary positive economic effects [5]. The essence of the cluster concept has its roots in what Marshall, as far back as 1890, called "externalities of specialized industrial locations". Somehow paradoxically in the current context of increasingly globalised markets, firm location and interdependence are significant explanations of their competitive performance according to cluster theory. At the beginning of the 20th century, two Swedish researchers, Ohlin and Hecksher, argued that the difference between countries is given by the production factors, and the products are different because of the production factors incorporated. According to the model (Ohlin – Hecksher factor proportion theory), a country holds a comparative advantage and thus will export the product that incorporates the abundant production factors in other countries.

Thus, the more abundant a production factor is, the cheaper it becomes. Therefore, the difference in the production factors is given by the difference in their prices, generating the competitive advantage.

The clusters and especially their policy are the attribute and the responsibility of the local, national and European political and decisional factors and the global crisis is a proof in this sense; however, they can also be a catalyst and the motivation of collaboration within an innovative and entrepreneurial society.

A BRIEF IMAGE OF DEVELOPMENT AND COMPETITIVENESS IN ROMANIAN AND EUROPEAN TEXTILE AND CLOTHING INDUSTRY

Historically, the Romanian textile and clothing industry was highly concentrated in Transylvania. However, during the 1970's it spread to most major cities. Factories typically employed thousands of workers with the largest one in Bucharest employing around 16,000 workers. By 1989, the industry was the country's largest employer. If, after 1990, the textile and clothing industry experienced a decline, the clothing industry has seen since the mid-1990s a remarkable growth, supported by the development of the production and the increase in exports, contributing to the European clothing markets. The lohn is a type of international agreement, widely practiced in countries with cheap labor force, whereby a producer undertakes to execute a product ordered by a beneficiary in return for remuneration. Within outsourcing operations, the importing company usually sends all necessary textiles (fabrics, jersey), design, technical documentation, clothing accessories, and the manufacturer within the partner country often contributes only with the workmanship to the making of the clothing and knitwear [11].

Since 2005, the changes in global trade agreements have resulted in a decline of the Romanian industry of textiles and clothing products. On 1 January 2005, the validity of the agreement ceased for textiles and clothing and hence there was a radical change in international trade through the complete liberalization of trade and the elimination of any quantitative restrictions. In the review of the Romanian textile industry, there has been used the cluster definition given by Porter (1998), as this sector is considered a traditional one, where the geographical proximity is important.

In 2011, the textile and clothing sector has achieved the following weights in macroeconomic indicators:

- 2.49 % of GDP, of which 0.76% for textile and 1.73% for clothing;
- 3.78 % for industrial production;
- 7.88 % for Romanian exports;
- 6.03 % for Romanian imports;
- 13.76 % – the average number of the employees in industry;
- 5,428 company assets.

Romania lies at an average level of competitiveness, being disadvantaged in terms of the availability of raw materials in its production and of the degree of technical and technological equipment in spinners, weaving and finishing workshops**.** Regarding the value added/employee, Romania occupies the penultimate place, before Bulgaria (under 30% of the EU-27 average), the value added tax being calculated on the total wage cost in excess of the EU average in industry for the production of textiles and clothing. Compared to the country with the highest value added/employee in the EU, Romania shall not exceed 12% of its performance. Romania also has a very small share in the EU turnover with regard to the number of the employees in this industry. This is due to an incomplete added value chain, the missing links having the greatest potential contribution. A study [6] published by DG Enterprise and Industry at the end of 2012 reveals that, among the EU countries, Romania has the largest untapped export potential in the textile and clothing industry, about 15% of the EU's entire untapped potential. On a short term, the low level of pay can be considered a competitive advantage, although this aspect has a negative impact on the competitiveness of these industries.

Effective measures are required on the medium and long term in order to harness the untapped potential and increase the complexity of the products. Textile and clothing industry still plays a major role in terms of the offer of employment and ensure a high employment rate. According to official statistics, in 2013, the average number of the employees in the textile industry and clothing products was more than 27 thousand, most of them women; it was lower by over 11,000 people compared to 2008.

Textiles and clothing are among the sectors with a major contribution in regional exports. In 2013, the total value of the export of the goods from the two branches amounted to over 626 million EUR, having increased by 30% since 2003. Although the export of textiles and clothing products has increased in absolute values, the number of those 2 industries dropped substantially in the last 10 years, from 26.6% in 2003 to just 9.2% in 2013, remaining, however, over the share recorded at the national level (7.5% in 2013). The future development of the intelligent textile and clothing industry should consider a strategic shift, by moving the emphasis from the production based on high quantities and a low added value to the production based on innovation. At the same time, measures should be taken in order to stimulate the development of design activities and the use of new textile materials. The solid tradition and knowledge acquired in the field and the high quality of the products are the strengths of the regional textile industry. These strengths can be coupled with a much better use of the resources of creativity and the untapped potential in this area. A better organization of economic actors, including through the formation and development of clusters in this area, would facilitate the transition to a qualitatively higher stage and should allow the maintenance of textile and clothing industry in the competitive sectors. In 2013, the European textile market had an income of 190 billion euro and in 2010, it had an income of 172 billion euro. The largest textile market segment is represented by the casual wear – with a share of 36.7% of all textiles – and the next place is occupied by the textiles, with a share of 35.4%.

The increase of the international competitiveness on the market belongs to the new “players” such as China; the companies in Europe must be aware that the basis of competition is not represented only by the low price. In order to face the challenges, they must develop certain skills, such as flexibility. The customer’s needs should prevail, as well as the importance of the speed of the response to requests, from producers to users. Manufacturers’ focus on the niche markets is an asset owned by the Europeans because they are hardly satisfied; most often, these markets are focused on product customization, but at small series. The access to these markets of the manufacturers-competitors from China is difficult because the response speed, quality, and innovation are key features of this market. Although, at present, the textile and clothing industry in Europe is not competitive in terms of production costs, the solution found by the major manufacturers is the outsourcing, in order to optimize production. It also benefits from the ability of European producers to anticipate their customers’ needs, which are increasingly difficult to satisfy [7]. According to the data from 2013, there were 185,000 companies in the industry, employing 1.7 million people and generating a turnover of 166 billion EUR. The sector accounts for a 3% share of value added and a 6% share of employment in the total manufacturing in Europe. In the EU-28, the biggest producers in the T&C industry are the 5 most populated countries, i.e. Italy, France, UK, Germany and Spain, accounting for about three quarters of EU-28 production of textiles and clothing. Southern countries such as Italy, Greece and Portugal, and some of the new Member states such as Romania, Bulgaria and Poland and, to a lesser extent, Spain and France, contribute more to the total clothing production, while northern countries such as the UK, Germany, Belgium, the Netherlands, Austria and Sweden contribute relatively more to the textile production. At the same time, globalization and technological progress led to rethinking the textiles and clothing industry's clustering strategy. While still playing an important role for some activities, cooperation at local, district or regional level has increasingly proved inadequate to ensure that the chain of production remains at close geographical proximity to the Pan European area. The EU textile and clothing industry is a leader in world markets. EU exports to the rest of the world represent more than 30% of the world market while the EU Single Market is also one of the most important in terms of size, quality and design. The European Commission works to ensure a level-playing field in international trade. It does this at multilateral level through the application of World Trade Organization agreements, at bilateral level, through negotiations on Free Trade Agreements, and via dialogues such the Euro-Mediterranean Dialogue on the textile and clothing industry, and bilateral dialogues with Colombia and China. The leading world role of the EU textile and clothing sector is attributed to its high-end specialization, its flexibility, the continuous adaptation of its structure to the market, and the development of products that address new needs (such as technical textiles for industrial uses). Because of this, and despite a negative trade balance, the sector increased its exports by 13% in the past few years, while imports have increased by 4%. The textile and clothing industry is a very global industry, with constantly increasing trade flows all over the world. The increasing importance of markets in emerging economies and the development of new uses and product applications in areas such as aerospace, medicine, construction and architecture, automobile, transport and personal protection, makes the need for better access to non-EU markets more important than ever.

THE ROLE AND THE BENEFITS OF ROMANIAN CLUSTERS IN INCREASING THE COMPETITIVENESS OF THE TEXTILE AND CLOTHING INDUSTRY

Clusters represent a solution successfully tested in Europe over the past decade, being considered today the central pillar of local development and competitiveness. Michael Porter’s economic theory was the starting point in the implementation of the cluster and regional competitiveness pole concept. He defines the "cluster" as an economic concentration of enterprises, small and medium sized enterprises, especially, on a given geographical area, interconnected with its own cores of research, professional training centers, specialized suppliers, in a certain field, that are in competition with one another but also in relations of cooperation. A competitive pole is a regional innovative cluster with national and international vocation or a cluster network [9].

The economic reality in Romania required the presence of a catalytic member. Cluster members retain their autonomy, acting at the same time, in partnership, in order to implement a common development strategy, built around innovative projects to serve the association as a whole and bring tangible benefits to all members. Clusters are a driving force in increasing exports and they are magnets for attracting foreign investment. Clusters also represent an important forum in which new types of dialogue can and must take place among companies, government agencies, and institutions, such as schools, universities, and public utilities [8]. The cluster concept has its origins in Marshall's cluster theory and its characteristics are triggered from the industrial agglomeration, setting the emphasis on the relationship between enterprises; furthermore, it has a structure in various stages of maturity. Therefore, the "cluster" term mainly indicates the industrial agglomerations and emphasizes the concentration of some enterprises in the same field or related fields with economic effects as identified by Marshall (labor force, specialization of suppliers, the technological transfer and innovation).

A widely accepted model is the "triple helix" that groups together, within a cluster, representatives from:

– enterprises – representing the economic side of the cluster;
– universities and research institutes – representing the providers of the innovative solutions applicable to the real needs of the enterprises from the cluster;
– local authorities, regional authorities, etc.

They can have a "triple helix" complete structure or not. The fundamental objectives of clusters are focused on:

– the establishment of partnerships between the stakeholders with expertise in clusters;
– the promotion of a global environment conductive to innovation;
– the availability of strategic research and development projects that would benefit from the support of public authorities.

The economic reality in Romania required the presence of catalytic institutions (entities specialized in the innovation and technological transfer, consulting firms, chambers of commerce etc.) within the pattern called "the Four Clover". The clusters in Romania have no legal personality. They are established based

Fig. 1. Triple Helix model cluster
Source: Etzkowitz, 2002 – The Triple Helix of University-Industry-Government: Implications for Policy and Evaluation

on a protocol of cooperation signed and sealed by all the members; however, the management association of the joint structure has a legal personality.

Regarding the clusters' policy, Romania is interested in the following:

– attracting foreign investment and investment funds in clusters, for the competitiveness of the clusters' members in Romania;
– exchanging experience with the entities which produce cluster policies and strategies;
– developing benchmarking clusters in partnerships;
– exchanging experience and best practices with other clusters, both in business and economic cooperation;
– including the Romanian clusters in cross-border and transnational networks;
– preparing cluster managers and study visits, economic missions, etc.;
– supporting the participation of Romanian clusters to Innovation Tours, fairs and international exhibitions, in order to promote regional brands;
– the international cooperation (public-private) in the creation of theme parks like Technopolis, Copernicus, etc.

The clusters thus formed will be the cores of competence, contributing, in the future, to the increase in the competitiveness of the regional business environment and to the development of initiatives, with the support of local public authorities, universities and other business and research support structures.

Cluster aims are:

– Stimulating innovation through information exchange and carrying out joint projects with immediate application in production;
– Creating new products with increased added value;
– Optimizing costs through process innovation and technology transfer between partners; Training and continuous development of human resources through joint programmes
– Adopting a joint marketing strategy designed to ensure the consolidation and extension of existing market share;
– Developing partnerships at regional and international level as eligible structures in research and development programmes;

– Protection of trademarks and industrial property rights;
– Creating more jobs better paid.

The benefits of belonging to a cluster structure are:

- Higher productivity, product quality and process know-how transfer;
- Increased workforce training and qualification through continuous training;
- Enlarged market share through participation in fairs and exhibitions and enhancement of own resources in a common commercial policy;
- Advice, steady information and direct access to innovations in the field;
- Developing new products and processes by accessing national and European funding.

Some of researchers have identified in Romania the incipient clusters from the textile and clothing products, as shown in table 1 [11–14].

For the time being, in the textile and clothing industry, Romania has developed 4 clusters established in Savinesti, Focsani, Bucharest and Sf. Gheorghe, all those situated in the South-East Region, the North-East Region, Bucharest-Ilfov Region and Center Region. These are represented in table 2.

According to the data submitted by the Romanian Cluster Association, only 3 clusters can be assessed based on quantitative indicators. Therefore, in 2013, these indicators were the following (see table 3).

Table 1

Empirical research	**Cluster or agglomeration to potentially become cluster (underachieving clusters)**
Ferrari (1999)	Focşani region
Majocchi (2000)	Timis and Arad
WEID Project (West-Eastern Industrial Districts, 2001 – 2004)	Timiş region
INCLUD Project (Industrial Cluster Development, 2003-2004)	NE region, especially Bacau Western region, especially Timis
Cluster Mapping Report (2010)	Bucharest (clothes, fashion) Timisoara (textiles) Piatra Neamt (also in NE, clothes and footwear)
Watermode Project (2011), quoting as source the Ministry of Economy, Commerce and Affairs, Department of Industrial Policy and Competitiveness (2010)	Savinesti Bucharest

Table 2

NO.	CLUSTER NAME	FIELD OF ACTIVITIES	CITY
1.	ASTRICO -Cluster-	Textiles	Savinesti
2.	CLUSTER TRADITIONS MANUFACTURE FUTURE TMV SUD EST -Cluster-	Textiles	Focsani
3.	ROMANIAN TEXTILE CONCEPT -Cluster-	Textile - Clothing, Footwear	Bucharest
4.	TRANSYLVANIA TEXTILE & FASHION -Cluster-	Textile - Clothing	Sf. Gheorghe

Table 3

CLUSTER NAME	INDICATOR	UNIT OF MEASURE	VALUE
ASTRICO	Turnover	EUR	160,000,000
	Companies number	No.	19
	Exports	EUR	120,000,000
	Number of employees	No.	2591
ROMANIAN TEXTILE CONCEPT	Turnover	EUR	80,300,000
	Companies number	No.	28
	Exports	EUR	69,650,000
	Number of employees	No.	3042
TRANSYLVANIA TEXTILE & FASHION	Turnover	EUR	1,600,000
	Companies number	No.	13
	Exports	EUR	1,668,287
	Number of employees	No.	128

The values show very clearly that the most powerful textile cluster in Romania is Astrico Textil Regional Cluster. It was conceived as an industrial group, in 2007, in order to promote the interests of seven textile companies in the North-East Region, with knitting production and marketing activities; these companies include RIFIL SA, a well-known company that is supported to bring credibility to the new entity [10]. The other members are also successful companies in the textile-clothing sector, as described in a business directory drawn up at the country level by the regional Chamber of Commerce and Industry. The capital of these members is entirely private and the association **ASTRICO NORD-EST** is chaired by a Managerial Board, appointed by the General Assembly. The association members have invested heavily in technology, resulting in a competitive price-quality ratio, based on a core of professional and stable staff. At the same time, all legal requirements on labor contracts (both individual and collective), the health and safety rules, as well as the hygiene and sanitary requirements, and environmental protection standards are met. Besides their highly competitive technical component, there is a strong concern to make new products according to market trends. Thus, in recent years, **Astrico** has carried out several projects in collaboration with well-known designers, in order to promote the raw materials and products made by the group members. In addition, there are strong creative departments, and some members of the group have managed to promote their own brands, especially on the domestic market. In 2010, **ASTRICO N. E.** has set forth a partnership with the North-East Development Agency, "Gh. Asachi" Technical University from Iasi – the Faculty of Textiles, Leather, and Industrial Management, the National Research Institute – Textile and Leather Development, and Inno Consult SRL, in order to create a "textile cluster" in the Northeastern region. Thus, **Astrico Nord Est textile cluster** was born. The goals of this partnership are to strengthen the already existing relationships relative to pre-service as well as to in-service training, i.e. undergraduates and specialists, respectively, as well as to identify all opportunities, in order to achieve high added-value products, through technology transfer and applied research. Currently, **Astrico Nord Est** Association deals with the executive management of **Astrico Nord Est cluster**.

Regarding the actions taken to increase productivity, the members of clusters have invested in technology, in order to achieve a competitive price-quality level, and in specialized human resources, in order to strengthen a core of professional and stable staff.

LOCATION QUOTIENT METHOD – A BASIC TOOL IN EVALUATION OF DEGREE OF CONCENTRATION, IDENTIFYING AND ANALYSIS THE CLUSTER STRUCTURES

The location quotient is a useful tool for comparing area characteristics. It has applications in areas such as health care and economics [18]. Location quotient (LQ) is a technique that allows for the comparison of local area characteristics such as employment rates to the national characteristics [19]. This technique has been widely used by economic geographers and regional economists since 1940 [20–21].

The location quotient is a method that quantifies the degree of concentration of an industry/sector/area in a given region at the national profile. This quotient can be used in cluster analysis, in order to identify potential agglomerations of economic clusters. It must reflect the degree of concentration of the relevant domain that shows whether there is potential in this region for the formation of such mergers based on the competitive advantage of the region, in terms of the specialized workforce in that area, the capacity for innovation and the innovative companies in the area of concentration, etc. Since 2000, some researchers have used location quotients to identify spatial concentrations of industry and high location quotients are interpreted as an indicator of a cluster [22].

This coefficient basically reports the share of the employees in a particular field at regional level to the share of the employees in that area at national level. The formula is as follows:

$$LQ = \frac{R1/R2}{N1/N2}$$

$R1$ – number of employees in region y in sector x;
$R2$ – number of employees in region y;
$N1$ – number of employees in sector x at national level;
$N2$ – total employees at national level.

By developing this calculation formula and by interpreting it, we can calculate this coefficient also by reporting the population employed at the regional level to the national profile. In addition, in the cluster analysis, we believe that the formula used in order to quantify its degree of concentration and specialization at regional or national level may be

$$LQ = \frac{C/N1}{R1/R2}$$

C – no. of the employees of a cluster;
$N1$ – no. of the employees in the field x at national level;

or at national level:

$$LQ = \frac{C/N1}{N1/N2}$$

Location Quotient method is thus a way of quantifying how concentrated an industry is in a region compared to a larger geographic area and how is that industry capable to generate potential cluster agglomeration in that region.

The localization coefficient can take values between 0 and 1 or greater than 1. The more the value is closer to 1 or higher, the more we can speak of a better concentration of the employees of that area within the region. This can practically generate potential clusters in the region, in the field with a LQ value greater than 1.

In order to illustrate the usefulness of the *LQ* method in identifying the potential clusters in the textile and clothing industry in Romania, we calculated the *LQ* on four regions where the four textile clusters are already located since 2011, based on data from Statistical Yearbook in the same year. It is noteworthy that the regions also have a clustering potential in other sectors of the economy and in other industrial branches.

Therefore, the cluster potential can be identified by regions as follows:

1. North-East Region: agriculture, industry and construction (0.9 < *LQ* <1.5);
2. South-East Region: agriculture, industry, construction, trade, transport, tourism (09 < *LQ* <1.5), less in information and communications (*LQ* = 0.4);
3. Bucharest-Ilfov Region: information and communications, construction, trade, transport, tourism (1 < *LQ* < 2.8) are sectors with a very good concentration and that's why with a high potential of clustering; in industry, unfortunately, *LQ*=0.5 and the process to create clusters around our research field is at a low level.
4. Center Region: industry, construction, trade, transport and tourism (0.9 < *LQ* < 1.250);

Table 4

1. North-East Region						
Area	**Employed population at regional level (thousand pers.)**	**Employed population at national level (thousand pers.)**	**LQ**	**No. of employees at regional level (thousand pers.)**	**No. of employees at national level (thousand pers.)**	**LQ**
Agriculture	486	2 780	1.356	15	95	1.4
Industry	197.8	1 944	0.785	135.2	1 310.4	0.902
Constructions	73.1	705	0.802	37	346	0.933
Trade; repair of motor vehicles	143.7	1 134	0.983	94.6	808.9	1.022
Transport and storage	46.8	444	0.812	23.9	268	0.775
Hotels and restaurants	14.8	180	0.631	11.5	111.6	0.875
Information and communication	8.7	126	0.538	6.6	113.7	0.500
Other activities	221.30	1 927	irrelevant	199.2	1 527.4	-
Total	1 192.2	9 240		523	4 581	

Processing based on NSI data

Table 5

2. South-East Region						
Area	**Employed population at regional level (thousand pers.)**	**Employed population at national level (thousand pers.)**	**LQ**	**No. of employees at regional level (thousand pers.)**	**No. of employees at national level (thousand pers.)**	**LQ**
Agriculture	325.3	2 780	1.093	15.5	95	1.5
Industry	189.9	1944	0.909	147	1 310.4	0.993
Constructions	81.6	705	1.078	40.8	346	1.053
Trade; repair of motor vehicles	127	1134	1.049	92.9	808.9	1.022
Transport and storage	55.6	444	1.166	38.9	268	11.293
Hotels and restaurants	16.9	180	0.894	14	111.6	11.125
Information and communication	8.9	126	0.615	5.3	113.7	0.416
Other activities	185.7	1 927	irrelevant	161.6	1 527.4	-
Total	990.9	9 240		516	4 581	

Processing based on NSI data

Table 6

3. Bucharest-Ilfov Region						
Area	**Employed population at regional level (thousand pers.)**	**Employed population at national level (thousand pers.)**	**LQ**	**No. of employees at regional level (thousand pers.)**	**No. of employees at national level (thousand pers.)**	**LQ**
Agriculture	36,8	2 780	0,100	4,6	95	0,200
Industry	180,4	1 944	0,704	143,4	1 310,4	0,513
Constructions	154,9	705	1,671	93,7	346	1,280
Trade; repair of motor vehicles	231,7	1134	1,557	204,4	808,9	1,193
Transport and storage	74,1	444	1,250	62,3	268	1,103
Hotels and restaurants	26	180	1,105	23,9	111,6	1
Information and communication	69	126	4,307	66,1	113,7	2,833
Other activities	510,90	1 927	irrelevant	372,8	1 527,4	
Total	1214,80	9 240		971.2	4 581	

Processing based on NSI data

Table 7

4. Center Region						
Area	**Employed population at regional level (thousand pers.)**	**Employed population at national level (thousand pers.)**	**LQ**	**No. of employees at regional level (thousand pers.)**	**No. of employees at national level (thousand pers.)**	**LQ**
Agriculture	239,9	2 780	0,796	10,6	95	0,900
Industry	266	1 944	1,266	203	1 310,4	1,234
Constructions	67,5	705	0,881	39,6	346	0,920
Trade; repair of motor vehicles	143,4	1 134	1,172	92,8	808,9	0,914
Transport and storage	56,4	444	1,166	33,2	268	0,982
Hotels and restaurants	21,5	180	1,105	17,6	111,6	1,250
Information and communication	9,8	126	0,692	7,7	113,7	0,541
Other activities	195,10	1 927	irrrelevant	169,2	1 527,4	
Total	**999,60**	**9 240**		**573,7**	**4 581**	

Processing based on NSI data

Table 8

No.	**Cluster name**	**No. of employees**	**LQ Regional**	**LQ National**
1.	Astrico Textiles Cluster	3 031	3031/187000 : 135200/523000 = = 0.08	3031/187000:0,210 = 0,0771
2.	Cluster Traditions Manufacture Future TMV Sud Est	12 000	12000/187000:147000/516000 = = 0.2250	12000/187000:0,210 = 0,3052
3.	Romanian Textile Concept Cluster Bucharest	2 595	2595/187000:143400/971200 = = 0.0934	2595/187000:0,210 = 0,0657
4.	Transyvania Textile&Fashion	128	128/187000:203000/573700= = 0.0020	128/187000:0,210 = 0,0033

Similar, we can calculate *LQ* for each region from Romania or from other country in order to identify a cluster potential in a field or branch.
We will also examine the coefficient for locating the clusters of textile and clothing industries identified in Romania, in 2011, wherefore we have the data necessary in order to calculate their degree of concentration.
As shown in table 8, the LQ values are between 0 and 1, but slightly over 0, indicating a weak concentration and, therefore, the existing clusters are small and under the potential of the regions where they are located.

RESULTS

International trade in textiles and clothing has showed more dynamic growth in the last decade in terms of trends in the global production of textile and clothing products. The future development of the intelligent textile and clothing industry should consider a strategic shift, by moving the emphasis from the production based on high quantities and a low added value to the production based on innovation. The globalization and technological progress led to rethinking the textiles and clothing industry's clustering strategy.
Romania wants to become an economy that generates value at all levels, to increase the investments in research, development and innovation, taking the example of other countries that have succeeded because they have specialized and have created competitive advantages through innovation and thus increased their productivity and quality of life of their residents, i.e. competitiveness. Therefore, clusters in textile industry might be a long-term solution for increasing the exports turnover, attracting foreign investments, creating jobs and rising companies and state competitiveness.
Increasing the competitiveness of textile individual companies, provides macroeconomic benefits, some of which are: raising attractiveness of regions; increasing need-orientation of business supporting. Therefore, clusters contribute to further develop the regional competence and research infrastructure; securing employment and fostering entrepreneurship. Clusters represent a solution successfully tested in Europe over the past decade, being considered today the central pillar of local development and competitiveness.
The Romanian textile industry faces and assists to an internationalization of trade and production processes as well as to an economy based on knowledge and innovation, its benefits cannot be appealed, and in these circumstances the creation of clusters represents an approach that is ambitious for a country that still needs several pieces to complete the puzzle of functional open market economy. But in the absence of a government strategy, of public funds to support these structures, the identification of the clusters does not imply their functionality. Through clusters not only individual textile company can be supported but groups of companies, which represents a more promising approach in terms of the efficiency and potential impact of individual public support actions. As a result, the commercialisation of R&D results can be better ensured and SMEs can be better engaged into larger scale projects through cluster organisations. Thus, the challenge today for any industry is not to create more clusters but rather to create better, powerful and more sustainable ones, capable to create new jobs, added value and productivity for all the actors of clusters. Because for now, in Romania there are only 4 textile clusters the process of development of clusters in textile industry must be continued because these economic agglomerations are a driving force in increasing exports and are magnets for attracting foreign investment.
The quantitative analysis done by calculating the location quotient reveals that most Romanian functional clusters within these industries are small and justify the beginnings of this clustering phenomenon; however, the most important aspect is that there is potential. We should appreciate the initiatives of these entities that understood the benefits of clusters and implemented agreements on these economic concentrations, mostly without governmental financial support. The Romanian regional potential does not justify the weak existence of clusters because we have a fabulous potential that could form the basis for the identification of several clusters. As we seen, one of the roles of clusters is to increase the competitiveness of participants - individual companies and further more to provide macroeconomic benefits like raising attractiveness of regions. Romania needs to concentrate more companies from textile and clothing industry (because there is potential), to stimulate them and the local authorities also, through allocation of public funds, governmental programs to create and develop clusters in these industries for increasing the competitiveness of participants and regions. However, the disinterest of national, regional and local policies make these structures be poorly understood and developed as the state has a decisive role in creating these economic clusters; therefore, the benefits of the identification and operation of clusters are ignored.

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