Industria Textilă

ISSN 1222–5347 (1–62)

1/2014

Revistă **cotată ISI** și inclusă în **Master Journal List** a Institutului pentru Știința Informării din Philadelphia – S.U.A., începând cu vol. 58, nr. 1/2007/
***ISI rated** magazine, included in the **ISI Master Journal List** of the Institute of Science Information, Philadelphia, USA, starting with vol. 58, no. 1/2007*

Editată în 6 nr./an, indexată și recenzată în:
Edited in 6 issues per year, indexed and abstracted in:
Science Citation Index Expanded (SciSearch®), Materials Science Citation Index®, Journal Citation Reports/Science Edition, World Textile Abstracts, Chemical Abstracts, VINITI, Scopus

Recunoscută în România, în domeniul Științelor inginerești, de către
Consiliul Național al Cercetării Științifice din Învățământul Superior
(C.N.C.S.I.S.), în **grupa A** /
Aknowledged in Romania, in the engineering sciences domain,
*by the **National Council of the Scientific Research from the Higher Education** (CNCSIS), in **group A***

Sumar

Contents

Referenții articolelor publicate în acest număr al revistei INDUSTRIA TEXTILĂ/
Scientific reviewers for the papers published in this number:

Cerc. şt. dr. ing./*Senior researcher dr. eng.* SABINA OLARU
Cerc. şt. gr. III ing./*Senior researcher eng.* LILIOARA SURDU
Cerc. şt. mat./*Senior researcher mat.* MIHAI STAN
Ing./*Eng.* CONSTANȚA HULEA
Artist plastic/*Designer* ALEXANDRA MOCENCO
Ec./*Ec.* FLOAREA BUMBAȘ
Dr. ing./*Dr. eng.* CORINA MOGA
Prof. univ. dr./*Prof. univ. dr.* DOINA I. POPESCU
Dr. R. BEFRU BÜYÜKBAYRAKTAR – Turkey

Revista „INDUSTRIA TEXTILĂ“, Institutul Național de Cercetare-Dezvoltare pentru Textile și Pielărie – București

Redacția (Editura CERTEX), administrația și casieria: București, str. Lucrețiu Pătrășcanu nr. 16, sector 3, tel.: 021-340.42.00, 021-340.02.50/226, e-mail: certex@ns.certex.ro; Fax: +4021-340.55.15. Pentru abonamente, contactați redacția revistei. Instituțiile pot achita abonamentele în contul nostru de virament: RO25RNCB0074029214420001 B.C.R. sector 3, București.

Lucrare realizată în colaborare cu **Editura AGIR**, Calea Victoriei nr. 118, sector 1, București, tel./fax: 021-316.89.92; 021-316.89.93; e-mail: editura@agir.ro, www.edituraagir.ro

The influence of heat-setting process on physical properties of ribbon-type fancy yarns and fabrics produced from them

AYSE BEDELOGLU

REZUMAT – ABSTRACT

Influența procesului de termofixare asupra proprietăților fizice ale firelor fantezie tip panglică și ale materialelor textile realizate din acestea

În lucrare a fost studiată influența procesului de termofixare asupra proprietăților firelor fantezie tip panglică, obținute cu număr diferit de ace, și ale tricoturilor realizate din acestea. Odată cu creșterea numărului acelor de tricotat, s-au obținut fire fantezie mai groase, cu o capacitate mai mare de deformare și o pilozitate mai redusă, cu o mai bună rezistență la abraziune și o conductibilitate termică mai mare, precum și cu o creștere a masei pe unitatea de suprafață și a densității de volum. Din punct de vedere statistic, s-a constatat o influență semnificativă a procesului de termofixare asupra proprietăților firelor și tricoturilor tip fantezie, cu un coeficient de siguranță de 95% (α = 0.05). De asemenea, tricoturile din fire termofixate au prezentat o capacitate mai mică de absorbție a căldurii, conferind o senzație de căldură mai mare, în comparație cu alte tipuri de materiale.

Cuvinte-cheie: termofixare, fir fantezie tip panglică, material textil, proprietăți fizice

The influence of heat-setting process on physical properties of ribbon-type fancy yarns and fabrics produced from them

In this paper, the influence of heat-setting process on the properties of ribbon-type fancy yarns with different needle numbers and fabrics manufactured from them was investigated. With the increasing number of knitting needle, thicker fancy yarns, higher strain, lower hairiness and so, thicker fabrics and higher mass per unit area and volume density, better abrasion resistance and higher thermal conductivity were obtained. The influence of heat-setting process was statistically significant on fancy yarn and fabric properties at 95% confidence level (α = 0.05). Fabrics manufactured from heat-treatment applied yarns showed lower thermal absorptivity results giving warmer feeling compared to others.

Key-words: heat-setting, fancy yarn ribbon-type, fabric, physical properties

By providing fascinating colour and texture effects, fancy yarns create variations in aesthetic appearance of the fabrics and garments. Developments in the facts of fashion and design and in the inclination of society changed the textile sector and market, apparently and thus, opened windows for opportunities for manufacturing sector of fancy yarns and fancy doubled yarns. Recently, there is an increase in the interest of applications of fancy yarns. While the plain yarns exhibiting a uniformity in structure and applications have the great majority of the yarn production sector all the time, the size and value of the worldwide market for fancy yarns which are formed with mostly planned imperfections bIng more expensive compared top plain yarns, was determined by fluctuations of fashion and of seasons. General features of fancy yarns are strength, wear resistance, flexibility, comfort, stretch properties and suitability for a particular manufacturing or dyeing process [1].

The fancy yarns can be produced by using various techniques. Among them ribbon type fancy yarn can be produced with braiding, warp and weft knitting techniques by using different materials. They have a wide variety of application field including medical, upholstery, drapery, clothing and packaging. The parameters such as variation in machine constructions, number of feeding yarns, delivery and feeding speeds, needle number and alignment and loop densities determine the properties of ribbon type fancy yarns [1], [2].

Generally when polymer-based fibers are manufactured, they have some instabilities due to oriented semi-crystalline structures. These instabilities are imparted from fibers to yarns and fabrics resulting serious problems. The heat-setting process for textiles is an industrial thermal process occurred in either a steam atmosphere or a dry heat environment, and gives textile materials dimensional stability, bulkiness, wrinkle and temperature resistance. Moreover heat-setting affects the physical, chemical, optical and thermal properties of thermoplastic textiles [3]. Acrylic yarns with high-bulkiness are produced by blending unrelaxed and relaxed fibres in spinning. When a heat treatment (steam or hot water) is applied, fibers get over from strain and create bulkiness [4]. Shaikhzadeh Najar et al. (2005) [5] investigated the effect of shrinkable fibre blending ratio on bulk, shrinkage, tensile strength and elongation of high-bulk (steamed and dyed) and grey acrylic worsted yarns. It was stated that the specific volume and tensile strength of high-bulk acrylic yarns are more than those of dyed acrylic yarns but their shrinkage and elongation values are similar. Researchers suggested that maximum yarn (dyed and steamed) bulk; shrinkage and minimum yarn strength are obtained at about 40% shrinkable fibre blending ratio. Sardag et al. (2007) [6] investigated the effects of heat-setting conditions on the properties of twisted yarns. It was found that the tenacity, elongation at break (in per cent), and work of rupture of 30 tex and 20 tex yarns were enhanced thanks to heat-setting process. Çeven and Özdemir (2008) [7] studied the effects of vacuum steaming process parameters on the physical properties of chenille yarns which were produced with viscose and acrylic pile and core yarns in different yarns counts and fabrics. They reported that the physical parameters, like yarn count, twist, tenacity, elongation and work-of-break values were affected by the vacuum steaming process. Sarkeshick et al. (2009) [8] investigate the effects of dry steam heat-setting on the structure, properties and structural property relationship of industrially produced heat-setting BCF polypropylene yarns.

In the literature, there is a limited study about investigating properties of knitted fancy yarns and fabrics produced from them. Nergis (2002) [9] investigated the effect of the properties of the component yarns on the final count, tenacity at break and appearance of ladder-knit fancy yarns, and then, an expression was derived to determine the final count of these ladder type knitted yarns. It was reported that there is a good correlation between the measured and calculated counts which may be used for assessing the count of ladder-type knitted fancy yarns. Tvarijonavičienė et al. (2005) [2] investigated the effect of the knitting process and structural properties on the tensile behavior of ribbon-type knitted yarns. It was reported that the tensile properties of yarns depend on the tightness of the knits and affected by the processes of knitting and washing ribbon yarns. The theoretical and practical results of analyzes of ribbon-type knitted yarns and fabrics knitted from them were investigated in terms of structural parameters. Researchers proposed a method to calculate the linear density which is related to linear density of the initial yarn, stitch length and course spacing and a new geometrical model of the knitted loop shape for determining the area density and tightness factor of knitted fabrics from fancy ribbon-type knitted yarns [10]. Turay et al. (2009) [11] investigated the thermal comfort properties of fabrics produced from ribbon type knitted yarns and compared the results in terms of different raw materials and processing parameters. It was reported that thermal conductivity of the fabrics produced with thicker yarn structures increase and cold feeling was obtained at first touch. However warmer feeling was provided with yarns produced at higher drawing speeds. Çeven (2011) [12] investigated the influence of the centipede yarn parameters as filling in the woven fabric construction on the air permeability property of woven fabrics. It was reported that fabrics woven with the centipede yarns with higher chain number and band length had less air permeability than those with lower chain number and band length. An increase in centipede yarn linear density decreased the air permeability of the fabrics. It was also investigated that the effects of yarn production parameters (band yarn count and chain number) on drape and crease recovery behaviors of woven fabrics produced with centipede. It was concluded that the drape and crease recovery behaviors of the woven fabrics from centipede yarns were affected by the centipede yarn structural parameters. Higher chain numbers and coarser band yarns increased the drape coefficients and crease recovery angles of the fabrics [13].

There is a wide use of various fancy yarns; nevertheless, there is no research about investigating the influence of heat-setting process on structural and physical properties of ribbon-type fancy yarns and fabrics manufactured from them. The purpose of this study is to determine the main characteristics acrylic-based ribbon-type fancy yarns of knitted fabrics and to compare the test results by explaining the effect of heat-setting process on these materials.

MATERIALS AND METHODS

Materials used

The ribbon-type fancy yarns produced by using short staple acrylic fiber-based (100%) 30 N_e (~50 *Nm*, ~20 tex) ring yarns in 3 and 4 needles under the same conditions were obtained to investigate properties of yarns and fabrics before and after heat-setting procedure. Linear density of bright acrylic fiber in yarns was about 2.75 dtex having 115-130 mm length. Half part of the produced yarns was thermally fixed at 93°C for 35 minutes (Superba). The constructional features of ribbon-type fancy yarns and fabrics presented in table 1. The basic properties of produced yarns are given in table 2. By using these heat treated and untreated yarns, fabrics having plain structure were manufactured on a knitting machine (Stoll 320 TCC) with 0.8 m/s.

Table 1

BASIC FEATURES OF MANUFACTURED RIBBON-TYPE FANCY YARNS AND FABRICS

Codes	Yarn		Fabric	
	Type	***Process***	***Course,*** cm	***Wale,*** cm
A_1	3 needle	-	3	3
A_2	3 needle	Heat-treated	3	3
B_1	4 needle	-	3	3
B_2	4 needle	Heat-treated	3	3

Measurement methods of yarn and fabric characteristics

The linear density (yarn count), tensile, strain and hairiness measurements were performed for all of the heat treated and untreated ribbon-type fancy yarns. Linear density of all yarns was measured using standard test methods [14]. By using a strength tester

Table 2

THE TEST RESULTS OF MANUFACTURED YARNS AND FABRICS							
Codes	Yarn			Fabric			
	Count, tex	***Hairiness***, S_3	***Hairiness***, S_3, %	***Mass per unit area***, g/m^2	***Thickness***, cm	***Volume density***, g/cm^3	***Pilling grades***
A_1	226.96	6 262	12.99	430	0.30	0.145	3-4
A_2	248.23	2 167	8.91	315	0.26	0.121	4
B_1	317.44	8 745	14.52	554	0.33	0.169	3-4
B_2	340.89	2 231	8.12	437	0.30	0.147	3-4

machine (Instron 4411), the mechanical properties of heat-treated and untreated yarns were measured. Ten tests were performed for each type to obtain tensile and elongation values. Tenacity of yarns was calculated by dividing tensile values (cN) by yarn linear density (tex). Hairiness of ribbon-type fancy yarns was tested by using hairiness tester (Uster Zweigle Hairiness Tester 5) measuring 100 m length with a test speed of 50 m/min. and pretension of 5 cN. From hairiness results, S_3 hairiness (total hairs ≥ 3 mm) and S_3, % (percentage of S_3 in all hairs) was obtained. All measurements were performed in a laboratory under standard atmospheric conditions (20 ± 2°C temperature and 65 ± 2% relative humidity) [15]. Surface appearances and structures of produced ribbon-type fancy yarns were investigated by using Selectra stereo microscope. The magnification degree of microscope is 27.2.

By using balanced assay and fabric thickness tester, the weight and thickness of the fabrics were measured, respectively. Mass per unit area (g/m^2) values were calculated by dividing weight of fabric samples by the fabric area [16]. Fabric density values (g/cm^3) were obtained by dividing mass per unit area by fabric thickness (cm). In order to determine the influence of yarn structure and heat treatment on air permeability tests, fabrics were tested with an air permeability tester device (FX 3300 Tex Test Instruments Air Permeability Tester III) using 20 cm^2 test area under 100 Pa pressure [17]. Weight losses of fabrics were determined performing an abrasion test at 5 000 revolutions by using a Martindale pilling and abrasion tester [18]. The pilling resistance of the fabrics was determined using a Martindale pilling and abrasion tester [19]. Fabrics were rated for 2 000 revolutions. Afterwards, samples were evaluated according to EMPA Standard SN 198525 W2 (1 is being poor and 5 is being excellent).

Measurement of thermal properties including thermal conductivity, thermal resistance and thermal absorptivity measurements were performed with semi-automatic Alambeta device produced by Sensora. Alambeta device [20] determines the thermal resistance, thermal conductivity and thermal absorption values by simulating the dry human skin, to sense heat flow through the tested fabric thanks to different temperatures of two measuring plates. In the experiments, the measuring head temperature was about 32°C and the contact pressure was 200 Pa [21].

The percentage of yarn shrinkage was calculated according to give equation (1):

$$\text{Shrinkage} = \frac{N_{m0} - N_m}{N_{m0}} \times 100 \;\; [\%] \qquad (1)$$

where:

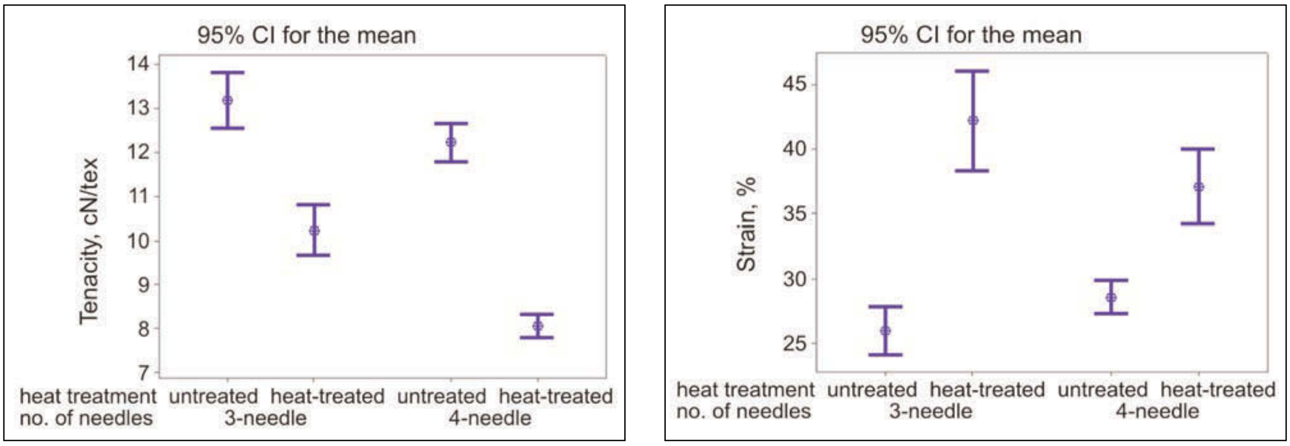
N_{m0} is grey yarn count;

N_m – the shrunk yarn count in metric system.

Statistical analyses were done to evaluate data obtained from measurement results of produced fancy yarns and fabrics. Variance analyses were performed for α = 0.05 significance level to get a 95% confidence interval. Correlations between yarn and fabric physical features were also evaluated. The related graphs (fig. 1 – 5) were drawn to describe ribbon-type fancy yarn and fabric test results.

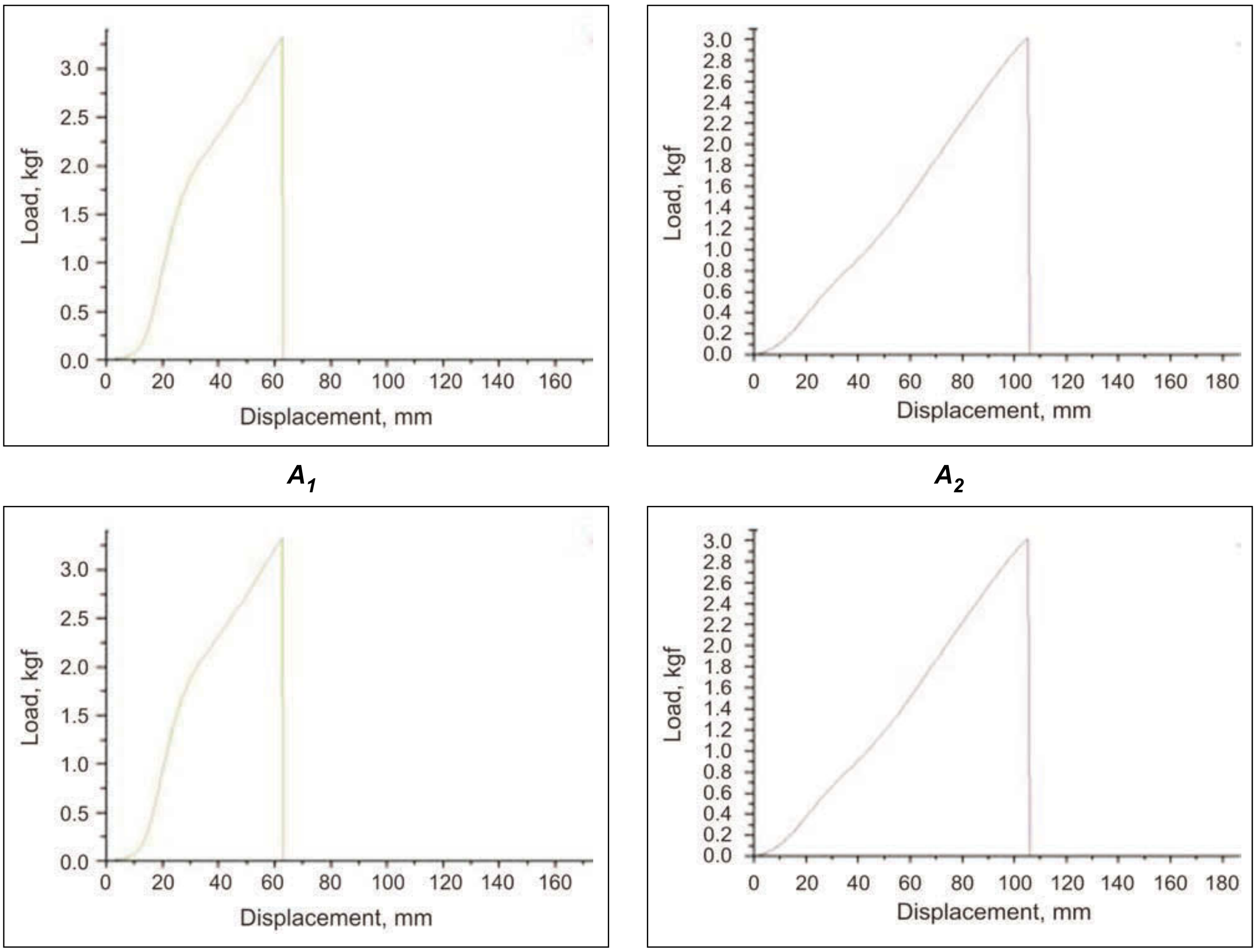
RESULTS OBTAINED

The effects of number of needles and heat-setting process on the yarn count and hairiness of ribbon-type fancy yarns are given in table 2. As can be seen from here, yarn count (tex) increased and hairiness (S_3 and S_3,%) decreased after heat-setting. S_3 hairiness was much higher in 4-needle yarns compared to 3-needle yarns in all cases. The graphs showing 95% confidence intervals for the means of tenacity and strain measurements of fancy yarns are given in figure 1. The effect of number of needles, heat treatment and number of needles* heat treatment is found significant on tenacity of fancy yarns. There is a statistically significant difference in tenacity means of fancy yarns in terms of number of needles and heat treatment. The effect of heat treatment and number of needles* heat treatment is found significant on strain of fancy yarns. The effect of number of needles is not statistically significant. There is a significant difference in strain means of fancy yarns in terms of heat treatment at α = 0.05 significance level. The tenacity and the strain of the yarns decrease with increasing number of needles. However the tenacity decreased and the strain of the yarns increased when heat-setting process was applied. After heat-setting



a *b*

Fig. 1. Confidence interval (95%) plot for the means of produced yarns:
a – the tenacity, cN/tex; *b* – stain, %



A_1 A_2 B_1 B_2

Fig. 2. Load-displacement graphs of heat treated and untreated yarns (selected randomly):
A_1 and B_1 are untreated; A_2 and B_2 are heat-treated yarns

process, yarn shrinkage was occurred 8.6% in 3-needle yarns and 6.9% in 4-needle yarns.

The graphs exhibiting the breaking behavior of heat-treated and untreated yarns are presented in figure 2. Different textile materials show different load-extension curves since they have different molecular structures in their fibers (Gupta, 2002). As can be seen from here, apparently, after heat treatment, since structures of yarns have changed, the extensions and shapes of the curves belonging to A_1 to A_2 and B_1 to B_2 have changed. Surface appearances and structures of produced ribbon-type fancy yarns are

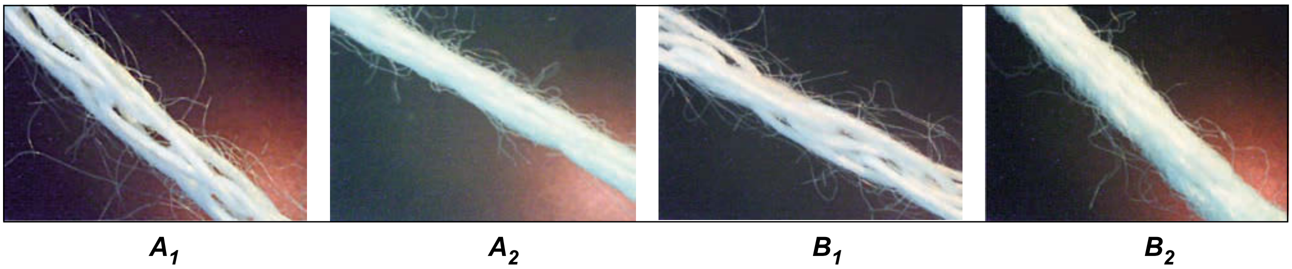


Fig. 3. Surface appearances and structures of produced ribbon type fancy yarns (27.2 X)

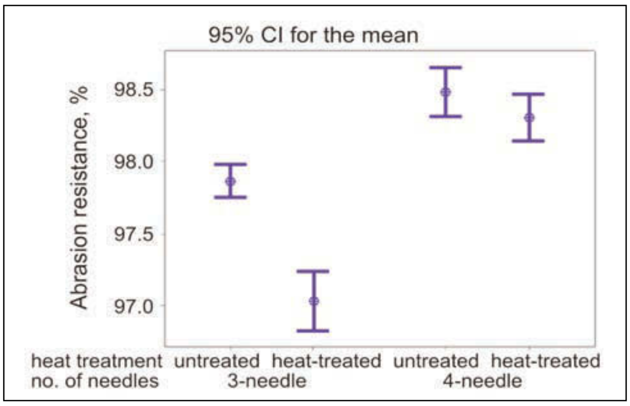
Table 3

MEAN TEST RESULTS OF PRODUCED FABRICS					
Fabrics	**Thermal conductivity**, W/mK	**Thermal absorbtivity**, $Ws^{1/2}/m^2K$	**Thermal resistance**, $m^2 \cdot K/W$	**Abrasion resistance**, %	**Air permeability**, mm/s
A_1	0.0474	103.34	0.0625	97.87	1 738
A_2	0.0431	89.10	0.0600	97.03	2 612
B_1	0.0479	101.04	0.0684	98.49	1 075
B_2	0.0448	88.14	0.0665	98.31	1 698

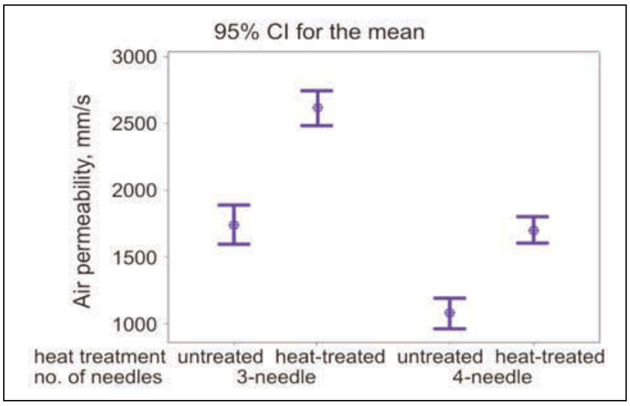
also given in figure 3. As can be seen from these images, yarns have gained full and bulky structure after heat-setting process.

The effects of number of needles and heat-setting process on the mass per unit area and volume density, thickness, pilling grades, abrasion resistance, air permeability and thermal properties of fabrics produced them are given in table 2 and table 3, respectively. As can be seen from here, the means of mass per unit area, thickness and volume density test results of fabrics made from fancy yarns decreased after heat-setting process. Pilling grades were also quite good. The graphs showing 95% confidence intervals for the means of abrasion resistance (%) and air permeability (mm/s) measurements of fabrics are given in figure 4. The effect of number of needles, heat treatment and number of needles* heat treatment is found significant on the abrasion resistance (%) and air permeability of fabrics. There is a statistically significant difference in abrasion resistance (%) and air permeability means of fabrics in terms of number of needles and heat treatment. Air permeability of fabrics increased, when heat-setting was applied. Results were much higher in fabrics made of 3-needle yarns compared to that of 4-needle yarns, since an increase in number of needles causes a thicker yarn and a more dense fabric structure. However, abrasion resistance was slightly decreased after heat-setting process and higher results were obtained from more compact fabrics made from 4-needle yarns.

The graphs showing 95% confidence intervals for the means of thermal properties' measurements of fabrics are given in figure 5. Thermal properties of fabrics were affected from heat-setting process. The effect of number of needles, heat treatment and number of needles* heat treatment is found statistically significant on thermal conductivity properties of fabrics. There is a statistically significant difference in thermal conductivity means of fabrics in terms of num-

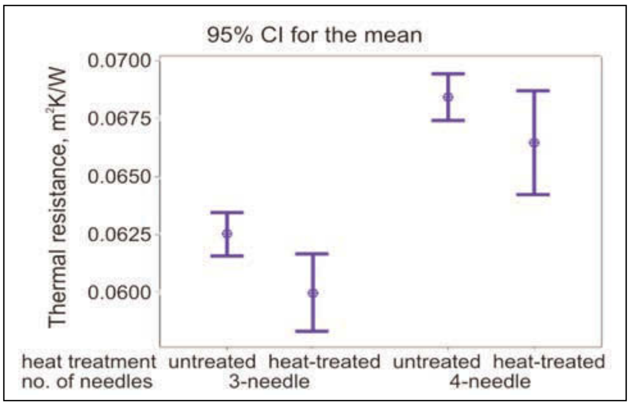


a

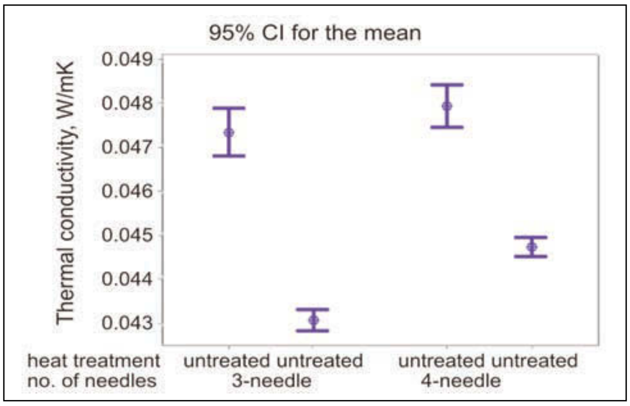


b

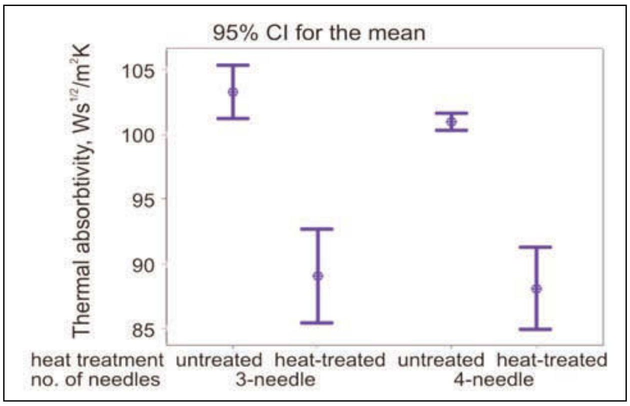
Fig. 4. Confidence interval (95%) plot for the means of fabrics made of heat-treated and untreated yarns of: *a* – abrasion resistance, %; *b* – air permeability, mm/s



a



b



c

Fig. 5. Confidence interval (95%) plot for the means of thermal properties of fabrics made of heat-treated and untreated yarns:
a – thermal resistance, $m^2 \cdot K/W$; *b* – thermal conductivity, W/mK; *c* – thermal absorbtivity, $Ws^{1/2}/m^2K$

ber of needles and heat treatment. It was observed that after heat-setting process, thermal conductivity slightly decreased. Fabrics made from 4-needle fancy yarns showed higher thermal conductivity results.

Thermal absorptivity value is directly related to fabric surface properties. Pac et al. (2001) [22] stated that warm-cool feeling of a fabric depend on the fibers, the yarn spinning method, and the fabric construction processes. Fabrics made from thicker yarns generally give colder feeling at first touch. The effect of heat treatment is found statistically significant on thermal absorptivity properties of fabrics. It was observed that after heat-setting process, thermal absorptivity dramatically decreased. There is a significant difference in thermal absorptivity means of fabrics in terms of heat treatment. However, the effect of number of needles and number of needles* heat treatment is not statistically significant. Fabrics made from 3-needle fancy yarns showed higher thermal absorptivity results. The effect of heat treatment and number of needles is found statistically significant on thermal resistance properties of fabrics. The effect of number of needles* heat treatment is not statistically significant. It was observed that after heat-setting process, thermal resistance slightly decreased. Due to their higher thickness, fabrics made from 4-needle fancy yarns showed higher thermal resistance results. There is a significant difference in thermal resistance means of fabrics in terms of heat treatment and number of needles.

CONCLUSIONS

The aim of this study was to investigate the effects heat-setting process on the physical and mechanical properties (yarn count, tenacity, strain, hairiness, percentage of shrinkage) of ribbon-type fancy yarns as well as on the mass per unit area and volume density, abrasion resistance, air permeability and thermal properties of knitted fabrics made from ribbon-type fancy yarns. After heat-setting process, higher yarn shrinkage was occurred in 3-needle yarns compared to 4-needle yarns. Heat-setting process influenced the properties of ribbon-type fancy yarns and fabrics made from them and its effect is statistically significant. Important features of yarns (hairiness and strain) and fabrics (abrasion resistance, air permeability and thermal absorptivity) were improved thanks to heat-treatment process. Especially, after heat-setting process, fabrics give warmer feeling at first touch. For further studies it will be useful to investigate the effect of heat-setting process on other properties of yarns and fabrics to explain the relations between textile structures and heat-setting process and to predict the final product properties.

ACKNOWLEDGEMENT

Prof. Dr. Yalcin Bozkurt (Dokuz Eylul University), Prof. Dr. Ayse Okur (Dokuz Eylul University), Assoc. Prof. Dr. Nilgun Ozdil (Ege University) and Ali Ayturan (Batik Örme) are acknowledged for their support.

BIBLIOGRAPHY

[1] Gong, R. H., Wright, R. M. *Fancy yarns: their manufacture and application*. Woodhead Publishing Limited Cambridge England, 2002

[2] Tvarijonavičienė, B., Mikučionienė, D., Čiukas, R. *Influence of knitting process conditions and washing on tensile characteristics of knitted ribbon yarns.* In: Fibres and Textiles in Eastern Europe, 2005, vol. 13, issue 4 (52), pp. 74-77

[3] Gupta, V. B. *Heat-setting.* In: Journal of Applied Polymer Science, 2002, vol. 83, pp. 586–609

[4] Wynne, A. *Textiles*. Macmillan Education, New Zealand, 1997

[5] Shaikhzadeh Najar, S., Etrati, S. M., Seyed-Esfahani, M. H., Hadi, H. *The effect of blend ratios, of unrelaxed and relaxed acrylic fibres on physical properties of high-bulk worsted yarns.* In: Journal of the Textile Institute, 2005, vol. 96, issue 5, pp. 311-318

[6] Sardag, S., Ozdemir, O., Kara, I. *The effects of heat-setting on the properties of polyester/viscose blended yarns.* In: Fibres & Textiles in Eastern Europe, 2007, vol. 15, issue 4 (63), pp. 50-53

[7] Çeven, E. K., Özdemir, O. *The effect of vacuum steaming parameters on the physical properties of chenille yarns.* In: Fibres & Textiles in Eastern Europe, 2008, vol. 16, issue 2 (67), pp. 35-40

[8] Sarkeshick, S., Tavanai, H., Zarrebini, M., Morshed, M. *An investigation on the effects of heat-setting process on the properties of polypropylene bulked continuous filament yarns.* In: Journal of the Textile Institute, 2009, vol. 100, issue 2, pp. 128-134

[9] Nergis, B. U. *Factors influencing the properties of ladder-knit fancy yarns.* In: Textile Research Journal, 2002, vol. 72, pp. 686-688

[10] Čiukas, R., Tvarijonavičienė, B., Mikučionienė, D. *Estimating the linear density of fancy ribbon-type yarns and the structure indices of fabrics knitted from them.* In: Fibres and Textiles in Eastern Europe, 2006, issue 14, pp. 41-43

[11] Turay, A., Özdil, N., Süpüren, G., Özçelik, G. *The effects of the production conditions of ribbon typed fancy yarns on the thermophysiological properties.* In: Tekstil ve Konfeksiyon, 2009, issue 4, pp. 280-285

[12] Çeven, E. K. *Influence of selected parameters centipede yarns on air permeability property of woven fabrics produced with these yarns.* In: Industria Textilă, 2011, vol. 62, issue 4, pp. 171–176

[13] Çeven, E. K. *Investigation of drape and crease recovery behaviors of woven fabrics produced from centipede yarns having different parameters.* In: Textile Research Journal, 2013, DOI: 10.1177/0040517513481874

[14] Saville, B. P. *Physical testing of textiles*. Woodhead Publishing Ltd. in association with The Textile Institute, Cambridge, 2000

[15] ASTM D1776-08e1. *Standard practice for conditioning and testing textiles*, 2008

[16] ASTM D3776/D3776M-09ae2. *Standard test methods for mass per unit area (weight) of fabric,* 2009

[17] ASTM D737-04. *Standard test method for air permeability of textile fabrics*, 2012

[18] ASTM 4966-12. *Standard test method for abrasion resistance of textile fabrics*: *Martindale abrasion tester method*, 2012

[19] ASTM D4970. *Standard test method for pilling resistance and other related surface changes of textile fabrics*: *Martindale tester*, 2010

[20] Hes, L. *Heat, moisture and air transfer properties of selected woven fabrics in wet state*. In: Proceedings of the 1st Textile Bioengineering and Informatics Symposium, Hong Kong, 2008, pp. 968-976

[21] ISO EN 31092-1994 *Textiles; physiological effects; measurement of thermal and water-vapour resistance under steady-state conditions (sweating guarded-hotplate test)*

[22] Pac, M. J., Bueno, M. A., Renner, M. *Warm-cool feeling relative to tribological properties of fabrics.* In: Textile Research Journal, 2001, vol. 71, issue 19, pp. 806-812

Authors:

AYSE BEDELOGLU
Department of Fiber and Polymer Engineering
Bursa Technical University
16190, Bursa, Turkey
e-mail: ayse.bedeloglu@btu.edu.tr; ayse.bedeloglu@gmail.com

The relationship between the bagging deformation and air permeability performance of woven fabrics

R. BEFRU BÜYÜKBAYRAKTAR

REZUMAT – ABSTRACT

Relaţia dintre deformarea țesăturilor în condiții dinamice și permeabilitatea la aer a acestora

În cadrul lucrării au fost efectuate studii experimentale pentru stabilirea efectelor deformării țesăturii în timpul utilizării acesteia asupra permeabilității la aer. Țesăturile cu diverse caracteristici structurale au fost deformate prin patru metode de încercare și testate pe un aparat Instron modificat. Proprietățile de permeabilitate la aer a țesăturilor au fost analizate înainte și la scurt timp după efecuarea testelor de deformare. Efectele au fost evaluate prin metode statistice, în funcție de parametrii de testare și de caracteristicile structurale ale țesăturilor. S-a constatat că proprietățile structurale ale țesăturilor au influențat caracteristicile de deformare și de permeabilitate ale acestora. Parametrii de testare, în special timpul de așteptare, au influențat gradul de deformare și valoarea permeabilității la aer.

Cuvinte-cheie: deformare, permeabilitate la aer, țesătură

The relationship between the bagging deformation and air permeability performance of woven fabrics

In this study, an experimental study was carried out in order to investigate the effects of bagging deformation of the fabric to the air permeability performance. In this study, a modified test apparatus was integrated to the Instron and fabrics having different structural properties were deformed by four different bagging test methods. The air permeability properties of tested fabrics were measured before and shortly after bagging deformation tests. The results were discussed depending on the effect of test parameters and structural properties of the fabrics by statistical methods. The results showed that the structural properties of fabric determined the deformation and permeability properties of the fabrics. The test parameters, especially waiting time, were effective at the deformation degree and increase of the air permeability.

Key-words: deformation, air permeability, woven fabric

Fabrics are exposed to long-term and repetitive forces during usage and these forces, such as compression, shear, tensile, bending and friction, cause deformation at the structural properties of fabrics which cause the change of the performance properties. Therefore, the deformation problem of a textile structure is an important research area for many scientists.

The bagging deformation of the fabric is an important property especially in clothing, because it affects the appearance of product. Besides it defines the usage performance of some technical fabrics. Bagging deformation of a fabric is occurred under a force normal to its plane, and it is a three dimensional deformation problem. Kawabata et al. denoted that the bagging was a complex biaxial tensile and shearing deformation of fabric [1]. In the researches, the bagging deformation of the textile was investigated by experimental and theoretical studies which analyzed the effect of forces, test periods, cycles, deformation types, degrees and the mechanical and structural properties of fabrics such as biaxial tensile properties of fabric, Poisson's ratio, viscoelastic behavior of fibers, weave type etc. [2] – [15]. On the other hand a few studies focused the change in the performance properties of fabrics after deformation. For instance, Verleye et al. (2008) noted that the shear properties of fabric play an important role in permeability [16]. In this study, it was aimed to investigate the change in the air permeability performance of fabrics after bagging deformation. Fabrics were deformed by different bagging deformation test procedures and the air permeability performance of the fabric was measured immediately after these deformation tests. The effect of cycle and relaxation were neglected. The results were discussed statistically according to test parameters and structural properties of fabric.

MATERIALS AND METHODS

In this study, the bagging deformation of the fabrics was investigated by two different test groups in order to analyze the effect of the structural parameters of fabrics. The first set of fabrics, called control fabrics, consisted of nine different cotton fabrics having three different weave types being plain, 2/1 twill and 3/1 twill weaves, and three different weft settings for each weave types. They were produced with same yarn count and warp setting in both warp and weft directions. By these control fabrics, the effect of deformation to the air permeability results of the fabrics was discussed easily according to structural properties of fabrics and test parameters. In the second test group, it was aimed to test different fabrics used in suiting in order to discuss the effect of bagging deformation on the air permeability results of commercial fabrics. The tested commercial fabrics were divided into two groups according to raw material. These were cotton and worsted commercial fabrics having different weave types, yarn counts and settings. The structural properties of fabrics for first and second test groups were given in table 1.

This study aimed to investigate the air permeability performance of the fabric after bagging deformation. Therefore the air permeability of the fabrics were determined before and after the deformation tests by using Tex test Air Permeability Tester FX 3300 Labotester III according to TS 391 EN ISO 9237 [17]. All tests were performed at standard atmosphere conditions.

A bagging testing apparatus was designed which was integrated to the Instron 4411 in order to provide the bagging deformation of the fabric samples as seen in figure 1. The bagging test apparatus consisted of two square metal plates which had a hole in the middles. The diameters of holes were 7 cm. This dimension was determined in order to ensure a bigger testing area than the testing area of air permeability tester which was 20 cm^2. The metal plates were coated with rubber to prevent the slipping or tearing of fabric. Before the deformation test, fabric sample was placed between these two metal plates. Then, the plates were compressed with screws at the corners to prevent the slipping of fabric during the test. During bagging deformation test, a load was applied onto the fabric up to a certain distance with a defined speed by using a sphere. The speed of the test was decided being 60 mm/min., according to literature [11]. In this study, bagging height was determined according to bursting test. Three repeat were done for each fabric samples and load-displacement curve was investigated. According to bursting test and some pre-trials with different bagging heights it was

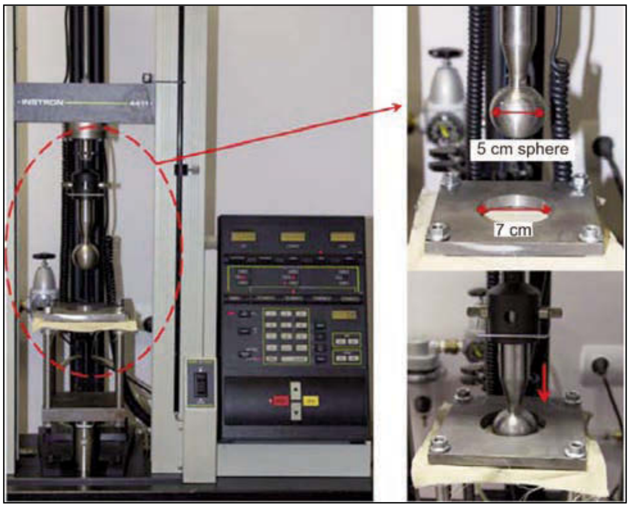


Fig. 1. Bagging test apparatus integrated to Instron

Table 1

STRUCTURAL PROPERTIES OF TESTED FABRICS

Fabrics	Fabric code	Raw material	Weave type	Mass per unit area, w, g/m^2	Warp-weft count, N_1, N_2, tex	Warp-weft setting, cm^{-1}
Control cotton fabrics	A_0	Co	Plain	148	30/30	36-14
	A_1	Co	Plain	163	30/30	36-18
	A_2	Co	Plain	175	30/30	36-22
	B_1	Co	2/1 Twill	158	30/30	36-18
	B_2	Co	2/1 Twill	171	30/30	36-22
	B_3	Co	2/1 Twill	186	30/30	36-26
	C_1	Co	3/1 Twill	161	30/30	36-18
	C_2	Co	3/1 Twill	186	30/30	36-22
	C_3	Co	3/1 Twill	190	30/30	36-26
Commercial cotton fabrics	P_1	Co	Plain	106	11/11	60-35
	P_2	Co	Plain	114	11/11	56-30
	P_3	Co	2/2 Twill	126	10/9	62-56
	P_4	Co	4/1 Twill	215	12/19	90-50
	P_5	Co	2/1 Twill	235	18/36	60-26
Commercial worsted fabrics	Y_1	Wo	Plain	122	20x2/15	35-28
	Y_2	Wo	Plain	143	30x2/19	28-24
	Y_3	Wo	Plain	159	26x2/20	34-28
	Y_4	Wo	2/2 Twill	205	30x2/24	38-30
	Y_5	Wo	2/1 Twill	260	25x2/26x2	58-32

Table 2

THE TEST PARAMETERS OF BAGGING DEFORMATION TESTS				
Test code	**Tested area,** cm^2	**Test dis-placement,** cm	**Sphere diameter,** cm	**Time,** min.
T_2	38.5	1.8	3	-
T_4			5	-
T_6			3	3
T_8			5	3

decided being 18 mm for all fabric types. Because, the higher values caused bursting of some samples and at the lower ones (for instance 12 mm) the residual deformation of tested fabrics was small for all samples because of being at the elastic region of the load-displacement curve.

In this study the effect of two different test parameters to the air permeability test results of deformed fabrics were investigated. These were the effect of sphere diameter and applied waiting time after the sphere reached defined displacement. The diameters of spheres were 3 cm and 5 cm, respectively. Two different test procedures were carried out for each sphere size according to waiting time of the load. In the first procedure fabric sample was deformed and then the fabric sample was taken off from the test apparatus immediately and the air permeability value of the sample was measured within one minute after the sphere reached defined bagging height. In the second procedure, fabric sample was waited 3 minutes under load after the sphere reached to the determined bagging height then the deformed sample was taken off and the air permeability was measured. The properties of four test methods were given in table 2. All tests were repeated for 10 times for each fabric types. The results of the study were discussed statistically according to test and fabric properties by one-way ANOVA test. Minitab 14 was used as statistical software.

RESULTS AND DISCUSSIONS

In this study, a comprehensive experimental study was performed in order to investigate the effect of bagging deformation to the air permeability results of the fabrics.

Control cotton fabrics

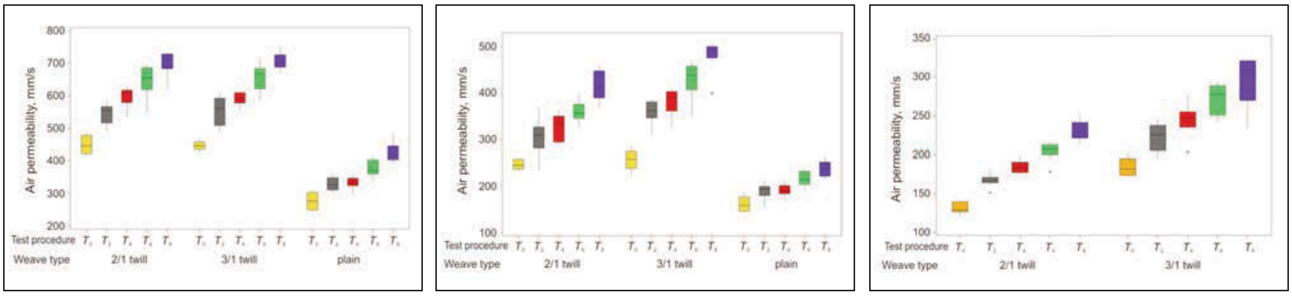
In table 3, the air permeability (*AP*) results of control fabrics were given for un-deformed fabrics and deformed fabrics according to bagging deformation tests T_2, T_4, T_6 and T_8. The air permeability of the fabrics increased for all control fabrics after each deformation tests. Maximum air permeability results were found after T_8 test in which the sphere having bigger diameter was waited 3 minutes after the fabric was reached to the defined displacement. The air permeability results of T_2 deformation test having 3 cm diameter of sphere and no waiting time was observed as minimum when compared with the results of T_4, T_6 and T_8 tests. At 18 cm^{-1} and 22 cm^{-1} weft settings the increase of air permeability after deformation tests was less in plain fabric and highest in 3/1 twill fabric. This result could be explained by the yarn geometry of plain weave which had more intersecting points. Deformation of the fabric increased with the less intersecting points in the weave unit.

Table 3

AIR PERMEABILITY (*AP*) RESULTS OF CONTROL FABRICS BEFORE AND AFTER DEFORMATION TESTS					
Fabric code	***AP***, mm/s	**AP-** T_2, mm/s	**AP-** T_4, mm/s	**AP-** T_6, mm/s	**AP-** T_8, mm/s
A_0	497	642	642	721	773
A_1	276	327	333	377	425
A_2	160	190	192	216	238
B_1	450	544	598	646	702
B_2	247	305	327	360	417
B_3	130	167	184	204	233
C_1	447	555	592	655	705
C_2	257	359	381	431	484
C_3	184	223	246	273	296

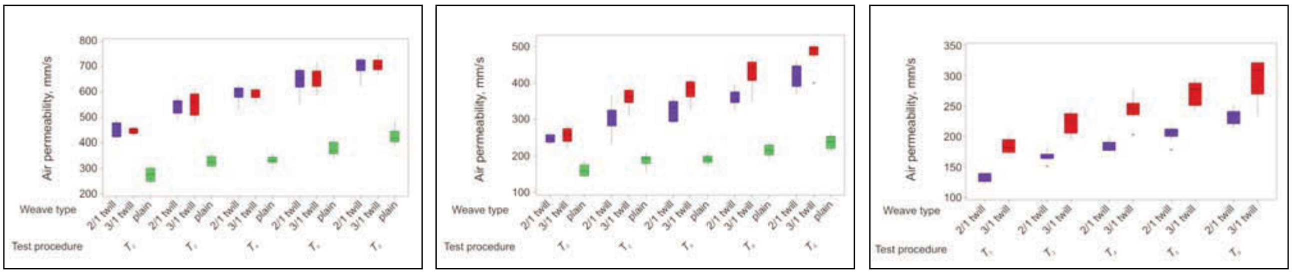
The effect of test parameters were investigated using the air permeability results of deformed control fabrics. The relationship between test parameters could be observed in figure 2. T_2 and T_4 test results and T_6 and T_8 test results were compared according the sphere diameter. In plain woven fabrics, the differences between the air permeability of T_2 and T_4 were not significant at 95% confidence level; on the other hand the differences between T_6 and T_8 were significant for all settings. The difference between the air permeability results of all deformation tests were significant at 95% confidence level for 2/1 twill fabrics having 18 and 26 cm^{-1} weft settings. But in 2/1 twill fabrics having 22 cm^{-1} weft setting the differences between T_2 and T_4 were not significant statistically, although the others are significant. For 3/1 twill fabrics, the differences between the air permeability results of T_2 and T_4 tests were not significant at 22 cm^{-1} and 26 cm^{-1} weft setting. In 3/1 twill fabrics, at 18 cm^{-1} weft setting, the differences between the air permeability results of all deformation tests were found significant. In summary, the differences between T_2 and T_4 tests were not significant for all fabrics although the difference between T_6 and T_8 were significant for all fabric types at 95% confidence level. This means that the diameter of the sphere was more effective when the samples were kept waiting for a certain time at the deformed condition.

It was observed that applied waiting time, after the load was reached defined bagging height, increased



a *b* *c*

Fig. 2. The relationship between the air permeability results of deformation tests T_2, T_4, T_6 and T_8:
a – weft setting 18 cm^{-1}; *b* – weft setting 22 cm^{-1}; *c* – weft setting 26 cm^{-1} (T_0 – un-deformed state)



a *b* *c*

Fig. 3. The relationship between the air permeability results of different weave types for each deformation tests T_2, T_4, T_6 , T_8 and un-deformed state T_0 :
a – weft setting 18 cm^{-1}; *b* – weft setting 22 cm^{-1}; *c* – weft setting 26 cm^{-1}

the deformation of the fabrics thus the air permeability. In all control fabric types the differences between T_2 and T_6 deformation tests and between T_4 and T_8 deformation tests were found significant at 95% confidence level. This means that the waiting time is effective in the bagging deformation of the fabric.

The air permeability results of control fabrics having different weave types and same structural parameters were investigated before and after deformation and same relationships were observed for un-deformed and deformed fabrics. The increase of setting decreased the air permeability. The relationship of air permeability results of weave types at different weft settings could be observed by figure 3. At same weft settings (18 cm^{-1}, 22 cm^{-1}), the air permeability of plain weave was less than 2/1 twill and 3/1 twill weaves and the differences between plain weave and twill weaves were significant at 95% confidence level for both deformed and un-deformed states. This was because of yarn geometry of weave type. The increase of the intersecting units in the weave unit decreased the air permeability. On the other hand the long floating regions in the weave unit increased the porosity and also the air permeability [18]. Therefore, plain fabrics had minimum air permeability comparing with twill weaves having same settings. The differences between 2/1 twill and 3/1 twill weaves were not found significant at 18 cm^{-1} both for un-deformed and deformed fabrics. However, the differences between the air permeability results of 2/1 and 3/1 twill weaves having 22 cm^{-1} weft setting were found significant after deformation tests. The differences between air permeability of 2/1 and 3/1 twill weaves were significant for un-deformed and all deformed fabrics at 26 cm^{-1} weft setting, as seen in figure 3. 3/1 twill weaves had maximum air permeability values comparing with other weaves because of having long floating.

Commercial fabrics

Five cotton and five worsted commercial fabrics were deformed according to defined test procedures. The air permeability results of un-deformed and deformed commercial fabrics having different structural parameters were given in table 4. When the results were examined for cotton commercial fabrics statistically it was seen that P_1 plain fabric having low mass per unit area had highest average air permeability. The differences between air permeability results of P_1, P_2 and P_3 cotton fabrics were significant at 95% confidence level for both deformed and un-deformed states. The differences between the air permeability results of P_4 and P_5 fabrics was not found significant at 95% confidence level before and after deformation tests. P_5 fabric having maximum mass per unit area and thicker yarn structure and P_4 fabrics having maximum setting values had minimum air permeability results. Plain fabrics (P_1, P_2) having low mass per unit area, thinner yarn structure and low setting had higher air permeability values when the results were

Table 4

AIR PERMEABILITY (*AP*) RESULTS OF COMMERCIAL FABRICS BEFORE AND AFTER DEFORMATION

Fabric code	*AP*, mm/s	AP- T_2, mm/s	AP- T_4, mm/s	AP- T_6, mm/s	AP- T_8, mm/s
P_1	372	420	446	483	542
P_2	160	175	186	193	217
P_3	207	236	251	259	274
P_4	16	18	19	21	23
P_5	25	29	31	31	33
Y_1	118	125	124	143	162
Y_2	170	174	175	186	190
Y_3	53	55	57	63	67
Y_4	106	106	106	108	108
Y_5	34	35	34	39	41

discussed according to structural parameters of other fabrics. The setting values and mass per unit area of P_3 fabric was higher than P_2 and their yarn counts were approximately same. However, the air permeability result of P_3 fabric was higher than P_2 fabric. This could be explained by the weave type of P_3 which was 2/2 twill weave having long floating compared to plain weave structure.

The differences between deformation tests were investigated for cotton commercial fabrics and it was found that the differences between air permeability results of un-deformed state and all deformed states were significant at 95% confidence level for P_1, P_3, P_4 and P_5 fabrics. For P_1, P_2 and P_3 fabrics, the differences between T_2 and T_4 tests (according to sphere diameter) were not significant at 95% confidence level, as seen in figure 4. The difference between T_6 and T_8 was found significant at 95% confidence level for P_1, P_4 and P_5 fabrics. According to waiting time, the difference between T_2 and T_6 tests having 3 cm sphere diameter was found significant at 95% confidence level for P_1, P_3, P_4 and P_5 fabrics. The difference between T_4 and T_8 tests was significant for all fabric types. The increase of the air permeability result after deformation was observed maximum at T_8 test and minimum at T_2 test (fig. 4). This situation supported the results of control fabrics.

The difference between air permeability results of worsted fabrics was significant at 95% confidence level for both deformed and un-deformed samples. When the results were discussed according to structural parameters of fabrics it was observed that the air permeability value of Y_2 plain fabric having low mass per unit area had maximum average permeability. Y_5 fabric having higher mass per unit area, settings and 2/1 twill weave type had minimum value. Y_1 plain fabric has less mass per unit area then Y_2 plain fabric, but the settings of Y_1 were higher then Y_2 thus the air permeability of Y_2 fabric was higher then Y_1. When Y_3 plain fabric and Y_4 2/2 twill fabric was compared it was noted that although Y_4 had higher mass per unit area, thicker yarns and higher settings

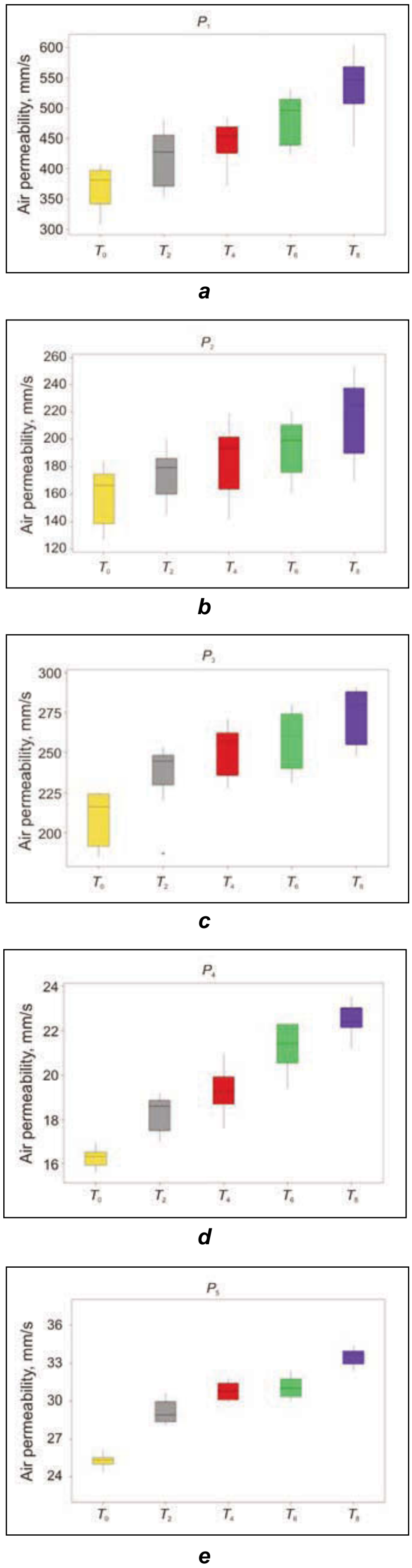
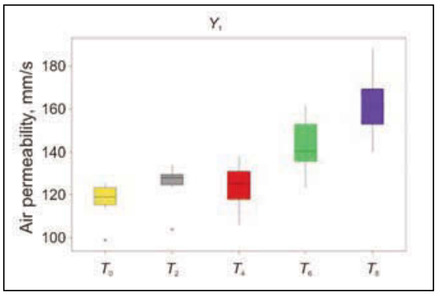
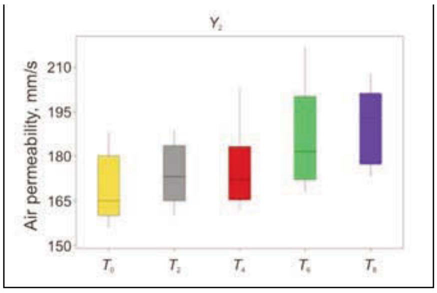


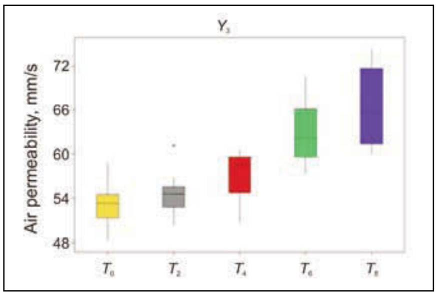
Fig. 4. The relationship between the air permeability results of deformation tests for each cotton commercial fabrics: *a* – P_1; *b* – P_2; *c* – P_3; *d* – P_4; *e* – P_5



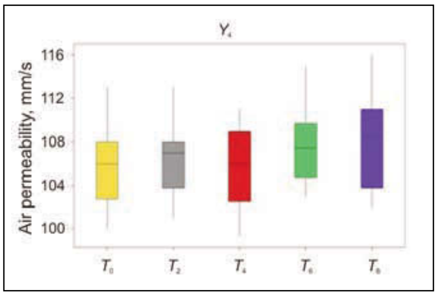
a



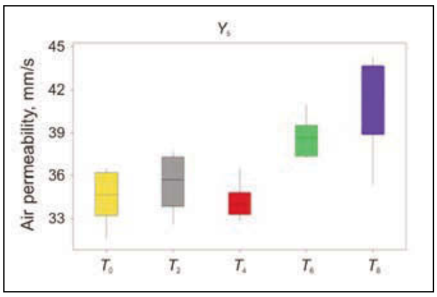
b



c



d



e

Fig. 5. The relationship between the air permeability results of deformation tests for each worsted commercial fabrics: *a* – Y_1; *b* – Y_2; *c* – Y_3; *d* – Y_4; *e* – Y_5

the air permeability of Y_4 is higher than Y_3. This situation could be explained by the effect of weave type. It was noted that the increase of air permeability was maximum after T_8 deformation test as seen in figure 5. The increase of air permeability was found minimum after T_2 and T_4 tests. The air permeability value of Y_4 and Y_5 fabrics after T_2 and T_4 tests and Y_5 fabric after T_4 test were not changed. These results were related with the applied bagging height to the worsted fabrics. In the study, the bagging height of deformation tests was determined by bursting tests. The bagging height was chosen as being a smaller value then the minimum bursting height of all fabrics. The minimum bursting height of all tested fabrics was found approximately 20 mm and bagging height was defined as 18 mm depending on this result. However, differently from cotton fabrics, the minimum bursting height of worsted fabrics was found 28 mm for 3 cm sphere diameter and 31 mm for 5 cm sphere diameter. This means that worsted fabrics had not shown a permanent deformation at 18 mm bagging height because of being at the elastic region of load-displacement curve. Besides the structural parameters of the fabric, the properties of the raw material was affected the bagging behavior of the fabric. The extension properties of wool fiber were higher than cotton fibers. In addition, wool fiber showed higher recovery from extension which was affected the permanent bagging properties of the fabrics. Therefore the increase of air permeability after T_2 and T_4 deformation tests were not found significant for all worsted fabrics. Besides the differences between T_2 and T_4 test was not significant according to sphere diameter. The increase of air permeability after T_6 and T_8 deformation tests in which 3 minutes waiting time was applied were significant at 95% confidence level for Y_1,Y_2,Y_3 and Y_5 worsted fabrics. Although defined bagging height was not effective at the deformation of worsted fabrics, the waiting time has an effect on the increase of deformation degree and also the air permeability results of these fabrics. The effect of raw material properties to the bagging deformation results should be investigated by special produced fabrics in order to compare the results more effectively.

CONCLUSIONS

In this study, the effect of bagging deformation to the permeability properties of fabric was investigated by an experimental study. The effect of test procedures and structural properties of the fabrics were discussed statistically. It was observed that test parameters, such as sphere diameter and load waiting time affected the deformation degree of the fabric so the air permeability. Generally, bigger sphere diameter caused higher air permeability results at deformed fabrics. Although the diameter of sphere was not found significant for all fabric types, the waiting time increased the deformation of fabric and the differences was significant at 95% confidence level for both spheres. In all fabric types the highest increase of air permeability of deformed fabric was observed with T_8 test which had 5 cm sphere and 3 minutes waiting time. The relationship between structural parameters and air permeability differences after each deformation tests were analyzed easily by control cotton fabrics. Higher settings caused the decrease of air permeability both in un-deformed fabrics and deformed fabrics. Weave type was determined the bagging deformation and also the air permeability results of deformed fabrics when all other structural parameters were same. Consequently, there was a complicated relationship between all these parameters. The applied load caused a change at the three dimensional structure and performance properties of fabric. The change of yarn and fabric geometry during and after the deformation test should be investigated to analyze the fabric behavior. Therefore, in further studies, it was aimed to model the bagging behaviour of fabric by investigating the change of three dimensional structure during and after the deformation test in order to predict the change in the performance properties.

BIBLIOGRAPHY

[1] Kawabata, S., Niwa, M., Kawai, H. *The finite-deformation theory of plain-weave fabrics. Part I: The biaxial-deformation theory.* In: Journal of the Textile Institute, 1973, vol. 64, pp. 21-46

[2] Zhang, X., Li, Y., Yeung, K. W. *Fabric bagging. Part I – Subjective perception and psychophysical mechanism.* In: Textile Research Journal, 1999, vol. 69, pp. 511-518

[3] Zhang, X., Li, Y., Yeung, K. W. *Fabric bagging. Part II – Objective evaluation and physical mechanism*. In: Textile Research Journal, 1999, vol. 69, pp. 598-606

[4] Zhang, X., Li, Y., Yeung, K. W., Yao, M. *Mathematical simulation of fabric bagging*. In: Textile Research Journal, 2000, vol. 70, pp. 18-28

[5] Kısılak, D. *A new method of evaluating spherical fabric deformation*. In: Textile Research Journal, 1999, vol. 69, pp. 908-913

[6] Zhang, X., Li, Y., Yeung, K. W., Yao, M. *Viscoelastic behavior of fibers during woven fabric bagging*. In: Textile Research Journal, 2000, vol. 70, pp. 751-913

[7] Zhang, X., Li, Y., Yeung, K. W., Yao, M. *Relative contributions of elasticity and viscoelasticity of fibers and inter-fibre friction in bagging of woven wool fabrics*. In: Journal of the Textile Institute, 2009, vol. 91, pp. 577-589

[8] Amirbayat, J. *An improved analysis of bagging of textile fabrics. Part I: Theoretical*. In: International Journal of Clothing Science and Technology, 2006, vol. 18, pp. 303-307

[9] Amirbayat, J., Namiranian, B. *An improved analysis of bagging of textile fabrics. Part II: Experimental work.* In: International Journal of Clothing Science and Technology, 2006, vol. 18, pp. 308-313

[10] Abghari, R., Najar, S. S., Haghpanahi, M., Latifi, M. *Contributions of in-plane fabric tensile properties in woven fabric bagging behaviour using a new developed test method.* In: International Journal of Clothing Science and Technology, 2004, vol. 16, pp. 419-433

[11] Sengoz, N. G. *Bagging in textiles*. In: Textile Progress, 2004, vol. 36, pp. 1-64

[12] Yokura, H., Nagae, S., Niwa, M. *Prediction of fabric bagging from mechanical properties*. In: Textile Research Journal, 1986, vol. 56, pp. 748-754

[13] Yeung, K. W., Li, Y., Zhang, X., Yao, M. *Evaluating and predicting fabric bagging with image processing*. In: Textile Research Journal, 2002, vol. 72, pp. 693-700

[14] Juodnukyte, D., Daukantiene, V., Gutauskas, M. *Investigating the implications of static and dynamic loading in high-performance fabrics for outdoor clothing.* In: International Journal of Clothing Science and Technology, 2008, vol. 20, pp. 7-14

[15] Sülar, V. *A new testing instrument with artificial arm to simulated fabrics bagging by human elbow*. In: Industria Texilă, 2011, vol. 62, issue 5, pp. 259-264

[16] Verleye, B., Croce, R., Griebel, M., Klitz, M., Lomov, S. V., Morren, G., Sol, H., Verpoest, I., Roose, D. *Permeability of textile reinforcements: Simulation, influence of shear and validation*. In: Composites Science and Technology, 2008, vol. 68, pp. 2 804-2 810

[17] TS 391 EN ISO 9237. *Textiles-determination of the permeability of fabrics to air*. Ankara: Turkish Standards Institution, 1999

[18] Backer, S. *The relationship between the structural geometry of a textile fabric and its physical properties. Part IV – Interstice geometry and air permeability*. In: Textile Research Journal, 1951, vol. 21, pp. 703-714

Author:

Dr. R. BEFRU BÜYÜKBAYRAKTAR
Dokuz Eylul University
Department of Textile Engineering
Tinaztepe Campus
35397 Buca, Izmir, Turkey
e-mail: befru.turan@deu.edu.tr

Determining the optimal operating mode for the embroidery machine by using the vibration measurement technique

MARIUS ŞUTEU
MARIUS BAIDOC
LILIANA INDRIE
MACEDON GANEA

REZUMAT – ABSTRACT

Determinarea regimului optim de funcționare a mașinii de brodat, folosind tehnica măsurării vibrațiilor

Scopul lucrării îl constituie determinarea regimului optim de lucru al mașinillor de brodat, prin tehnica măsurării vibraţiilor. Deoarece vibrațiile pot determina, adesea, întreruperi accidentale ale mașinii de brodat, provocând ruperea firului și uzura acului, trebuie luate măsuri de înlăturare sau reducere a acestora. Pentru diagnosticarea cauzelor opririlor mașinii de brodat Happy, s-au efectuat măsurători ale vibrațiilor în fiecare punct de măsurare, prin instalarea unui senzor de vibrații pe cele trei direcții ale sistemului de coordonate cartezian: axial, orizontal și vertical. Colectarea datelor de pe mașina de brodat s-a efectuat în următoarele domenii de vibrații: viteză, deplasare și accelerație. Dupa colectarea datelor și transferul acestora într-un calculator dotat cu aplicația Data Explorer, s-a efectuat analiza și diagnosticarea defecțiunilor.

Cuvinte-cheie: vibrații, mașină de brodat, defecte, soft Data Explorer

Determining the optimal operating mode for the embroidery machine by using the vibration measurement technique

The goal of this paper is to determine the optimal operating mode for embroidery machines by using the vibration measurement technique. Since vibrations can often lead to accidental embroidery machine shutdowns, and can cause thread breaking and needle damage, measures must be taken to remove or reduce them. To this end, for diagnosing the causes for Happy embroidery machine halts, vibration measurements were taken in each measuring point, by installing vibration sensors on the three directions of the cartesian coordinate system: axial, horizontal, vertical. The data collected from the embroidery machine focused on the following vibration characteristics: velocity, displacement and acceleration. After the data was collected and transferred to the computer running the Data Explorer application, fault diagnosis and analysis were done.

Key-words: vibrations, embroidery machine, faults diagnosis, Data Explorer software

Many textile technological processes require high energy consumption and generate environment pollutants. Also, noise and vibration are other major factors of pollution produced by textile equipment. Reducing negative environmental impacts and reduce energy consumption involves rethinking textile machinery active structures [1].

Over time, a major concern of enterprise administrations and equipment and machinery experts has been to develop technologies and organizational measures in order to reduce accidental equipment shutdowns and reduce downtime while repairing [2].

The technical state of an equipment operation can be measured based on the way it behaves while in use: vibrations, noises, temperature rises in bearings, temperature and pressure variations in the cooling circuit etc. The vibration level and noise level are the main parameters for evaluating the technical state of operation of an equipment. It is required that the level of vibration fall within the allowed limits. If it exceeds the maximum allowable value, it is necessary to stop the machine and take it apart to determine the cause of the vibrations and repair the damages.

The evaluation of the technical state and safety in use of a machine involves collecting all the technical information from the measurement and control instruments that the machine is equipped with: lubrication, pressures, temperatures etc. In addition to these, the most useful information is that provided by vibration measurements.

In everyday life, vibrations are primarily the product of technological progress, a mechanical agent with a harmful effect on people, buildings and machines, and only secondly a movement whose energy is applied in useful industrial processes. In practice, vibrations cannot be avoided, as they are the result of operating vehicles and machines, and of the environment acting on mechanical structures built by man [3].

The increased vibrations recorded for a machine in the textile industry are usually due to to its faulty operation. This leads to machine downtime and can attributed to a number of reasons, such as:

- common wear and tear of its components. The lifetime of an industrial sewing machine is a result of its reliability;
- excessive wear and tear of components due to the premature occurrence of various defects (mechanical looseness, misalignment etc.).

The characteristics of the machines used in the textile industry make it necessary in some cases to continuously monitor the amplitude of the vibrations. Thus, in order to schedule service times, an assessment of the evolution of amplitude values is required. Also, to protect the machines and avoid technological accidents, the instantaneous vibration amplitude value must be evaluated, and action taken if it exceeds the imposed limit value. When the amplitude of the vibration exceeds the normal operating value, the diagnosing and location of faults is required.

It is considered that increased vibrations in industrial textile machines can lead to several faults which significantly affect the production process, such as: breaking of the thread; needle damage; excessive wear and tear of the mechanisms and components of the kinematic chain.

Our study is important not only in terms of the influence of vibration on product quality but also in economic terms because by limiting this phenomenon it entails reducing the needle and thread use, embroidery machine mechanisms and thus a reduction of production cost which as has been stated in numerous studies is one of the main factors that influence the evolution of production and textile products and garment exports [4].

To reduce vibrations and diagnose the causes for accidental halts of the Happy embroidery machine, a number of vibration measurements were done, in order to determine the optimal operating mode [5]. At the end of the round of measurements a report was issued, based on which the vibration level was assessed in conformity with the existing standards, and we made recommendations as to what should be done. Note that we did not intend to modify the original Happy machine, only to monitor the technological process and find solutions to increase reliability.

The measuring was done at S.C. Confidex S.R.L – Oradea. Measurements were taken in each of the measuring points, by installing vibration sensors on the three directions of the Cartesian coordinate system: axial (X), horizontal (Y), vertical (Z) as figure 1 and figure 2 shows.

Vibration measurements were made with Impaq FFT spectrum analyzer, manufactured by Benstone Instruments Inc., USA. Impaq is a portable analyzer with color graphic display, keyboard and display functions for the graphics measured and analyzed. The technical characteristics of the analyzer are listed in the figure 3 [6]. Vibration analyzers come with an application for data analysis, which needs to be installed on a PC.

The application can download and analyze the measurements done with the software modules installed on the vibration analyzer. It also has functions for data post-processing, simultaneous viewing of several types of diagrams and spectra, mathematical operations (+, –, *, /), integration, derivation, real-time filters etc. The best programs also have features for data export in the following formats: UFF, BUFF, ASCII UFF, MATLAB, ASCII files (e.g. MS Excel) or user defined, as well as automated technical reports depending on the application examined, defining custom templates, saving to HTML, PDF, EXCEL and WORD.

We can therefore say that the vibration analyzer is the ideal tool for all industrial fields.

To analyze and diagnose the faults of the embroidery machine the following were also used:

- *a vibrometer* – for measuring global vibration in order to establish the operational mark of the embroidery machine;
- *waveform analysis and FFT(vibration signal frequency analysis)* – in order to effect the waveform and the frequency spectrogram on one or more channels; the frequency domain, measurement parameters, number of mediations etc. can be configured with this software;
- *the Data Explorer software* – for analyzing and interpreting the data measured with the Impaq analyzer.

EXPERIMENTAL PART

The essential purpose of the experiment, conducted on the Happy embroidery machine, was to determine the optimal operating mode, the conditions in which the quality of the embroidery and the productivity are increased, and the machine's reliability will me maintained at a high level.

Before vibration measurement, the following technical conditions were set: type of vibration measurement, points and direction of measuring, vibration parameters and their values, operating modes.

The vibration sensor used for measurements was a general use piezoelectric accelerometer of medium frequency with a sensitivity of 100 mV/g, recommended for vibration measurements for machines with a

Fig. 1. The Happy embroidery machine

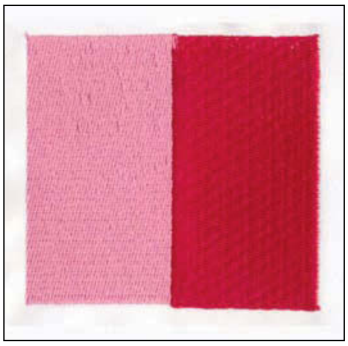


Fig. 2. Embroidery on fabric

Fig. 3. Impaq analyzer description [source: http://www.benstone.com]

rotative speed over 600 rpm. Vibration measurements were taken in each measuring point, in three directions, defined by the cartesian coordinate system (*X, Y, Z*). The frequency domains for global variation measurements and FFT analysis were saved in the memory of the Impaq analyzer, and subsequently transferred on the PC to the Data explorer application. Taking into consideration that the embroidery machine manufacturer does not specify the machine's admissible level of vibration or the optimal operating mode which would lead to an increase in reliability, we established that these can be determined by measuring vibrations and diagnosing needle faults through thermography.

To achieve this, the following measurement parameters were set, in accordance with the provisions [7], [8]. Mechanical fastening of accelerometers, as follows [8]:

- effective vibration velocity [mm/s] rms, in the 2 – 1 000 Hz < 600 sinking/min. frequency domain;
- effective vibration displacement [μm] rms, in the 2 – 1 000 Hz < 600 sinking/min. frequency domain;
- root mean square is the square root of the mean square value of the waveform, rms;
- acceleration of gravity [g], although it does not appear in the ISO, 1 g = 9,81 m/s^2.

Vibration spectral analysis and fault diagnosis

The following vibration data was collected from the Happy embroidery machine: velocity, displacement and acceleration. Data collection was carried out with transducers which captured the vibration spectra and turned them into electrical impulses which were sent to the data collection system. Based on the assessed vibration parameter, the transducers can evaluate vibration amplitudes, speeds or accelerations.

After collecting the data from the embroidery machine and transferring it on the PC on which the Data Explorer application is running, it was time for the fault detection and diagnosis stage.

The frequency domains for data collection were selected in such a way as to cover the entire manifestation field of any faults, not just those concerning the causes for embroidery machine halts. After deciding on the working method, the operating modes were set ranging from 300 to 1 000 sinking/min. [5], [6].

The fabric chosen for the embroidery (fig. 4) was 100% cotton duck, and the measurement direction presented in this paper is *Z* (the direction on which the sensor was installed) and fabric advance on *X* (embroidery direction).

RESULTS AND DISCUSSIONS

The vibration amplitude recorded on the *Z* measurement direction and the *X* fabric advance direction is shown in table 1.

Note that figure 5 shows that the lowest velocity amplitude which does not affect productivity is 7.6 mm/s when operating at 700 sinking/min. The domain standards recommend that the lowest vibration amplitude is taken into consideration, on any measurement direction. As figure 6 shows, the amplitude of displacement from 700 sinking/ min. to 1 000 sinking/ min. is approximately constant. In the figure 7 the acceleration shows the impact of “metal on metal”, the result being an approximately linear acceleration. After measuring vibrations, spectral analysis for the Happy embroidery machine was done, on the *Z* measurement direction (the direction on which the sensor was installed) and fabric advance on direction *X*.

Figure 8 shows the wave form for the acceleration amplitude (the peak-to-peak value increases lineary based on the machine's operating frequency from 0.1 g to 0.8 g).

Table 1

VIBRATION AMPLITUDE BASED ON OPERATING MODES WITH THE SENSOR INSTALLED VERTICALLY (ADVANCE ON *X*)

Operating mode	**Vibration amplitude**		
No. of sinking/min.	***Velocity***, mm/s [rms]	***Displacement***, μm [rms]	***Acceleration***, *g* [rms]
300	6.4	70	0.1
400	2.2	28	0.18
500	3.8	50	0.22
600	10.8	160	0.33
700	7.6	80	0.4
800	13.7	84	0.5
900	14.4	75	0.7
1000	14.46	76	0.8

Fig. 4. The HAPPY embroidery machine with the sensor installed vertically

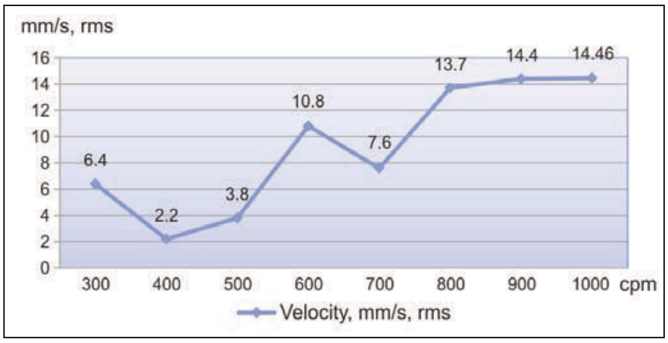


Fig. 5. Amplitude of velocity based on operating modes

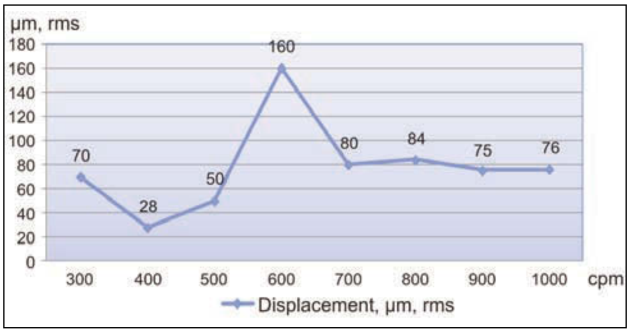


Fig. 6. Displacement amplitude based on operating modes

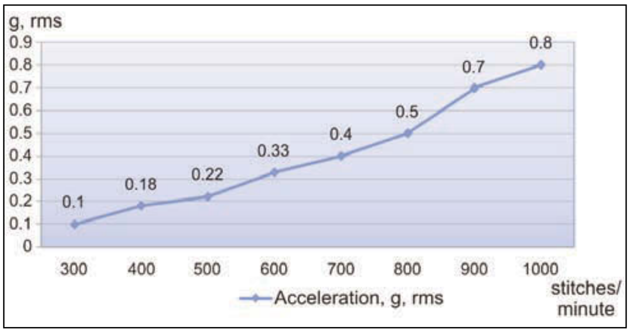


Fig. 7. The amplitude of acceleration based on operating modes

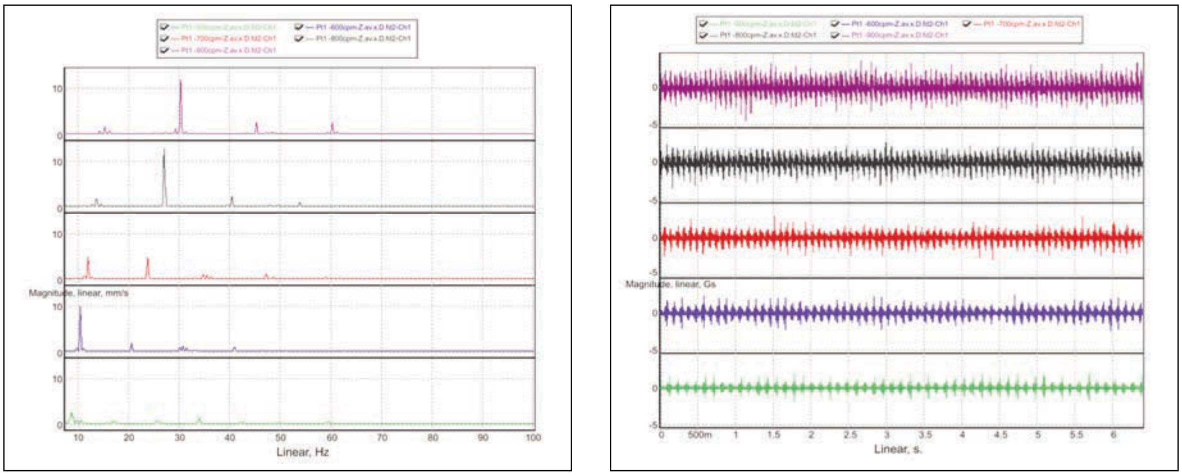


Fig. 8. Wave forms and frequency spectrograms recorded in measuring point P_t 1, on the vertical measurement direction with advance on *X*

Following the spectral analysis, it was determined that:

- when operating at 500 sinking/min., the spectral components are relatively low and the vibration velocity amplitude has the lowest value of 3.8 mm/s. The disadvantage of this operating mode is the low productivity;
- when operating at 600 sinking/min. the dominant component in the spectrum is the 1 *X* – fundamental of value 10 mm/s, the upper spectral components are low and the global velocity vibration is 10.8 mm. In these conditions, the vibration amplitudes have almost tripled from those recorded at 500 sinking/min. and this difference resulted at only 100 sinking/min., showing a significant variation in vibrations. The increase in the 1 *X* fundamental harmonic can be attributed to the excitation of a piece in the kinematic chain of the embroidery machine. In conclusion this operating mode is not recommended because it leads to a decrease in the machine's reliability;
- when operating at 700 sinking/min. the frequency spectrogram shows a decrease in the fundamental while the 2 *X* spectral component is increasing, both having values of approx. 5 mm/s, resulting in a decrease in the global amplitude of vibration velocity at a value of 7.6 mm/s. This is considered the optimal operating mode because compared to the other operating modes at 800, 900 and 1 000 sinking/min., the amplitudes of global vibrations are at their lowest, resulting in a relatively high productivity and leads to an improved machine reliability compared to operating at 800–1 000 sinking/min.;
- when operating at 800 sinking/min. and 900 sinking/min. the frequency spectrum shows a significant increase in the 2 *X* spectral component, of over 12 mm/s as well as a slight increase in the spectral components of orders 3 and 4, therefore resulting in an increase in global vibrations over the 13.5 mm/s value. These operating modes are not recommended at all due to the high vibration amplitudes which lead to a significant decrease in the machine's reliability.

CONCLUSIONS

Determining operating modes by measuring vibrations can be considered as a personal contribution to increasing the reliability of the machines used in the textile industry. For the *Z* measurement direction (the direction on which the sensor is installed) and fabric advance on the *X* direction, the optimal operating mode is at 700 sinking/min. Operating modes can change based on the wear of machine parts (components of the kinematic chain, needle, motor drive etc.) and highlight the weaknesses or nonconformities that may occur in the production process. These can be influenced by needle type, fabric density etc. and can be considered a complex process based on vibration level analysis and thermography, this method being suitable for application to other machines in the textile industry.

Modern factories implement technological monitoring systems in order to increase reliability and quality. The Happy company already introduced the varying needle frequency depending on the radius and with of the embroidery, but this is a simple implementation with a maximum of three frequency levels and does not take into account other factors such as: the thickness and density of the fabric, needle wear etc., all of which affect vibrations. By measuring vibrations, the machine's behavior while embroidering can be monitored in detail and it would be possible (theoretically speaking) to make continuous adjustments to the needle contour frequency, by communicating with a separate computer. The problem lies in accessing the operating mode automatically (access in currently possible only manually and only at the start of the stage of a program). If the level proposed in this paper were implemented, then the contour frequency could be modified in several ways: manually, automatically (on-line) in stages, continuously (adaptively), or by dividing the program in multiple phases on the contour embroidery, to enable it to adjust frequency on the embroidery curve. This operating mode could implicitly lead to an expert system, which could address other technological aspects as well.

The results obtained in this study will allow a number of potential directions to be sketched out and followed in order to continue this research. The most obvious ulterior development directions for the study are, in the author's opinion:

- A system for measuring, monitoring and analyzing vibrations with triaxial piezoelectric accelerometers installed on every machine in the textile industry which will be connected to a retrieval system with FFT spectral analysis, a system which will include an application to automatically calculate the optimal operating modes. The vibration measurement system consists of: piezoelectric accelerometers – *n* pieces; ICP modules – *n* channels; AMDT retrieval module – *n* analog inputs, 8 digital inputs, 8 digital outputs, 4 analog outputs.

  The data retrieval system consists of: 2 base devices with 16 GB of memory; 2 retrieval modules for AMDT vibrations.
- System for measuring, monitoring and FFT spectral analysis with laser vibrometer for non-contact measurements of vibration velocity, displacement and acceleration. This laser vibrometer will include a computer program to automatically calculate the optimal operating modes and perform modal analysis. The laser vibrometer system consists of: laser sensor ("laser head"), emitting the laser beam towards the measurement sample; the central unit (modulated controller), which processes the signal from the sensor. The central unit contains a D-VD-3 decoder to extract from the measured signed the vibration velocity of the sample in the section illuminated by the laser beam.

BIBLIOGRAPHY

[1] Hanganu, L. C., Grigoraş, Ş., Pantilimonescu, F. G., Balaşca, M. *Specific components of mechatronics systems dedicated to textile and leather equipment and technology.* Part I. In: Industria Textilă, 2012, vol. 63, nr. 6, pp. 302-306, ISSN 1222–5347

[2] Dima, I. C., Nedelcu, M. V. *Managementul producției industriale*. Editura Economică, Bucureşti, 2003

[3] Bereteu, L., Smicala, I. *Vibrații mecanice.* Editura Mirton, Timişoara, 1998

[4] Tripa, S. *The main garment importers and exporters.* In: Industria Textilă, 2008, vol. 59, nr. 1, pp. 29-31

[5] Şuteu, M. Raport de cercetare nr. 3. *Cercetări și rezultate experimentale privind asigurarea fiabilității proceselor tehnologice din industria textilă.* Universitatea din Oradea, februarie 2012

[6] Şuteu, M., Indrie, L., Ganea, M. *Determination of optimum performance regime for SunStar buttonhole machine by vibrations measuring technique. Processing the data measured with Data Explorer Software.* Annals of the University of Oradea, Fascicle of Textiles-Leatherwork, Oradea, 2011, vol. XII, nr. 1, pp. 146-157

[7] ISO-10816-1-1995. *Mechanical vibrations. Assessing machine vibrations by measurements on non-rotating components.* Part 1: General requirements

[8] ISO-5348-1998. *Mechanical vibrations and shocks*

Authors:

Şef de lucrări ing. MARIUS ŞUTEU
Conf. dr. ing. LILIANA INDRIE
Universitatea din Oradea
Facultatea de Inginerie Energetică și Management Industrial
Departamentul de Inginerie și Management Industrial în Textile și Pielărie
Str. B. Şt. Delavrancea nr. 4, 410058 Oradea
e-mail: msuteu@uoradea.ro; lindrie@uoradea.ro

Dr. ing. MARIUS BAIDOC
SC Femaris Srl, str. Agricultorilor nr. 12, Oradea
e-mail: info@femaris.ro

Prof. dr. ing. MACEDON GANEA
Universitatea din Oradea
Facultatea de Inginerie Managerială și Tehnologică
Str. Universității nr. 1, 410087 Oradea
e-mail: macedonganea@yahoo.com

Colour recipe prediction in dyeing acrylic fabrics with fluorescent dyes using artificial neural network

BAHAR SENNAROGLU

ERHAN ÖNER
ÖZLEM ŞENVAR

REZUMAT – ABSTRACT

Stabilirea rețetei de vopsire a materialelor acrilice cu coloranți fluorescenți, folosind o rețea neurală artificială

Una dintre cele mai importante etape în vopsirea materialelor textile o constituie stabilirea rețetei de vopsire. Din cauza mecanismului complex și neliniar al coloranților și al procesului de vopsire, coloranții fluorescenți creează dificultăți în stabilirea rețetei de vopsire. De aceea, în cadrul acestui studiu, pentru stabilirea rețetelor de vopsire, s-a folosit o tehnică bazată pe o rețea neurală artificială, care să permită încadrarea în culorile de referință ale tricoturilor din fire acrilice 100%, vopsite cu un amestec de trei coloranți de bază, și anume: C.I. Basic Yellow 40, C.I. Basic Violet 39 și C.I. Basic Blue 3. Coloranții C.I. Basic Yellow 40 și C.I. Basic Violet 39 sunt fluorescenți, iar C.I. Basic Blue 3 are o nuanță de albastru briliant. În acest studiu, s-a folosit o rețea neurală de tip perceptron multistrat. Intrările au fost reprezentate de factorii de radianță spectrală pentru lungimi de undă cuprinse între 400 și 700 nm, la intervale de 10 nm, iar ieșirile au fost reprezentate de concentrațiile de colorant. Rezultatele arată că rețeaua neurală artificială este un instrument adecvat și puternic pentru stabilirea rețetelor de vopsire cu coloranți fluorescenți a materialelor acrilice.

Cuvinte-cheie: rețea neurală artificială (ANN), rețea neurală de tip perceptron multistrat (MLP), stabilirea rețetei de vopsire, coloranți fluorescenți, tricoturi acrilice

Colour recipe prediction in dyeing acrylic fabrics with fluorescent dyes, using artificial neural network

One of the most important processes in textile dyeing is the colour recipe prediction. Fluorescent dyes present difficulties for colour recipe prediction due to complex and non-linear mechanism of the dyes and dyeing process. For this reason, in this study, an artificial neural network technique is used to predict the colour recipes to match the reference colours of 100% acrylic knitted fabrics dyed by a combination of three basic dyes which are C.I. Basic Yellow 40, C.I. Basic Violet 39, and C.I. Basic Blue 3. C.I. Basic Yellow 40 and C.I. Basic Violet 39 are fluorescent, and C.I. Basic Blue 3 has a brilliant blue shade. The neural network developed is a multilayer perceptron network. The inputs are the spectral radiance factors at wavelengths from 400 nm to 700 nm at 10 nm intervals and the target outputs are dye concentrations. The results show that the artificial neural network is an appropriate and powerful tool for colour recipe prediction in dyeing acrylic fabrics with fluorescent dyes.

Key-words: artificial neural network (ANN), multilayer perceptron (MLP) neural network, colour recipe prediction, fluorescent dyes, acrylic knitted fabrics

Artificial neural network (*ANN*) technique is used to model non-linear problems and to predict the output parameters for given input parameters without any assumptions. Since most of the textile processes and the related quality assessments are non-linear in nature, and there are numerous large input and possible output parameters as well as interdependencies among these parameters, neural networks can be used [1]. In textile industry, neural networks are used in various areas including fibre classification, defect detection and classification of yarns and fabrics, prediction of properties and process behaviours of textiles, colour separation and categorization, treatment of dyeing effluents, colour recipe prediction, etc. [1] – [4].

Kandi and Tehran emphasize that one of the most important processes in textile dyeing is the colour match prediction. It needs a combinatorial solution of colorants to produce colour recipes for a target colour sample. They propose two basic steps in a colour recipe prediction. One is the selection of colorants for a specific colour match. The other one is the determination of the magnitude of each colorant concentration to match the reference colour [5].

The use of neural networks for solving recipe prediction problems was first suggested in 1991 [6]. One of the first studies was by Jasper et al. who predicted dye concentrations using neural networks and compared with Beer's Law model and a modified linear model. They concluded that the neural net outperformed the other two models due to the nonparametric nature of the model [7].

In textile industry, the most common approach to the optical properties of the substrate and colorant is through the Kubelka-Munk theory [8]. Bezerra and Hawkyard use the neural networks for computer match prediction for fluorescent acid dyes in dyeing of polyamide, although traditional methods of computer match prediction rely heavily on Kubelka-Munk theory [9]. They demonstrate that the neural network using *SRF* (spectral radiance factor) values in its input layer and dye concentrations in its output layer is the most appropriate one among the networks fed with *SRF, XYZ* or $L^*a^*b^*$ values in their input layers. They state that the fluorescent dyes present difficulties for match prediction due to their variable excitation and emission characteristics, which depend on a variety of factors. Some combinations of colorants also exhibit quenching effects, with one component absorbing at wavelengths that excite the fluorescence of another. One of the advantages of neural networks is their capability to establish relations between input and output data without explicit programming of Kubelka-Munk equations or analytical knowledge into the model [10].

ANN has computing power through parallel-distributed structure and ability of learning and generalizing. *ANN* that is producing reasonable outputs for inputs not encountered during learning or training is called generalization. These two information-processing capabilities lead *ANNs* to solve complex or large-scale problems, which are intractable [11].

In this study, an artificial neural network is used in order to predict the colour recipe to match the reference colour of 100% acrylic knitted fabric dyed by a combination of three basic dyes in which C.I. Basic Yellow 40 and C.I. Basic Violet 39 are fluorescent, and C.I. Basic Blue 3 has a brilliant blue shade.

There are many different types of neural networks. In textile industry, multilayer perceptron (*MLP*) neural network is the most widely used type of *ANN.* The *MLP* network is a function of the input parameters that minimizes the prediction error of the output parameters. *MLP* is known as a multilayer feed-forward network. Typically, the network consists of a set of sensory units called source nodes that constitute the input layer, one or more hidden layers of computation nodes, and an output layer of computation nodes. The input signal propagates through the network in a forward direction, on a layer-by-layer basis [11].

Figure 1 presents a feed-forward neural network with a hidden layer. In this three-layer neural network, the outputs of the first layer are the inputs of the hidden layer, and the outputs of the hidden layer are the inputs of the third layer. The first layer consists of nodes, which receive inputs and send them without any processing to all neurons of the hidden layer.

Five components exist in a neural network with a hidden layer [12]:

- node (or neuron) – a state variable *s* is associated with each node;
- link – links connect the nodes;
- threshold (or bias) – a real value *t* assigned to a node in the hidden and output layers;
- weight – a real value *w* associated to a link;
- transfer (or activation) function – a transfer function *f* describes the state of the node in terms of its threshold value, the weights of its incoming links, and the state variables of the nodes connected to it by the incoming links.

The processing elements of neural networks are neurons, which operate in a parallel way. Figure 2 presents a neuron in a hidden layer. Each neuron in the hidden layer sums up its input signals after weighing them with the strengths of the respective connections from the input layer and computes its output as a function of the sum by means of a transfer function. And then, it sends this output to all neurons of the output layer. Similarly, each neuron in the output layer sums up its input signals after weighing them with the strengths of the respective connections from the hidden layer and computes its output as a function of the sum by means of a transfer function.

One of the most important properties of a neural network is its ability to learn from its environment, and to improve its performance through learning, which is an iterative process of adjustments applied to synaptic weights of the neural network [11]. The procedure for adjusting the weights and thresholds in order to train a network is called a learning rule. The learning rules are classified as supervised, reinforcement, and unsupervised. The learning rule of perceptron network falls in the supervised learning category [13]. In supervised learning, both inputs and target outputs are applied to the network and the network outputs are compared with the target outputs. The training process of the neural network by performing calculations backward through the network, which is called "back propagation" process, continues until the network error is minimized. Generally, as the network performance function, the mean squared error between the network outputs and the target outputs is used with the learning algorithm. There are various

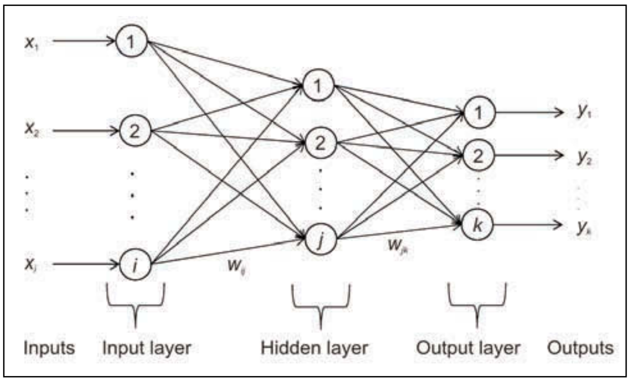


Fig. 1. A feed-forward neural network with a hidden layer

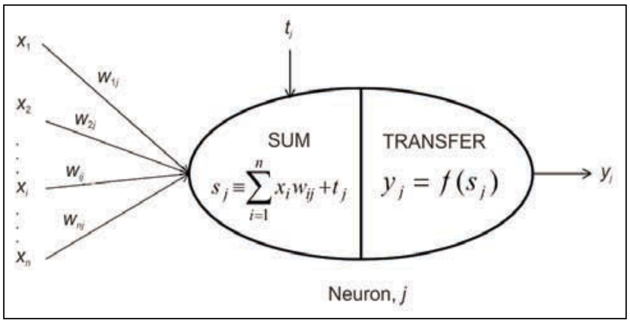


Fig. 2. A neuron in a hidden layer

supervised learning algorithms such as Levenberg Marquardt (*LM*), Back Propagation (*BP*), Scaled Conjugate Gradient, Bayesian Regularization, and so on. The most widely used ones are *LM* and *BP*. In this study, *LM* algorithm is used to train the network. *LM* algorithm is an iterative technique that locates a local minimum of a multivariate function that is expressed as the sum of squares of several non-linear, real-valued functions. This is based on minimizing the system error function as the objective function [14].

MATERIALS AND METHODS

Experimental part

In this study, in order to associate *SRF* values of fluorescent coloured 100% acrylic knitted fabrics with the basic dyes and their concentrations, the *SRF* data of 36 samples dyed with different combinations, the spectral data of the substrate, and also, the data for the calibration dyeing ranging from 0.001% to 1.5% of three basic dyes namely, C.I. Basic Yellow 40, C.I. Basic Violet 39 and C.I. Basic Blue 3 were taken from a work published elsewhere [15]. The *SRF* values of the materials were measured at wavelengths from 400 nm to 700 nm at 10 nm intervals with a Datacolor SF 600+ spectrophotometer (the specular component and the *UV* component were included, and *LAV* 30 mm measuring plate was used). The total amount of dye applied onto the materials was 0.1% o.w.f. for each combination. The mixture of three dyes was coded as described in figure 3.

Colour recipe prediction using *ANN*

The *ANN* model used in this study is an *MLP* neural network with one hidden layer (fig. 4). The Neural Network Toolbox of MATLAB R2011b was used for developing and performing *ANN* model [16]. Input layer consists of thirty-one nodes whose inputs are

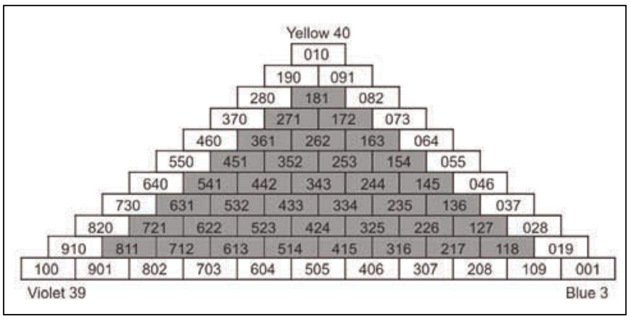


Fig. 3. The combination of three dyes used in the *ANN* model; the shaded three-dye mixtures were used and the samples were coded such as VYB325 for 0.3% o.w.f Violet, 0.2% o.w.f. Yellow and 0.5% o.w.f. Blue dyed sample

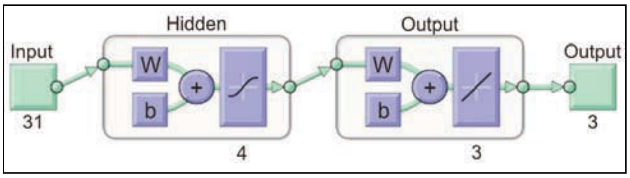


Fig. 4. The *MLP* network

SRF values at wavelengths from 400 nm to 700 nm at 10 nm intervals. Output layer consists of three neurons whose outputs are concentrations of three basic dyes in the formulation. The number of neurons in the hidden layer was decided to be four after trying different number of neurons between two and ten and achieving the best network performance with four neurons. The network performance was evaluated with respect to both the mean squared error *MSE*, which is the average squared error between the network outputs (predicted concentrations) and the target outputs (actual concentrations), and the correlation coefficient *R* between network outputs and target outputs. In the hidden layer, Hyperbolic Tangent Sigmoid transfer function was used equation (1). This non-linear transfer function allowed the network to learn non-linear relationships between inputs and outputs.

$$f(s) = \frac{e^s - e^{-s}}{e^s + e^{-s}} \tag{1}$$

The linear transfer function was used in the output layer equation (2):

$$f(s) = s \tag{2}$$

The data set of dye concentrations is given in table 1. Prior to the training, the data set was randomly divided into three subsets: training – 26 samples for 70% of 36 samples; validation – 5 for 15%; test – 5 for 15%. The training set was used in the training phase to allow the neural network to learn the relationship between the *SRF* values and dye concentrations and to adjust the neural network weights and thresholds. The *MLP* neural network was trained by Levenberg Marquardt learning algorithm with the mean square error performance function equation (3).

$$MSE = \frac{\sum_{i=1}^{n} (target\ output_i - network\ output_i)^2}{n} = \frac{\sum_{i=1}^{n} e_i^2}{n} \tag{3}$$

The error on the validation set was monitored during the training process. The best validation performance was achieved at 7 training iterations (epochs) (fig. 5).

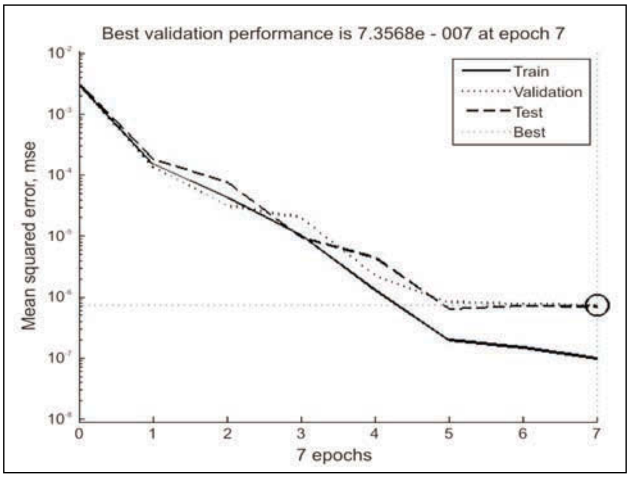


Fig. 5. Validation performance of the *MLP* network

Table 1

THE DATA SET OF DYE CONCENTRATIONS AND PREDICTIONS									
Sample no.	**Sample**			**Target outputs**			**Network outputs**		
	Training	***Validation***	***Testing***	***Violet 39***	***Yellow 40***	***Blue 3***	***Violet 39***	***Yellow 40***	***Blue 3***
1	-	-	1	0.01	0.01	0.08	0.0105	0.0114	0.0778
2	2	-	-	0.01	0.02	0.07	0.0109	0.0204	0.0695
3	3	-	-	0.01	0.03	0.06	0.0099	0.0301	0.0605
4	4	-	-	0.01	0.04	0.05	0.0099	0.0398	0.0506
5	5	-	-	0.01	0.05	0.04	0.0101	0.0504	0.0394
6	6	-	-	0.01	0.06	0.03	0.0103	0.0599	0.03
7	7	-	-	0.01	0.07	0.02	0.0102	0.0698	0.0204
8	8	-	-	0.01	0.08	0.01	0.0103	0.0803	0.0104
9	9	-	-	0.02	0.01	0.07	0.0202	0.01	0.07
10	-	10	-	0.02	0.02	0.06	0.0207	0.0207	0.0589
11	11	-	-	0.02	0.03	0.05	0.0202	0.0305	0.0498
12	12	-	-	0.02	0.04	0.04	0.0193	0.0397	0.0407
13	13	-	-	0.02	0.05	0.03	0.0205	0.05	0.0291
14	14	-	-	0.02	0.06	0.02	0.0199	0.0601	0.02
15	-	-	15	0.02	0.07	0.01	0.0198	0.0698	0.0107
16	-	-	16	0.03	0.01	0.06	0.0297	0.0108	0.0598
17	17	-	-	0.03	0.02	0.05	0.0302	0.0198	0.0502
18	-	18	-	0.03	0.03	0.04	0.0298	0.0303	0.0402
19	19	-	-	0.03	0.04	0.03	0.0301	0.0401	0.0305
20	-	20	-	0.03	0.05	0.02	0.0282	0.0513	0.0201
21	-	-	21	0.03	0.06	0.01	0.0292	0.0599	0.0109
22	22	-	-	0.04	0.01	0.05	0.0401	0.0102	0.0503
23	23	-	-	0.04	0.02	0.04	0.0403	0.0203	0.04
24	24	-	-	0.04	0.03	0.03	0.0404	0.0301	0.0299
25	25	-	-	0.04	0.04	0.02	0.0397	0.0399	0.0204
26	26	-	-	0.04	0.05	0.01	0.0401	0.05	0.0101
27	-	-	27	0.05	0.01	0.04	0.0505	0.0102	0.0406
28	28	-	-	0.05	0.02	0.03	0.0501	0.0202	0.0303
29	29	-	-	0.05	0.03	0.02	0.0503	0.0299	0.0199
30	30	-	-	0.05	0.04	0.01	0.0501	0.04	0.0101
31	31	-	-	0.06	0.01	0.03	0.0602	0.01	0.0303
32	32	-	-	0.06	0.02	0.02	0.0597	0.0198	0.0203
33	-	33	-	0.06	0.03	0.01	0.0611	0.0295	0.0099
34	34	-	-	0.07	0.01	0.02	0.0701	0.0102	0.02
35	-	35	-	0.07	0.02	0.01	0.0716	0.0197	0.0096
36	36	-	-	0.08	0.01	0.01	0.0801	0.0101	0.0103
MSE	9.82×10^{-8}	7.36×10^{-7}	7.03×10^{-7}	-					
R	0.99988	0.99908	0.99966	-	-	-	-	-	-

The test set was not used during training. It was used to check the ability of the neural network to generalize what had been learned during training.

RESULTS AND DISCUSSIONS

The developed *MLP* neural network enabled the relationship between *SRF* values and dye concentrations to be mapped successfully. The regression plots in figure 6, which belong to the training, validation, and test subsets, show linear fits between target outputs and network outputs. All correlation coefficients *Rs* with their values near 1 indicate good fits. As given in table 1, all *MSE* values are approximately zero. These network performance measures indicate that the network accuracy is very high and the network is generalizing well what has been learned during training.

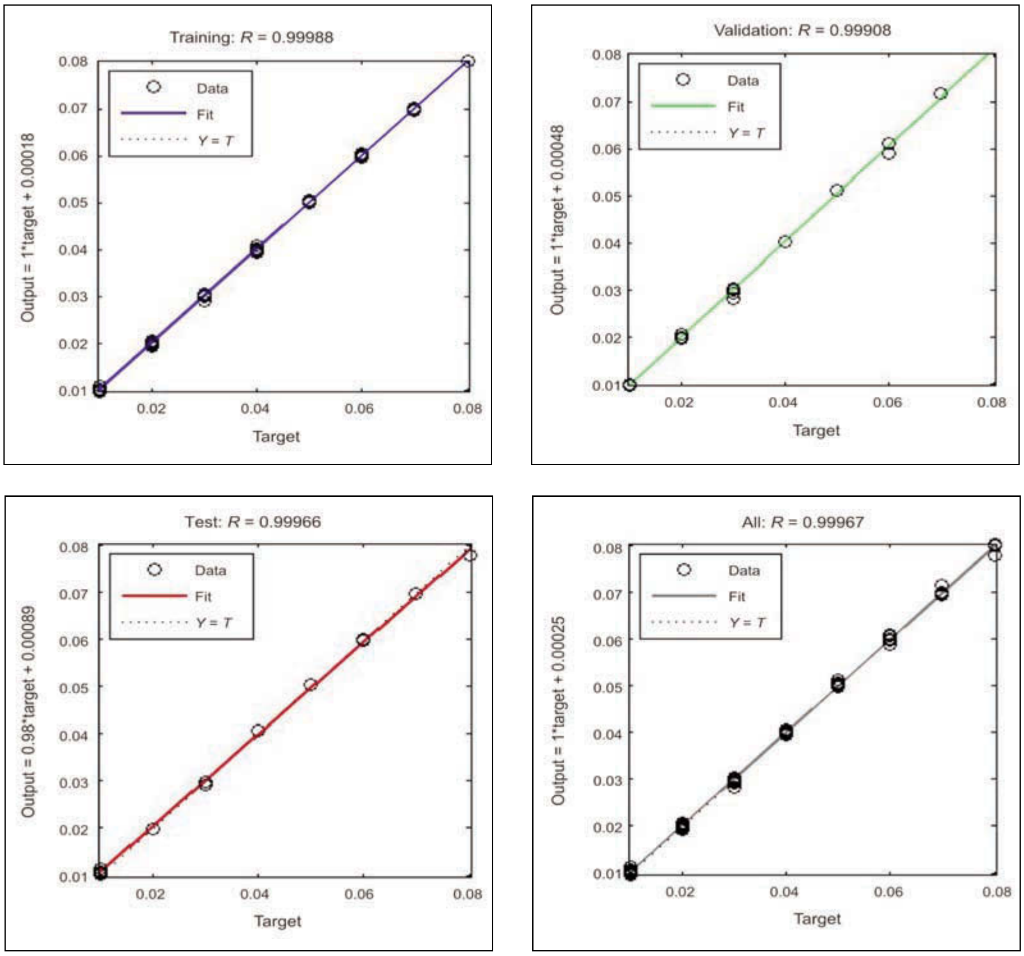


Fig. 6. Regression plots

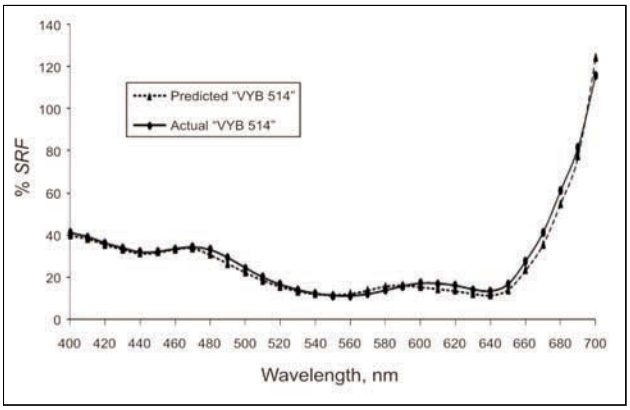


Fig. 7. The actual and predicted % *SRF* values of the *VYB 514* coded sample

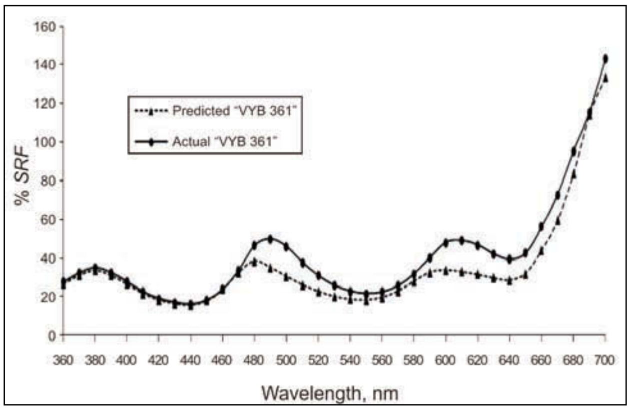


Fig. 8. The actual and predicted % *SRF* values of the *VYB 361* coded sample

For each combination, the spectral data obtained from the calibration dyeings of each dye [15], ranging from 0.001% to 1.5%, were used to predict the spectral radiance factor values for each predicted concentration obtained by the *MLP* neural network. Datacolor's Datamatch v3.5 "Manual Recipe Prediction" module was utilized for this purpose. In the classical Kubelka-Munk approach [17], the spectral radiance factors can be predicted by equation (4) where $f(R_{mix})$ is the reflectance function of the sample dyed with a mixture of three dyes $f(R_s)$ is the reflectance function of the substrate, $a_{\lambda v}$, $a_{\lambda y}$ and $a_{\lambda b}$ are the calibration coefficients of Violet 39, Yellow 40 and Blue 3 dyes at each wavelength from 400 to 700 nm, respectively, and C_v, C_y and C_b are the concentrations of Violet 39, Yellow 40 and Blue 3 dyes used in the calculations.

$$f(R_{mix}) = \frac{(1-R_{mix})^2}{2R_{mix}} = f(R_s) + a_{\lambda v}c_v + a_{\lambda y}c_y + a_{\lambda b}c_b \quad (4)$$

The predicted spectral radiance factors were later used to calculate CIELab values, and the colour difference $DE_{CMC(2:1)}$ values which are the values between the actual sample and the predicted sample were given in table 2. The $CMC_{(2:1)}$ formula was used to calculate the magnitude of the total colour difference. The lowest and the highest $DE_{CMC(2:1)}$ values obtained were 0.52 for *VYB 514* and 8.91 for *VYB 361* coded samples, respectively. The spectral curves for these samples are given in figure 7 and figure 8.

Table 2

ACTUAL AND PREDICTED CIELAB VALUES

Sample code	Actual CIELab values					Predicted CIELab values					$DE_{CMC(2:1)}$
	*L**	*a**	*b**	*C**	*h°*	*L**	*a**	*b**	*C**	*h°*	
VYB 118	55.57	-27.22	-20.10	33.84	216.45	55.05	-24.11	-20.77	31.82	220.75	1.82
VYB 127	56.45	-32.48	-12.21	34.70	200.61	55.82	-27.60	-13.85	30.88	206.65	2.76
VYB 136	58.75	-35.70	-6.01	36.20	189.56	56.73	-29.29	-8.25	30.43	195.73	3.47
VYB 145	60.74	-37.42	-0.06	37.42	180.09	57.83	-29.84	-3.21	30.01	186.15	4.09
VYB 154	63.86	-36.74	6.24	37.26	170.36	59.13	-29.28	1.48	29.31	177.11	4.66
VYB 163	65.97	-34.77	12.71	37.02	159.91	60.75	-27.43	6.28	28.14	167.10	5.11
VYB 172	68.64	-30.81	18.56	35.96	148.94	63.06	-23.58	11.87	26.40	153.28	5.07
VYB 181	73.26	-21.53	26.89	34.45	128.69	66.48	-15.66	19.22	24.79	129.18	5.18
VYB 217	52.51	-15.30	-24.03	28.49	237.51	51.81	-12.63	-24.07	27.19	242.31	1.84
VYB 226	54.36	-19.79	-15.58	25.18	218.21	52.52	-15.48	-17.19	23.13	227.99	3.30
VYB 235	55.59	-22.11	-9.11	23.91	202.40	53.40	-16.44	-11.58	20.11	215.14	4.25
VYB 244	58.63	-22.13	-3.12	22.35	188.04	54.49	-16.13	-6.48	17.39	201.90	4.90
VYB 253	60.53	-18.63	3.75	19.01	168.63	55.89	-14.34	-1.53	14.42	186.09	5.41
VYB 262	62.66	-14.53	10.20	17.75	144.91	57.91	-10.39	3.99	11.13	159.02	5.50
VYB 271	66.84	-4.53	18.83	19.36	103.54	61.01	-2.42	11.11	11.37	102.31	5.44
VYB 316	50.58	-6.58	-25.57	26.41	255.56	49.82	-4.29	-25.87	26.23	260.58	1.90
VYB 325	53.15	-9.89	-17.31	19.94	240.25	50.57	-6.54	-18.90	20.0	250.91	3.43
VYB 334	54.21	-10.72	-10.76	15.19	225.10	51.52	-6.82	-13.15	14.81	242.57	4.45
VYB 343	55.76	-8.48	-3.40	9.13	201.88	52.80	-5.47	-7.70	9.45	234.59	5.89
VYB 352	60.11	-4.90	4.08	6.38	140.22	54.68	-1.81	-1.94	2.65	227.02	7.93
VYB 361	64.08	5.08	12.88	13.84	68.47	57.63	5.86	5.29	7.89	42.07	8.91
VYB 415	49.11	2.15	-27.34	27.43	274.49	48.55	2.70	-26.85	26.99	275.73	0.62
VYB 424	51.50	-0.68	-18.10	18.11	267.86	49.39	1.09	-19.70	19.73	273.17	2.28
VYB 433	53.37	0.41	-10.95	10.96	272.15	50.56	1.77	-13.56	13.67	277.43	2.89
VYB 442	55.78	4.59	-3.36	5.69	323.80	52.35	4.91	-7.28	8.78	303.99	4.63
VYB 451	60.87	13.97	7.44	15.83	28.05	55.21	12.09	0.26	12.10	1.23	8.64
VYB 514	48.12	9.79	-27.54	29.23	289.57	47.76	9.18	-27.30	28.80	288.59	0.52
VYB 523	51.15	8.89	-17.59	19.71	296.81	48.83	8.51	-19.72	21.47	293.33	1.95
VYB 532	53.23	12.43	-9.23	15.48	323.39	50.53	10.91	-12.72	16.76	310.62	3.82
VYB 541	58.16	21.35	1.22	21.38	3.26	53.32	17.44	-4.62	18.04	345.16	6.07
VYB 613	48.75	18.65	-27.46	33.20	304.18	47.50	15.69	-27.13	31.34	300.05	2.03
VYB 622	52.16	19.31	-15.34	24.66	321.54	49.11	16.71	-18.65	25.04	311.85	6.61
VYB 631	55.79	27.25	-4.49	27.61	350.65	51.83	22.36	-9.79	24.41	336.37	5.21
VYB 712	49.31	27.44	-23.94	36.41	318.90	48.02	23.02	-25.96	34.70	311.56	3.18
VYB 721	53.53	32.92	-10.63	34.59	342.10	50.67	27.16	-15.54	31.29	330.22	4.74
VYB 811	51.89	39.43	-19.36	43.92	333.85	49.75	32.60	-22.83	39.80	325.0	4.20

CONCLUSIONS

The results of this study indicate that the *MLP* type artificial neural network with one hidden layer and *SRF* values fed into its input layer predicts colour recipes of fluorescent dyes in dyeing acrylic fabrics with great accuracy. The ability of the *ANN* in generating a non-linear mapping process offers distinctive advantage over traditional methods for colour matching recipe prediction due to complex and non-linear mechanism of the dyes and dyeing process.

BIBLIOGRAPHY

[1] Tehran, M. A., Maleki, M. *Artificial neural network prosperities in textile applications*. In: Suzuki, K. (Ed.), Artificial Neural Networks – Industrial and Control Engineering Applications, InTech, 2011, p. 35

[2] Hui, C. L. P., Fun, N. S., Ip, C. *Review of application of artificial neural networks in textiles and clothing industries over last decades*. In: Suzuki, K. (Ed.), Artificial Neural Networks - Industrial and Control Engineering Applications, InTech, 2011, p. 3

[3] Guruprasad, R., Behera, B. K. *Soft computing in textiles*. In: Indian Journal of Fibre & Textile Research, 2010, vol. 35, p. 75

[4] Shanbeh, M., Najafzadeh, D., Ravandi, S. A. H. *Predicting pull-out force of loop pile of woven terry fabrics using artificial neural network algorithm*. In: Industria Textilă, 2012, vol. 63, nr. 1, p. 37

[5] Kandi, S. G., Tehran, M. A. *Color recipe prediction by genetic algorithm*. In: Dyes and Pigments, 2007, vol. 74, p. 677

[6] Westland, S., Bishop, J. M., Bushnell, M. J., Usher, A. L. *An intelligent approach to colour recipe prediction*. In: Journal of the Society of Dyers and Colourists, 1991, vol. 107, p. 235

[7] Jasper, W. J., Kovacs, E. V., Berkstresse, G. A. *Using neural networks to predict dye concentrations in multiple-dye mixtures*. In: Textile Research Journal, 1993, vol. 63, p. 545

[8] Glogar, M. I., Parac-Osterman, D., Grundler, D., Rolich, T. *Research of influences of surface structure of coloured textiles: applying fuzzy logic*. In: Coloration Technology, 2011, vol. 127, p. 396

[9] Bezerra, C. M., Hawkyard, C. J. *Computer match prediction for fluorescent dyes by neural networks*. In: Journal of the Society of Dyers and Colourists, 2000, vol. 116, p. 163

[10] Golob, D., Osterman, D. P., Zupan, J. *Determination of pigment combinations for textile printing using artificial neural networks*. In: Fibres and Textiles in Eastern Europe, 2008, vol. 16, p. 93

[11] Haykin, S. *Neural networks: a comprehensive foundation*. 2nd edition, Pearson Prentice Hall, New Jersey, 1999

[12] Adeli, H., Hung, S. L. *Machine learning: neural networks, genetic algorithms and fuzzy systems*. John Wiley & Sons, New York, 1995

[13] Hagan, M. T., Demuth, H. B., Beale, M. H. *Neural network design*. PWS Publishing, Boston, 1996

[14] Zahlay, F. D., Rao K. S. R., Ibrahim, T. B. *A new intelligent autoreclosing scheme using artificial neural network and Taguchi's methodology*. In: IEEE Transactions on Industry Applications, 2010, vol. 47, no. 1, p. 306

[15] Acar, K. *A new method to improve the success of the fluorescent colour recipe prediction algorithms*. Ph.D. Thesis, Marmara University, Institute for Graduate Studies in Pure and Applied Sciences, Istanbul, 2009

[16] Beale, M. H., Hagan, M. T., Demuth, H. B. *MATLAB R2011b Neural Network Toolbox User's Guide*. The MathWorks, Inc., Natick, 2011

[17] McDonald, R. (Ed.) *Colour physics for industry*. 2nd edition, The Society of Dyers and Colourists, Bradford, 1997

Authors:

BAHAR SENNAROGLU
ÖZLEM ȘENVAR
Department of Industrial Engineering
Faculty of Engineering – Marmara University
Istanbul 34722, Turkey
e-mail: bsennar@marmara.edu.tr; ozlemsenvar@gmail.com

ERHAN ÖNER
Department of Textile Engineering
Faculty of Technology – Marmara University
Istanbul 34722, Turkey

Corresponding author:

Prof. dr. ERHAN ÖNER
e-mail: eoner@marmara.edu.tr

The effect of dye plant amounts on color and color fastness of wool yarns

MEMET İNAN

DURMUŞ ALPASLAN KAYA
SALIHA KIRICI

REZUMAT – ABSTRACT

Influenţa cantităţii de colorant din plante asupra culorii şi rezistenţei vopsirii firelor de lână

Nucul, sumacul, rodia, roiba și stejarul sunt utilizate pe scară largă în procesul de vopsire cu coloranți naturali. Pentru a măsura gradul de rezistență a vopsirii, fibrele de lână au fost mordansate, în prealabil, cu alaun. S-au folosit părți zdrobite ale plantelor în concentrații de 25%, 50%, 100% și 200% din cantitatea de lână vopsită. În cazul culorilor închise, pentru toate determinările, cantitatea de plantă utilizată a fost de două ori mai mare decât greutatea lânii. S-a constatat că, pe măsură ce concentrația de colorant a crescut, rezistențele la frecare și la spălare ale lânii au scăzut, în timp ce rezistența la picături de apă în stare umedă a crescut. De asemenea, rezistența la picături de apă în stare uscată s-a menținut ridicată (4-5).

Cuvinte-cheie: vopsire cu coloranți naturali, rezistență la frecare, rezistență la spălare, rezistență la picături de apă

The effect of dye plant amounts on color and color fastness of wool yarns

Walnut, sumac, pomegranate, madder and oak are plants widely used in natural dying. In order to measure fastness degree of wool dyed with these plants, dying were made by using mordant of alum. So, plant organs crushed at the weight of 25%, 50%, 100% and 200% of wool weight were used. Dark colors were determined at all samples with which plant two times of wool weight were used. However, as dye concentration increased, rubbing and washing fastness in wools decreased; whereas wet water dropping fastness increased. Dry water dropping fastness obtained from all concentration were found to be high (4-5).

Key-words: natural dying, rubbing fastness, wash fastness, water dropping fastness

Natural dyes have been used since ancient times and dying is ancient art. Many plants, some lichens and insects have been identified as potential rich in natural dye contents. Some parts of plants like fruits, seeds, flowers, leaves, stems and roots may contain coloring matter. Plant colorants are used in coloring foods, textiles, cosmetics and pharmaceutical preparations. A renewed international interest has arisen in natural dyes due to increased awareness of environmental and health hazards associated with the synthesis, processing and using of synthetic dyes [1]. Natural dyes are non-allergic to skin, non-toxic, easily available and renewable [2] – [5]. Majority of natural dyes need a chemical in the form of metal salts to create an affinity to the fibers and pigment. They are called mordants [6]. Common mordants used are potassium di-chromate ($K_2Cr_2O_7$), copper sulphate ($CuSO_4 \cdot 5\ H_2O$), ferrous sulphate ($FeSO_4 \cdot 7\ H_2O$), potassium aluminum sulphate ($KAl(SO_4)_2 \cdot 12\ H_2O$) etc. For acting as dye these chemicals have to have proper color and be capable to be fixed to the fabric and wool yarns [7].

Several bright colors with different shades were obtained depending on the nature of the used substrate, the concentration of the dye in the dying bath, and the type of the used mordant [8]. Moreover, mordants can make a positive impact on fastness values [9]. Plant species, mordants, the amount of mordant and dyeing methods are effective on fastness [10]. The effects of mordant on fastness have been known for a long time. There are many publications of fastness values [1], [3], [6], [8], [9], [11], [12]. Studies carried out related with the effect of amount of plant used on values fastness are limited. The aim of this study was determining values fastness of wool yarns and color transformation by using different amounts of plants.

EXPERIMENTAL PARTS

Materials used

In this study five different plants were using for natural dyes. These plants are heavily used of dyeing and sales on market yard or grows natural flora of Adıyaman of Southeast Anatolian Region, Turkey.

Fruit shells of *Juglans regia L.* (walnut), *Rhus coriaria L.* (sumac) and *Punica granatum L.* (pomegranate), roots of *Rubia tinctoria L.* (madder) and barks of *Quercus libani Oliver* (oak) were used for dying.

Methods used

Dystuff

The plant materials after drying are crushed to small pieces. Weight of wool 25%, 50%, 100% and 200% ratios of plant material were weighed, respectively. The plant materials were boiled in the water for an hour. This extraction was cooled and filtered.

Mordanting

$KAl(SO_4)_2 \cdot 12 H_2O$ (alum: Potassium aluminum sulfate) was used as stabilizer. The mordant used was 3% on the weight of the wool yarns and the amount of mordant were kept constant. The previously dampened wool yarns were boiled at 90ºC with the mordanted water for an hour. After mordanting, wool yarns were taken out of the solutions and dried at room temperature [3], [5], [7], [9].

Dyeing

Four dye concentrations were prepared from each plant dye solutions. The mordanted wool yarns were dyed by the exhaustion method at 90ºC for one hour with continuous mixing at liquor ratio (1:50). After cooling, the wool yarns were removed from the dye water and dried at room temperature [10].

Color identification

Dyed wool yarn samples were spread on a white background with the sunlight shining from one side and were coded according to their colours and tone differences (Y, Yellow; M, Red; C, Cyan blue) [3]. Colours identification were coded according to Küppers (1977) [13].

Fastnesses assessment

The dyed wool yarns were tested for rub fastness, wash fastness and water spotting (wet and dry) fastness. The rub fastness of dyed fiber was carried out by *Textiles – Tests for colour fastness. Part X12: Colour fastness to rubbing* [14]. The wash fastness was carried out by *Textiles – Tests for colour fastness – Part C10: Colour fastness to washing with soap or soap and soda* [15]. The water spot fastness was carried out by *Textiles - Tests for colour fastness. Part E07: Colour fastness to spotting: Water* [16]. This standard specifies a method for determining the resistance of the colour of textiles of all kinds and in all forms to spotting by water. Fastness measurements were made by researchers from Ankara University, College of Home Economics, Craft Department.

RESULTS AND DISCUSSIONS

Different plants and quantities of the plants were used in this research. The color of dye plants became darker by increasing the amount of plants in all studied samples. This is probably because the dyestuff concentration was increasing in the water solution. Thus, increasing the dye concentration darker shades were obtained. Tera et all. (2012) reported that the dying process is the availability of the dye molecules in the vicinity of fibers in the dyeing solution, and this in turn increases with increasing dye concentration in the solutions; similar results were obtained also in this study. The treated samples subject to light showed fairly good (3 to 4) rub and wash fastness for all ratio the amount of plants. However, while the amount of plants were increased, rubbing and washing fastness values were decreased. But, wet water drooping fastness was increased. Equal wool and plant samples gave medium values while 200% samples recorded low rub and wash fastness. The dry water dropping fastness grades ranged between excellent to good (4 to 5) for all of the treated samples. Fastness and the colors scales from all applications were shown in the table 1.

Walnut

Milk coffee, Fawn, and brown colors have been obtained from peel of walnut fruit. The fawn and brown were observed at high concentration, while milk coffee was observed for low dye concentration. Similarly, wide range of dark and light colors was obtained on wool using the dye extracted from walnut [17] and onion [8]. The wool dyed with walnut dye showed good (3 to 4) rub and wash fastness. The best results were obtained using 50% of the plant (3-4, 5). The color change to dry and wet water drooping from 200% treated samples was excellent (3-4 to 5) (table 1).

Sumac

The results in the table 1 show that by increasing the dye concentration darker shades were observed. Colors ranging from cane to khaki dying with sumac were obtained. Different colors were obtained with increasing the plant concentration. Light khaki and khaki were observed at high dye concentration. The effect of amount plants concentration on relative color strength is shown in table 1. It is clear that the increase of plants amount, decreases the rub and wash fastness (2). But, wet water dropping fastness was increased. For all that dry water dropping fastness was not changed (5).

Pomegranate

Table 1 shows that different shades of yellow were obtained from dye extracted from pomegranate. Cumin color was observed at highest dye concentration while mustard was observed at lawer; similar color was reported that by Kulkarni et al. (2011) [18]. The color strength values were displayed in table 1. The highest rub and wash fastness values (3-4 and, respectively, 4) were determined at lowest concentration (25%). The fastness decline after 25%. While there was little change in dry water dropping fastness, wet water dropping fastness values increased depend on concentration.

Madder

Red and shades of red color was obtained from madder (table 1). Claret red was observed at highest dye concentration when brick red was observed at lowest concentration. When the plant was equal to the weight of wool, color was observed light red. The dark brick red was found when amount of plant is reduced by 50%. The lowest rubbing fastness (1-2) in this research was obtained from the madder. However, excellent wet water drooping fastness (4) was determined in this plant. Good rub and wash fastness (3 to 4) were observed in 25% and 50% amount of plant dyed with the dye extracted from madder root.

Table 1

FASTNESS AND THE COLOR SCALES FROM ALL APPLICATIONS							
Plants	**The amount of plants, %**	**Color**	**Color scale**	**Rubbing fastness**	**Washing fastness**	**Water dropping fastness**	
						Wet	***Dry***
Walnut	25	Milk coffee	$Y_{50}M_{50}C_{40}$	3 - 4	3	2 - 3	5
	50	Fawn	$Y_{99}M_{60}C_{50}$	3 - 4	4	2 - 3	5
	100	Fawn	$Y_{99}M_{60}C_{50}$	3	3	3	4 - 5
	200	Brown	$Y_{99}M_{70}C_{50}$	3	3	3 - 4	5
Sumac	25	Cane	$Y_{60}M_{30}C_{40}$	3	4	2 - 3	5
	50	Light khaki	$Y_{60}M_{40}C_{40}$	3 - 4	3	2 - 3	5
	100	Light khaki	$Y_{60}M_{40}C_{40}$	3	3	3	5
	200	Khaki	$Y_{60}M_{50}C_{50}$	2	2	3	5
Pome-granate	25	Mustard	$Y_{80}M_{30}C_{30}$	3 - 4	4	2 - 3	5
	50	Dark mustard	$Y_{90}M_{30}C_{30}$	3	3	3	5
	100	Light cumin	$Y_{99}M_{40}C_{40}$	3	3	2 - 3	4 - 5
	200	Cumin	$Y_{99}M_{50}C_{50}$	2 - 3	3	3 - 4	5
Madder	25	Brick red	$Y_{90}M_{80}C_{00}$	3	4	2 - 3	4
	50	Dark brick red	$Y_{99}M_{80}C_{20}$	1 - 2	4	3 - 4	5
	100	Light red	$Y_{60}M_{99}C_{20}$	1 - 2	3	3	4 - 5
	200	Claret red	$Y_{60}M_{99}C_{40}$	1 - 2	3	4	5
Oak	25	Light caramel	$Y_{70}M_{50}C_{20}$	4	3	2 - 3	5
	50	Fallow	$Y_{70}M_{40}C_{20}$	2 - 3	3	3	4
	100	Dark fallow	$Y_{70}M_{40}C_{30}$	2 - 3	3	3	4-5
	200	Caramel	$Y_{70}M_{50}C_{30}$	3	2	3	5

Oak

Different shades of caramel were obtained from dye extracted from oak and the results are given in table 1. Light caramel was observed at lowest concentration when caramel was observed the highest concentration. Fallow and dark fallow were determined from 50% and 100% concentration, respectively. Samples dyed with oak bark extract with different concentrations have good rub fastness from another samples. Nevertheless, rub fastness decreases with the amount of plant decreases. Similarly, these results were obtained from fir cone (Abies sp.) extract [19]. Lowest wash fastness (2) was obtained from the highest concentration.

CONCLUSIONS

The natural dyes extracted from walnut, sumac, pomegranate madder and oak provide some beneficial properties. The dyes are eco-friendly and safe only when are easily biodegradable, having no health hazard effects. It was found from the study that when amount of plant was increased, the rubbing and wash fastness were decreased. On the other hand water dropping fastness was increased. However, darker colors can be achieved by increasing the amount of plant. But, such decreases of fastness degree is not important when getting dark color. For this reason, for a dark color and high fastness properties, different mordants, staining methods and different plants can be used.

ACKNOWLEDGEMENT

The authors of this paper are thankful to Mrs. Dr. Nuran Kayabaşı Craft Department of Ankara University and Ayşegül Karakelle Craft Department of Mustafa Kemal University, for her help and support in completion of this work.

BIBLIOGRAPHY

[1] Umbreen, S., Ali, S., Hussain, T., Nawaz, R. *Dyeing properties of natural dyes extracted from turmeric and their comparison with reactive dyeing*. In: RJTA, 2008, vol. 12, no. 4., p. 1

[2] Önal, A. *Extraction of dyestuff from madder plant (rubia tinctorum l) and dyeing of wool, feathered-leather and cotton*. In: Turkish Journal of Chemistry, 1996, vol. 20, issue 3, p. 204

[3] Türkmen, N., Kırıcı, S., Ozgüven, M., İnan, M., Kaya, D. A. *An investigation of dye plants and their colorant substances in the eastern Mediterranean region of Turkey*. In: Botanical Journal Linnean Society, 2004, vol. 146, issue 1, p. 71

[4] Dumitrescu, I., Vankar S. P., Srivastava, J., Mocioiu, A. M., Iordache, O. G. *Dyeing of cotton, silk and wool with Bixa orellana in the presence of enzymes*. In: Industria Textilă, 2012, vol. 63, issue 6, pp. 327-333

[5] Siva, R. *Status of natural dyes and dye-yielding plants in India*. In: Cur. Sci., 2007, vol. 92, issue 7, p. 916

[6] Kulkarni, S.S., Bodake, U.M., Pathade, G. R. *Extraction of natural dye from Chili (Capsicum Annum) for textile coloration*. In: Universal Journal of Environmental Research and Technology, 2011, vol. 1, p. 58

[7] İnan, M., Kırıcı, S. *The effect of different soaking times on colour and light fastness of wool yarns in the madder (Rubia tinctorum L.)*. Turkey VIIth Field Crops Congress, 25- 27 June 2007, p. 751

[8] Tera, F. M., Elnagar, K. E., Mohamed, S. M. *Dyeability and light fastness properties of onion scale dye on different fabric types for conservation applications*. In: Journal of Textile and Apparel, Technology and Management, 2012, vol. 7, issue 3, p. 1

[9] Kumaresan, M., Palanisamy, P. N., Kumar, P. E. *Application of eco-friendly natural dye on silk using combination of mordants*. In: International Journal of Chemistry Research, 2011, vol. 2, issue 1, p. 11

[10] İnan, M., Kırpık, M. *Effects of mordants used in different amounts of natural dye colors*. Turkey IXth Field Crops Congrees, 12 September 2011, vol. 2, p. 1 394

[11] Katarzyna, S. P., Kowalinski, J. *Light fastness properties and UV protection factor of naturally dyed linen, hemp and silk*. International Conference on Flax and Other Bast Plants, 2008, p. 364

[12] Chandra, M. S, Thiripura, S. S., Senthil, K. R., Thiyagarajan, A. *Dyeing of cotton with natural dye obtained from flower of tecoma stans*. In: Universal Journal of Environmental Research and Technology, 2012, vol. 2, issue 1, pp. 41- 46

[13] Küppers H. *Farbe, ursprung systematik Anwendung*. Munich: Callwey Verlag, 1977, pp. 175–195

[14] *Textiles – Tests for colour fastness – Part X12: Colour fastness to rubbing*, 2006, TS EN ISO 105-X12, TSE (Turkish Standards Institution)

[15] *Textiles – Tests for colour fastness – Part C10: Colour fastness to washing with soap or soap and soda*, 2011, TS EN ISO 105-C10, TSE (Turkish Standards Institution)

[16] *The water spot fastness was carried out Textiles – Tests for colour fastness – Part E07: Colour fastness to spotting: Water*, 2012, TS EN ISO 105-E07, TSE (Turkish Standards Institution)

[17] Kayabaşı, N., Şanlı, H. S., Etikan, S. *The colors obtained from some dye plants with mixed dying method and the light, friction and water dropping fastness values of these colors*. In: Gazi University Journal of the Faculty of Industrial Arts Education, 2003, vol. 13, p. 1

[18] Kulkarni, S. S., Gokhale A. V., Bodake, U. M., Pathade, G. R. *Cotton dyeing with natural dye extracted from pomegranate (Punica granatum) peel*. In: Universal Journal of Environmental Research and Technology, 2011, vol. 1, issue 2, p. 135

[19] Kılıçarslan, H., Arlı, M. *The fastness values on wool carpet yarns of the colors obtained from fir (Abies) cone*. In: Turkish Art Research Journal, 2011, vol. 2, issue 1, p. 161

Authors:

MEMET İNAN
Medicinal and Aromatic Plants Program
Kahta Voc. School, Adıyaman University
02400 Adıyaman, Turkey
e-mail: minan@adiyaman.edu.tr

DURMUŞ ALPASLAN KAYA
Department of Field Crops
Faculty of Agricultural
Mustafa Kemal University
31034 Hatay, Turkey

SALIHA KIRICI
Department of Field Crops
Faculty of Agricultura
Çukurova University
01330 Adana, Turkey

The introduction of water footprint methodology into the textile industry

LAI-LI WANG
XUE-MEI DING
XIONG-YING WU
DUNCAN-KARIUKI NDWIGA

REZUMAT – ABSTRACT

Introducerea metodologiei amprentei de apă în industria textilă

Aplicarea metodologiei amprentei de apă face posibilă măsurarea și evaluarea impactului asupra mediului al consumului de apă și al deversărilor de apă reziduală. În lucrare, este prezentat un algoritm de calcul al amprentei de apă într-o vopsitorie, pe baza datelor colectate din fabrică. Rezultatele arată că, în cadrul departamentului de producţie s-a înregistrat cel mai mare volum al consumului de apă și de generare a apelor uzate. Impactul asupra mediului cauzat de apele uzate este mai mare decât cel cauzat de consumul de apă. Epurarea apelor uzate poate reduce în mare măsură amprenta de apă, prin eliminarea poluanților din apă.

Cuvinte-cheie: amprentă de apă, consum de apă, deversări de apă reziduală, industria textilă

The introduction of water footprint methodology into the textile industry

The water footprint methodology makes it possible to measuring and assessing the impacts of water consumption and wastewater discharges. In this paper, we calculate water footprint of a dyeing factory based upon data collected from the factory. The results reveal that production department is the main source of water consumption and wastewater generation. Impacts on water environment caused by wastewater are severer than those caused by water consumption. Wastewater treatment can largely reduce water footprint through removing water pollutants.

Key-words: water footprint, water consumption, wastewater discharges, textile industry

The textile industry is a fragmented and heterogeneous sector dominated by small-and medium-sized enterprises. The whole life cycle of textiles involves many stages such as agriculture, industry, distribution, use and recycling. Industrial production of textiles is a long and complicated chain, and causes a wide range of environmental problems. Raw materials production, wastewater discharges from textiles processing and final products maintenance cause the majority of impacts on water environment [1]. Former study concluded that the industrial water consumption would show the most significant increase among the three major categories (i.e. agricultural, industrial and domestic) of water consumption, by about 76%, from 1995 to 2025 [2].

Water is used for cleaning the raw materials and for many flushing steps along the whole industrial production chain of textiles. As a result, large quantities of wastewater are generated and discharged to the natural water body, causing severe impacts on the water environment. As one of the most water intensive industries, there is a lot of published literature which gives attention to water saving and wastewater treatment technologies [3], [4]. However, researches related to water consumption and wastewater treatment in the textile industry were often carried out separately in former published literatures.

The water footprint *WF*, an idea introduced by Hoekstra and Hung, makes it possible to compare the environmental impacts caused by water pollution with those caused by water consumption [5] – [8].

Generally, the *WF* has three components: green water footprint, WF_{green}, blue water footprint, WF_{blue}, and grey water footprint, WF_{grey}. WF_{green} refers to the consumption of rainwater that do not become run-off, WF_{blue} refers to the consumption of surface and groundwater resources, WF_{grey} is an indicator of water pollution, and is defined as the volume of freshwater that is required to assimilate a load of pollutants to given natural background concentrations or existing ambient water quality standards [9], [10].

The *WF* provides a meaningful way for producers to better understand the environmental impacts of water consumption and wastewater discharges during the industrial production of textiles. It also enables the identification of ways for water consumption reduction and has the potential to underpin environmental friendly product declarations and initiatives involving communicating environmental and social performance to stakeholders.

In this paper, our research is focused on the application of the *WF* methodology to a textile factory that produces dyed yarns. We calculate WF_{blue} and WF_{grey} of the factory and water intensive processes. This study can provide specific guidance to the factory in promoting sustainable water consumption and reducing wastewater generation in different sectors and processes.

METHODOLOGY AND DATA

General approach

The *WF* of a dyeing factory consists of two main components: operational *WF* (WF_{oper}, m^3/year), the volume of water consumed or polluted due to factory's own operations and supply chain *WF* (WF_{sup}, m^3/year), the volume of water consumed or polluted when producing all the goods that form the inputs of production of dyed yarns in the factory [11]. The WF_{oper} is more important in the dyeing factory as it directly relates to its own water consumption, wastewater generation and discharges. The water consumed in this factory is sourced from the nearby river, and wastewater is discharged to a wastewater treatment plant. In addition, the WF_{oper} of the factory also consists of two components: operational blue *WF* ($WF_{blue,\ oper}$, m^3/year), the volume of water consumed due to the factory's own operations and operational grey *WF* ($WF_{grey,\ oper}$, m^3/year), the volume of freshwater that is required to assimilate the load of pollutants generated from factory's own operations to given natural background concentrations or existing ambient water quality standards. $WF_{blue,\ oper}$ and $WF_{grey,\ oper}$ can be calculated as:

$$WF_{blue,\ oper} = \sum_i WF_{blue,\ oper,\ depa[i]} = \sum_i FWA_{oper,\ depa[i]} \quad (1)$$

$$WF_{grey,\ oper} = \sum_i WF_{grey,\ oper,\ depa[i]} = \sum_i \frac{L^{COD}_{oper,\ depa[i]}}{c^{COD}_{max} - c^{COD}_{nat}} \quad (2)$$

where

$WF_{blue,\ oper,\ depa[i]}$ is the $WF_{blue,\ oper}$ of department *i*, m^3/year;

$FWA_{oper,\ depa[i]}$ – the volume of freshwater appropriated in operational department *i*, m^3/year;

$WF_{grey,\ oper,\ depa[i]}$ – the $WF_{grey,\ oper}$ of department *i*, m^3/year;

$L^{COD}_{oper,\ depa[i]}$ – the load of chemical oxygen demand – COD, the most critical pollutant in textile effluents that is associated with the largest pollutant-specific $WF_{grey,\ oper}$ – in wastewater generated in department *i*, kg/year;

c^{COD}_{max} – the maximum acceptable concentration of COD according to water quality standard, mg/l;

c^{COD}_{nat} – the natural concentration of COD in the receiving water body, mg/l;

Generally, c^{COD}_{max} is larger than c^{COD}_{nat} as setting standards equal to the natural concentration does not make sense.

For a specific production process *p*, $WF_{blue,\ oper}$ and $WF_{grey,\ oper}$ can be calculated as:

$$WF_{blue,\ oper,\ proc[p]} = FWA_{oper,\ proc[p]} \quad (3)$$

$$WF_{grey,\ oper,\ proc[p]} = \frac{L^{COD}_{oper,\ proc[p]}}{c^{COD}_{max} - c^{COD}_{nat}} \quad (4)$$

where:

$WF_{blue,\ oper,\ proc[p]}$ is the $WF_{blue,\ oper}$ of the production process *p*, m^3/year;

$WF_{grey,\ oper,\ proc[p]}$ – the $WF_{grey,\ oper}$ of process *p*, m^3/year;

$L^{COD}_{oper,\ proc[p]}$ – the load of COD in wastewater generated in process *p*, kg/year.

$WF_{blue,\ oper}$ and $WF_{grey,\ oper}$ of dyed yarns can be calculated as:

$$WF_{blue,\ oper,\ prod} = \frac{WF_{blue,\ oper}}{P} \quad (5)$$

$$WF_{grey,\ oper,\ prod} = \frac{WF_{grey,\ oper}}{P} \quad (6)$$

where:

$WF_{blue,\ oper,\ prod}$ is the $WF_{blue,\ oper}$ of the product (*i.e.* dyed yarns), m^3/t;

P – the production quantity of dyed yarns, t/year;

$WF_{grey,\ oper,\ prod}$ – the $WF_{grey,\ oper}$ of dyed yarns, m^3/t.

System boundary and data

Figure 1 is a simplified illustration of the system boundary for *WF* calculations. Data (table 1) used for *WF* calculation were directly collected from the dyeing factory [12]. c^{COD}_{max} (equals to 100 mg/l) refers to the Chinese standard, GB 4287-2010 Discharge standard of water pollutants for dyeing and finishing of textile industry. c^{COD}_{nat} was fluctuant along the research year and it was difficult to acquire precise data. In this case, we assumed c^{COD}_{nat} = 0 for simplicity ($WF_{grey,\ oper}$ was underestimated since c^{COD}_{nat} was actually not equal to zero) [11].

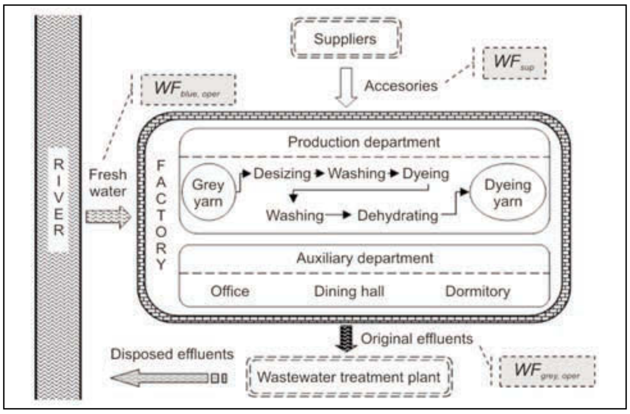


Fig. 1. System boundary for *WF* calculation

Table 1

DATA FOR *WF* CALCULATION				
Production quantity		**1 590 t/year**		
Departments and processes		***FWA,*** m^3/year	***Wastewater***	
			Quantity, m^3/year	*COD_{Cr},* mg/l
Production	Desizing	33 081	29 358	1 340
	B – washing (washing before dyeing)	70 036	68 282	540
	Dyeing	27 796	26 962	800
	A – washing (washing after dyeing)	26 357	25 531	470
Auxiliary		4 300	3 440	200

RESULTS AND DISCUSSIONS

Figure 2 and figure 3 show the calculated results of $WF_{blue,\ oper}$ and $WF_{grey,\ oper}$. As shown in figure 2, the $WF_{blue,\ oper}$ of the factory is 161 570 m^3/year. Production departments' $WF_{blue,\ oper}$ (157 270 m^3/year) is much larger (about 36.6 multiples) than that of auxiliary departments (4 300 m^3/year). Among the four processes, the $WF_{blue,\ oper}$ of *B*-washing is the largest (70 036 m^3/year), followed by desizing, dyeing and *A*-washing.

From figure 3, it can be seen that the factory's $WF_{grey,\ oper}$ is 110 4692 m^3/year. The $WF_{grey,\ oper}$ of production departments is 1 097 812 m^3/year, and represents about 99.4% of the total $WF_{grey,\ oper}$. Auxiliary departments share the rest (6 880 m^3/year) of $WF_{grey,\ oper}$. The sequence of production processes for $WF_{grey,\ oper}$ is different from that of $WF_{blue,\ oper}$. Desizing causes the largest $WF_{grey,\ oper,\ proc}$ with a value of 393 397.2 m^3/year. The $WF_{grey,\ oper,\ proc}$ of *B*-washing, dyeing and *A*-washing is 368 722.8 m^3/year, 215 696 m^3/year and 119 995.7 m^3/year, respectively. B-Washing's WF_{oper} (equal to the sum of $WF_{blue,\ oper,\ proc}$ and $WF_{grey,\ oper,\ proc}$) is the largest of the four processes. It is followed by desizing with a small difference (12 280.6 m^3/year). The WF_{oper} of *A*-washing is the least with a value of 146 352.7 m^3/year. Dyed yarns' $WF_{oper,\ prod}$ is about 796 m^3/t. The $WF_{blue,\ oper}$ and $WF_{grey,\ oper}$ of dyed years are 102 m^3/t and 695 m^3/t.

The calculated results indicate that production departments are the main source of water consumption and wastewater generation. The percentages of the two types of WF_{oper} exceed 95% (97.3% for $WF_{blue,\ oper}$ and 99.4% for $WF_{grey,\ oper}$). Therefore, more attention must be given to the production departments in order to reduce water consumption and wastewater generation.

Wastewater causes severer impacts on water environment. This is the same in the four production processes. The factory's $WF_{grey,\ oper}$ is nearly seven times of the $WF_{blue,\ oper}$. Proportion of $WF_{grey,\ oper,\ proc}$ caused by desizing, *B*-washing, dyeing and *A*-washing is about 92.2%, 84.0%, 88.6% and 82.0%, respectively.

The desizing process can remove sizing materials, which protect yarn against abrasion and snagging, prior to dyeing and finishing of woven fabrics. It contributes the largest proportion of the overall COD.

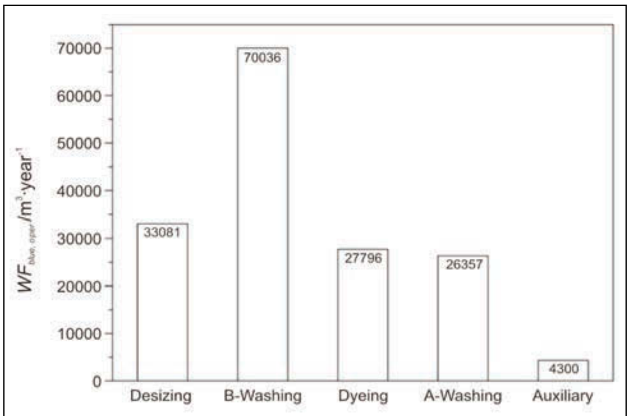


Fig. 2. Results of $WF_{blue,\ oper}$

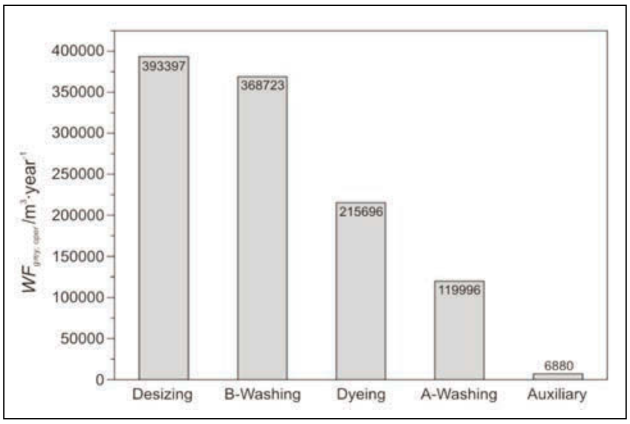


Fig. 3. Results of $WF_{grey,\ oper}$

Washing is closely related to desizing and dyeing. It can remove surplus dyes, auxiliaries and other chemicals to some extent. However, water consumed in this process is more compared to the other three processes. Dyeing is another process that generates effluents with high COD values caused by a wide range of dyestuffs and auxiliaries that are used in the process.

Pre-treatment is important to diminish the impacts caused by original generated effluents. The concentration of COD decreased to 78 mg/l after effluents treatment and 152 150 m^3 of disposed effluents were discharged into the river. Therefore, $WF_{grey, oper}$ of the factory decreased to 118 677 m^3/year, about 10% of the original $WF_{grey, oper}$.

CONCLUSIONS

The idea of *WF* is an important step towards evolving methodologies, approaches and indicators for measuring and assessing the impacts of water consumption and wastewater pollution. WF_{grey} makes it possible to compare the impacts of water pollution on water environment with those of water consumption. This paper has presented actual WF_{oper} of a dyeing factory based on data collected from the factory. The results reveal that:

- Production departments are the main source of water consumption and wastewater generation;
- Wastewater discharges cause severer impacts on water environment compared to water consumption;
- Wastewater treatment can largely diminish WF_{grey}.

ACKNOWLEDGEMENTS

The authors are grateful to Ministry of Science and Technology of the People's Republic of China for providing funding support to this research through project 201010041 and to the National Natural Science Foundation of China for providing funding support to this research through project 71373041.

BIBLIOGRAPHY

[1] Morrison, J., Schulte, P. *Water disclosure 2.0: assessment of current and emerging practice in corporate water reporting*. Oakland, CA, USA, 2009

[2] Cardone, R. *Wet business risks*. In: Business Knights Magazine, 2004, issue 3, p. 16

[3] Volmajer, Valh J., Majcen Le Marechal, A., Vajnhandl, S., Jerič, T., Šimon, E. *Water in the textile industry*. Elsevier Science, 2011, ISBN: 978-0-444-53199-5

[4] Pricop, F., Scarlat, R., Iordănescu, M., Moga, C., Ghiţuleasa, C., Popescu, A. *Integrated systems of monitoring and controlling wastewater quality.* In: Industria Textilă, 2013, vol. 64 , issue 1, pp. 40-45

[5] Rees, W. E. *Ecological footprints and appropriated carrying capacity: what urban economics leaves out*. In: Environment and Urbanization, 1992, vol. 4, issue 4, p.121

[6] Wackernagel, M., Onisto, L., Bello, P., Linares, A. C., López Falfán, I. S. et al. *National natural capital accounting with the ecological footprint concept.* In: Ecological Economics, 1999, vol. 29, issue 3, p. 375

[7] Chapagain, A. K., Hoekstra, A. Y., Savenije, H. H. G., Gautam, R. *The water footprint of cotton consumption: An assessment of the impact of worldwide consumption of cotton products on the water resources in the cotton producing countries.* In: Ecological Economics, 2006, vol. 60, issue 1, p. 186

[8] Hoekstra, A. Y., Chapagain, A. K. *Globalization of Water: Sharing the Planet's Freshwater Resources*. Blackwell Publishing, Oxford, 2008, ISBN: 978-1-4051-6335-4

[9] Hoekstra, A. Y., Hung, P. Q. *Virtual water trade: A quantification of virtual water flows between nations in relation to international crop trade*. Value of Water Research Report Series no. 11. UNESCO-IHE, Delft, the Netherlands, 2002

[10] Chapagain, A. K., Hoekstra, A. Y. *Water footprints of nations: water use by people as a function of their consumption pattern.* In: Water Resources Management, 2007, vol. 21, issue 1, p. 35

[11] Hoekstra, A. Y., Chapagain, A. K., Aldaya, M. M., Mekonnen, M. M. *The water footprint assessment manual: Setting the global standard*. Earthscan, London, UK, 2011

[12] Wang, H. Z. *Cleaner production practice in Jiangsu's key industries*. Hohai University Press, Nanning, 2006, ISBN: 978-7-5630-2311-0

Authors:

LAI-LI WANG
XUE-MEI DING
Fashion Institute of Design
Donghua University
Shanghai, China

XIONG-YING WU
Shanghai Entry-exit Inspection and Quarantine Bureau
Shanghai, China

DUNCAN-KARIUKI NDWIGA
International Cultural Exchange School
Donghua University
Shanghai, China

Corresponding author:

XIONG-YING WU
e-mail: wuxy@shciq.gov.cn

A customer-oriented perspective on retail brand equity in the fashion industry

DAN-CRISTIAN DABIJA

NICOLAE AL. POP
SILVIU G. SZENTESI

REZUMAT – ABSTRACT

Abordarea valorii brandului în industria vestimentației din perspectiva clienților

Una dintre temele majore în societatea contemporană – puternic marcată de hiperconcurență, globalizare și modificare rapidă în conduita comportamentală a cumpărătorilor – o reprezină dezbaterile teoretice și confruntările practice în jurul conceptului de brand. Distincția între brand, marcă a fabricantului, marcă proprie a comerciantului, marcă de magazin sau marcă a corporației nu beneficiază încă de o separație clară, atât în teorie, cât și în practică. De aceea, pentru toți stakeholderii unei afaceri este mai importantă valoarea capitalizată în marcă. Cercetarea întreprinsă încearcă să surpindă perceperea de către clienți a unor dimensiuni specifice unităților din România, care comercializează articole vestimentare și felul în care acestea sunt reflectate în customer-based brand equity. Analiza – derulată din perspectiva clienților magazinelor de modă, de articole sportive, respectiv de încălțăminte – scot în evidență pronunțate implicații manageriale și științifice. Autorii au în vedere evidențierea vectorilor specifici, prin intermediul cărora managementul unităților de comercializare a articolelor vestimentare poate acționa asupra clienților, determinându-le un anumit comportament preferențial sau de recomandare a magazinelor, în vederea creșterii încrederii acestora în unitățile analizate, a cantității achiziționate sau a nivelului de simpatie resimțit. Cu alte cuvinte, pentru managementul unității este relevantă identificarea unei căi optime prin intermediul căreia, acționând sinergic, să se poată obține un răspuns viabil din partea cumpărătorilor.

Cuvinte-cheie: brand, customer-based brand equity, marcă de magazin, textile, încălțăminte

A customer-oriented perspective on retail brand equity in the fashion industry

One of the major themes in the contemporary society – greatly affected by hyper-competition, globalization and rapid change in the behavior of demand agents (buyers) – consists of theoretical debates and practical challenges raised in relation to the concept of brand. There seems to be no clear-cut distinction, both in theory and particularly in practice, between brand, producer's brand, dealer's brand, store brand or corporate brand. Therefore, brand equity is even more important to corporate stakeholders. The present research attempts to capture customers' perception of some dimensions typical of Romanian fashion retailers and how these dimensions are reflected in the customer-based brand equity. The analysis, conducted from the perspective of customers of fashion, sporting goods and shoe stores, has significant managerial and scientific implications. In fact, the authors highlight specific directions that the management of fashion retailers may take to have customers adopt a particular behavior of preference or recommendation of stores so as to increase their trust in, and appeal of the said retailers as well as the quantity of purchased goods. In other words, it is important for the management of the fashion retailers to identify the most appropriate way whereby they can, through synergistic efforts, obtain a lasting response from demand agents.

Key-words: retail brand, customer-based brand equity, store brand, textiles, footwear

Brand has been one of the most debated themes in the scientific literature of the contemporary marketing. Specialists have pushed forward the idea that in the future the battle of the brands will be the most effective way of using marketing tools to ensure a company's competitiveness. In our opinion, brand represents the value judgments of all stakeholders involved in a business about the product, service, idea or the right to possess it [38].

Marketing researchers have a broad array of concerns related to the significance of brands for consumer behavior in general, and for the purchasing process, in particular. From representations of human values [45] to the impact of brand equity [7], [28], [30], [44], from the significance of brand for a company's rating [31] to the development of brand-based behavior decision models [33] the studies capture various facets having a common denominator: the major role of brand in delivering market performance by the companies that own it. The theme is also broadly approached by recent neuromarketing studies [19], [6]. These studies show that strong brands trigger significant neuronal effects unable to be "detected" through classical marketing research methods. The potential of such brands to stir up emotions in most customers is an element of subconscious, thus providing neurosciences with greater access to the marketing research [8], [31], [40]. The studies on sustainable development also tackle the 'brand' theme as major concerns exist, on designing and developing sustainable brands that meet some principles laid down in the literature and in practice [32], [34].

Brand equity

Embracing linguistic and visual identities, brand also possesses a subjective side generated by the emotional relationship between buyer and his/her images of the supply (good, service, idea, right) he or she receives and which is covered by a particular brand. This relationship is mainly supported by the values promoted by the particular brand [7]. At the same time, brand is also one of the company's intangible assets for which some accounting systems have a sum recorded on the balance sheet [29]. This is best reflected in the annual classification of the world's highest ranked brands. For example, the data for 2012 [www.interbrand.com/en/best-global-brands/2013] show that Apple is the current world leader, with a brand value amounting to 98.3 billion US dollars. The highest ranked brands in the fashion industry listed in "Top 100" hold positions ranging between 17 (Louis Vuitton – 24.893 billion US dollars) and 100 (GAP – 3,920 billion US dollars), among which one can mention H&M – 18.168 billion US dollars (position 21), Nike – 17.085 billion US dollars (position 24), Zara – 10.821 billion US dollars (position 36), Gucci – 10.151 billion US dollars (position 38) etc. [www.interbrand.com/en/best-global-brands/2013].

Although the above assessments are a matter of debate in terms of methodology, their purpose is to highlight the profound significance of the brand in furthering the economy of the company owning that particular brand.

The debates among the Romanian specialists about the concepts of "brand" and "trademark" are not yet over. At international level, a noteworthy contribution in this regard was made by the work of the American professor David A. Aaker [1] – [4]. In Romania, a long-standing advocate for a proper understanding of these concepts – both in theory and in practice – is Aneta Bogdan, founder of the company Brandient. In her book "Brandingul pe frontul de Est/Branding on the Eastern front", she pleads for the correct understanding and practical use of the concept of brand. Although "…it has not yet been found a Romanian designation" [7] for the concept of brand, it can be assimilated into the literature for proper use, different from the concept of trademark. The significance of the latter focuses on legal and figurative elements able to single a product or service out from similar products or services and on guaranteeing the owner's intellectual property rights.

Unlike trademark, brand establishes one-to-one relationships between exchange partners. Brand also incorporates a psychological subjective component related to how it is perceived by the potential and/or actual buyer of the good it represents. The evaluations derived from this perception are incorporated in brand equity [28], [29], [41].

Brand equity has been researched extensively throughout the world over the last few years. The importance of studying brand equity lies in its significance in shaping consumer behaviour and in determining the ways that contribute to triggering a particular response from consumers. The value, "deposit" or "capital" of the brand [20] represent the assets and liabilities related to the brand and its symbol, name or logo. Attaching tangible as well as intangible (awareness, appeal, trust, satisfaction, contentment etc.) elements to a brand determines an exponential increase or decrease of the market value of a product, service or company as a whole. Certainly, the gist of the concept of brand equity lies in its value according to consumers' perceptions, namely, the differential effect that brand knowledge has on consumer response to the marketing of that brand [28], [35], [42]. In other words, brand equity is and should be relevant to a company not only with respect to its tangible elements (assets, turnover, profit, market share etc.) but also with respect to intangible elements that shape consumers' behaviour and ensure better brand positioning in consumers' mind.

Any attempt to conduct rigorous research on a brand's perception by potential and current customers means significant gains for the companies promoting that brand. The value created and conveyed by a brand is directed towards both customers (so as to be recognized) and the company owning the brand (so as to be used in competition). For the customer, brand is the supplier's commitment to provide quality, an element of differentiation, a framework for valuation (ostentatious consumption of luxury brands), while its financial side, degree of attractiveness and its role of trade facilitator bring extra benefits to the company [28], [29]. Within this context, a distinction should be made between brand and producer, retail, own or corporate brand equity. In fact, a product or service may be branded at all these levels [27], [33].

An essential factor in marketing a particular brand is the retail framework within which the brand is offered to the customers [13], [14]. Specifically, it is about the chain of retail outlets through which selling is accomplished. Various elements such as assortment, ambience, location, POS advertising, etc. typical of a particular concept of retail trade [15], [16] may exert a significant effect, either directly on the outcome of the retail action or indirectly on the value of brands provided within that framework. While brand equity is difficult to measure in monetary units, it is much easier to quantify the perception of various elements that influence the purchase of a brand.

Research objectives and methodology

The purpose of the current research is to investigate, from the customers' perspective, how the dimensions of Romanian fashion retailers impact on the value of well-known fashion brands and of the stores that market them (retail brands). The empirical model that the authors propose for testing is presented in figure 1. This model is the result of previous research conducted by one of the authors, and is based on empirical studies already validated in the food and non-food

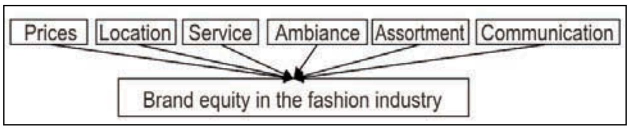


Fig. 1. Proposed analysis model

retail [15]. The research covered the whole range of fashion items, from shoes to hats, and was conducted in stores run under the brand of famous international retailers. Respondents were invited to state at least three clothing, shoe and sporting goods stores where they shop most frequently and interviewers had to select one of the previously stated stores in order to have the questionnaire filled in. The interviewees made value judgments most frequently with respect to big stores marketing clothing items such as H&M, Zara, C&A etc., units marketing various sports items-clothing and equipment (fashion, sports etc.) such as Decathlon, Intersport, Hervis and boutiques such as Debenhams, Bigotti, Bershka, Calliope, CATO etc. Relatively few assessments were collected for designer stores (Jolidon, Braiconf), stores of “famous brand” producers (Puma, Nike, Adidas, Leonardo, Deichman) as well as "concept stores". Although an attempt was made to obtain a relatively equal number of responses for each store category (retail format), this was prevented by the random selection of respondents. The research was conducted inside stores and shopping centers in Transylvania during the period of October 2011 – January 2012.

In order to ensure a careful organization of the research, the authors achieved a proper implementation by operationalizing all dimensions presented in figure 1.

The translation of theoretical concepts into indicators valuable by customers of fashion stores is presented in table 1.

Table 1

OPERATIONALIZATION OF DIMENSIONS	
The preferred store ...	**Dimension**
... has a wide assortment of own brands.	**Assortment**
... has always available items and I never stand in front of an empty shelf.	
... offers high-quality products.	
... provides the needed products in one location only.	
... has a layout that allows me to find easily the needed product.	**Ambiance**
... has a pleasant ambiance for shopping.	
... facilitates simple and easy purchases.	
... is always clean and tidy.	
... has a good ambiance.	
... keeps constant good prices over a long period of time.	**Price**
... charges, in general, reasonable prices.	
... charges good prices by comparison with similar stores.	
... offers a good quality/price ratio.	
... provides special assortments at attractive prices.	
... is generally well advertised.	**Communication**
... is frequently advertised.	
... promotes information-oriented advertising.	
... offers service which makes me feel attention is paid to my problems.	**Service**
... has very friendly employees eager to help customers.	
... has well-trained and highly-qualified employees.	
... offers good service in general.	
... is at a quick reachable location.	**Location**
... is at a convenient location.	
... is at an optimal location.	
... is at a good location near other stores.	
... is at a good location near food stores.	
... is in the neighborhood of other service providers.	
... treats fairly its customers.	**Brand equity**
... is appealing to me.	
I enjoy every purchase from the preferred store.	
I have made a firm decision to buy from the preferred store.	
I am ready to recommend positively the preferred store to my acquaintances.	
I generally have confidence in the preferred store.	

Sources: adapted by [5; 10; 11; 14; 16; 17; 21; 22; 23; 24; 29; 36; 43; 47; 48]

Table 2

RESULTS OF DATA VALIDITY AND RELIABILITY TESTING						
Dimensions	**No. of items**	**$\alpha^1 > 0,7$**	**$KMO^2 > 0,7$**	**χ^2; *df*; p^3**	**Eigen-value**	**% variance**
Assortment	5	0.799	0.769	1266.15; 6; ****	2.458	61.45
	4	0.814				
Ambiance	5	0.904	0.885	3 281.95; 10; ****	3.612	72.23
Price	5	0.888	0.848	3 032.19, 20; ****	3.461	69.22
Communication	3	0.885	0.819	1 908.53; 12; ****	2.443	81.45
Service	5	0.878	0.827	2 826.23; 16; ****	3.104	77,60
	4	0.904				
Location	6	0.883	0.861	3 536.59; 15; ****	3.84	63.99
Retail brand equity	6	0.874	0.871	3 102.50; 15; ****	3.70	61.72

Note: [1] is Cronbach's alpha coefficient (checking data reliability); [2] – Kaiser-Meyer-Ohlin criterion (exploratory factor analysis) for each dimension; [3] – Bartlett's test of sphericity (χ^2 – hi square, *df* – degrees of freedom, *p* – probability; ****p < 0,001; ***p < 0,01; **p < 0,05; *p < 0,1)

The concepts were operationalized into questionnaire statements to which people visiting frequently fashion stores in Transylvania were asked to respond. To facilitate the assessment, respondents were asked to judge the characteristics in table 1 on a five-point Likert scale (total agreement – total disagreement). Given the experimental nature of the research, the survey technique was used to administer questionnaires to customers shopping at malls, in public places, and at their workplace or home. Questionnaires were distributed by several interviewers under the supervision of one of the authors. Out of over 1 500 collected questionnaires, only 1 088 could be validated. The questionnaires contain consumers' assessments recorded in clothing general stores (593 answers – 54.5%), sporting goods and clothing stores (281 answers – 25.8%) and in footwear stores (214 answers – 19.7%).

The fashion stores were selected at random. Thus, interviewers asked respondents to name three non-food stores where they frequently go shopping. Interviewers were instructed to select at random one of the three above-named stores and ask respondents to state their opinion against the questionnaire statements. Interviewers had to comply with a pre-set sampling plan during the selection of respondents. The sampling plan is based on the quota sampling method typical of exploratory research [9], [38] according to a range of socio-demographic variables such as age, gender, members in a household, net income per person, in compliance with the data provided by the Romanian Statistical Yearbook of 2010.

The most frequently evaluated fashion stores were H&M (97 evaluations), C&A (38 evaluations), Zara (116 evaluations) while fewer evaluations were recorded for the smaller units: Bershka (34 evaluations), New Yorker (32 evaluations), Pull&Bear (25 evaluations), Kenvelo (19 evaluations) etc. As far as sporting goods stores are concerned, the analysis covered the units of famous producers such as Puma (18 evaluations), Nike (26 evaluations) or Adidas (46 evaluations) as well as retailers marketing a wide range of items for all sports, from clothing and footwear to sports equipment, such as Decathlon (49 evaluations), Hervis (31 evaluations) or Intersport (40 evaluations). Footwear stores were also included in the survey, both large retail chains like Leonardo (106 evaluations) and Deichmann (84 evaluations), and small retail chains like Benvenutti (17 evaluations) and Humanic (11 evaluations) etc.

Following their collection, the answers were systematically introduced into SPSS and subject to various tests. Thus, the data were checked for correctness, reliability and internal consistency through the use of the Cronbach's alpha coefficient ($\alpha > 0.7$), the "item-to-total" correlation, the *KMO* criterion (> 0.7), Bartlett's test of sphericity (the exploratory factor analysis) and the calculation of fit indices for the aggregated model presented in figure 1. The items were further analyzed by means of the AMOS structural equation modeling [12], [15]. As some items did not feature a sufficient level of consistency, they were removed, following the application of Cronbach's alpha coefficient, while the remaining analyses of each dimension were conducted with fewer items. The results of the tests are presented in table 2.

Once the stability of the "retail brand equity" dimension and of the six factors peculiar to fashion retailers (assortment, ambiance, price, communication, service and location) was ascertained, the six factors were aggregated into a single oblique rotation factor analysis typical of empirical exploratory research [47]. The results showed that the six dimensions through which retailers can influence consumers are clearly delineated by respondents (table 3). At the same time, high values were recorded for the fit indices, as can be seen in table 3 (*KMO* = 0.940, x^2 = 19,259.773; *df* = 351; eigenvalues 6.018/3.682/1.312).

Table 3

DELINEATION OF RETAIL MARKETING COMPONENTS OF FASHION STORES FOLLOWING THE EXPLORATORY FACTOR ANALYSIS						
Structure matrix[a]	Factor					
	1	*2*	*3*	*4*	*5*	*6*
... has a layout that allows me to find easily the needed product.	0.862	-	-	-	-	-
… has a pleasant ambiance for shopping.	0.827	-	-	-	-	-
... facilitates simple and easy purchases.	0.770	-	-	-	-	-
... is always clean and tidy.	0.674	-	-	-	-	-
... has a good ambiance.	0.633	-	-	-	-	-
... is at a quick reachable location.	-	0.822	-	-	-	-
... is at a convenient location.	-	0.801	-	-	-	-
... is at an optimal location.	-	0.729	-	-	-	-
... is at a good location near other stores.	-	0.716	-	-	-	-
... is at a good location near food stores.	-	0.686	-	-	-	-
... is in the neighborhood of other service providers - banks, agri-foodstuff market.	-	0.653	-	-	-	-
... is generally well advertised.	-	-	0.917	-	-	-
... is frequently advertised.	-	-	0.859	-	-	-
... promotes information-oriented advertising.	-	-	0.752	-	-	-
... keeps constant good prices over a long period of time.	-	-	-	0.880	-	-
... charges, in general, reasonable prices.	-	-	-	0.752	-	-
... charges good prices by comparison with similar stores.	-	-	-	0.684	-	-
... offers a good quality/price ratio.	-	-	-	0.622	-	-
... provides special assortments at attractive prices.	-	-	-	0.517	-	-
... offers service which makes me feel attention is paid to my problems	-	-	-	-	-0.901	-
... has very friendly employees eager to help customers.	-	-	-	-	-0.809	-
... has well-trained and highly-qualified employees.	-	-	-	-	-0.799	-
... offers good service in general.	-	-	-	-	-0.597	-
... has a wide assortment of own brands.	-	-	-	-	-	0.705
... has always available items and I never stand in front of an empty shelf.	-	-	-	-	-	0.607
... offers high-quality products.	-	-	-	-	-	0.474
... provides the needed products in one location only.	-	-	-	-	-	0.434
Eigen values	11.22	2.32	1.83	1.60	1.13	1.03
% of variance	41.55	8.62	6.77	5.93	4.18	3.82
Extraction method: principal axis factoring. Rotation method: oblimin with Kaiser normalization						
a. Rotation converged in 8 iterations						

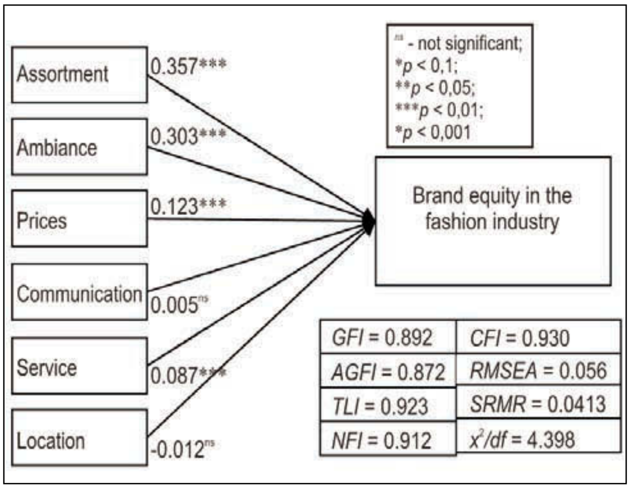
Source: own research

As the exploratory factor analysis conducted on the dimensions of the retail marketing mix revealed a clear delineation in terms of data consistency, all dimensions in figure 1 were subject to the structural equation modeling with AMOS. The model fit was confirmed by high values for the *GFI, AGFI, TLI, NLI, CFI* > 0.8, *SRMR* > 0.8 (Standardized root mean square residual) indices and the *RMSEA* > 0.8 index [15], [21], [26].

Results for the general model

As the main fit indices (*GFI, AGFI* etc.) exceed the minimum required value (fig. 2), the investigated phenomenon was tested with the structural equation modelling.

It has been noticed that ambiance (0.303****) and particularly assortment (0.357****) contribute to building the brand equity of clothing, sports and footwear stores, while communication ($0.005^{n.s.}$) and location



Source: own research

Fig. 2. Factors affecting retail brand equity

(–0.012$^{n.s.}$) are not significant in terms of scope and representativeness. Although prices do not make a great contribution to building retail brand equity, their impact is highly significant (0.123****). Service exerts a weaker impact in terms of significance and intensity (0.087**). In order to outperform the competition, the companies' decision makers should focus on the elements that do not have a major and significant impact on brand equity (location and communication), without neglecting the elements which yield a favorable perception (mainly assortment and ambiance).

Assortment. The strong impact of assortment (0.357) is accounted for by respondents' choosing to visit the stores motivated by the width, depth and diversity of assortment. In other words, assortment variety and the various and ever-changing themes prompts individuals to visit these units. Assortment acts like a powerful magnet to customers, capturing their attention and generating competitive advantage. Quality is likely another significant contributor to the formation of opinions about the marketed items and assortments.

Ambiance. Respondents expressed a proper appreciation of the fact that stores make efforts to offer a pleasant and familiar environment where customers feel good and relaxed. The interior design, the play of light and shadow, the departments layout contribute to a favourable valuation of the stores (0.303****). Interior decoration and design may actually be the main element that differentiates stores from their competitors.

Price. The price policy exerts *a* more-than-marginal impact on building brand equity (0.123****). Consumers assess price favourably, highlighting its full contribution to building retail brand equity. Being a positive impact, most respondents assess the price level as a fair one, despite the relatively high prices charged by other stores like "Zara". However, respondents believe that the purchased clothes, footwear or sporting goods are worth the money due to their quality and because a part of the assortment is regularly changed. The less strong impact of the 'price' vector on building brand equity may be due to situational factors and also to respondents-related subjective factors. It is very likely, therefore, that respondents do not state price is a determining factor because they are reluctant to admit they choose to purchase expensive items when going shopping. The motivation behind such behavior is represented by social belonging or self-surpassing which usually are not admitted openly by interviewees

Communication. The very limited and insignificant impact of communication lies in the relatively high social and financial risk incurred by purchasing these products. In other words, respondents' involvement in selecting the store and the goods as well as in drawing comparisons between various offers, product characteristics, advantages and disadvantages is significantly greater than in the case of food items/stores. Any possible functional risk that may arise (the purchased clothes do not fit or fail to meet the expectations) prompts consumers to actively search for information so that their needs may be fully satisfied. On the other hand, retailers' communication is by no means unitary. Thus, there are sustained communication campaigns launched by "newcomers" or by retail chains that afford it or want to change how respondents perceive them (H&M). There are also retailers that only focus on "communicating" the advantageous or seasonal offers (sporting goods stores). Relying solely on the "strength" of their own brand, other retailers completely neglect proper communication (Zara), choosing to draw customers mainly through varieties and regular changes of assortments.

Service. Although of a relatively low intensity and significance (0.087**), service makes a positive contribution to building retail brand equity in consumers' mind. The low representativeness of this dimension may be the result of a shortage of personnel and the fact that these are not always properly informed or do not know precisely where to find/locate a particular item. On the other hand, a consumer buying a sports, clothing or footwear item is generally a well-informed person, a fact that reduces the need to inform him or her. However, respondents assess favourably employees' behaviour as well as their suggestions, advice and kindness.

Location. The extremely low and utterly insignificant impact of location is somewhat surprising at first sight but is entirely justifiable in view of the fact that the majority of surveyed stores are located in shopping centers. The main reason behind visiting shopping centers often lies in purchasing food or enjoying leisure time. Therefore, people do not choose to visit a particular clothing or footwear store but, since they are in a shopping center, enter one store after another hoping to find a new, innovative item that meets their own expectations and possibilities.

Breakdown of results by clothing, sports and footwear items

The breakdown of results by the three types of stores (table 4) revealed a situation similar to that for the retail as a whole, albeit with slight differences.

Table 4

IMPACT OF CHARACTERISTICS OF FASHION, SPORTS AND FOOTWEAR STORES ON RETAIL BRAND VALUE

	Fashion	Sport	Shoes	χ^2		χ^2/df	*TLI*
Assortment à *RBV*	0.377****	0.268*	0.379****	3 924.834	1 474	2.663	0.901
Ambiance à *RBV*	0.306****	0.270***	0.295***	*RMSEA* (≤ 0.08)		*GFI*	*AGFI*
Price à *RBV*	0.057*	0.154$^{n.s.}$	0.113$^{n.s.}$	0.039		0.849	0.804
Communication à *RBV*	-0.041$^{n.s.}$	0.117*	0.080*	*SRMR* (≤ 0.08)		*NFI*	*CFI*
Service à *RBV*	0.071$^{n.s.}$	0.231**	0.030$^{n.s.}$	0.0492		0.857	0.898
Location à *RBV*	-0.016$^{n.s.}$	-0.074$^{n.s.}$	-0.011$^{n.s.}$	$^{n.s.}$ is insignificant		*$p < 0.1$	
Respondents	593	281	214	***$p < 0.01$	**$p < 0.05$	**** $p < 0.001$	

Note: *RBV* is retail brand value
Source: own research

Assortment. The impact of assortment on the perception of brand value of the analyzed retailers differs in intensity and significance. A major impact has been recorded with fashion (0.377****) and footwear (0.379****) stores, while sporting goods stores only exert an insignificant impact (0.268*). This striking contrast may lie in respondents' penchant for wide assortments in fashion and shoe stores at the expense of sports items/stores. Consumers' exhibiting a weaker perception may result from the fact that, unlike fashion and shoe stores where assortment is relatively homogenous, product assortments on sporting goods stores are, by comparison, much more heterogeneous-various sports equipments as well as fashion items covering a wide range of needs. Consequently, it may even be a case of "watering down" respondents' perception of the retail units as they view assortment as being too wide to create a proper opinion about it.

Ambiance. The ambiance of the three types of stores is relatively similar in terms of impact and significance. In other words, all surveyed units decorate properly – and beautifully, we might add – the interior and related components. According to results, however, companies fail to achieve significant differentiation in terms of ambiance.

Price. A favourable but weak (in intensity) and less significant impact on building the retail brand value is exerted by the price policy of fashion stores (0.057*), while the same characteristic of retailers is insignificant in the case of the other types of stores (sports and shoes). While with the fashion stores the impact of the price policy is determined by a reasonable price level, the insignificance of the impact with sports and shoes stores is surprising at first sight. It is to be noted that respondents consider the quality-price ratio of the analysed fashion stores as being appropriate.

Service. A differentiated impact of service quality has been recorded across the three types of stores. Service does not play a significant role in building the brand value of fashion or shoes retailers. However, it has a major impact (0.231**) in the case of sports stores, much like that of assortment (0.268*) and ambiance (0.270***). This is likely due to the assortment depth of some items which cannot be "tracked down" without the help of specialized personnel. On the other hand, the store personnel are also appealed to in the case of customized sports items. By comparison with the other two types of stores, the number and training of the personnel in sports stores is quite high.

Communication. Communication differs considerably among the three types of surveyed stores. While respondents do not perceive communication in the case of fashion stores, the communication efforts in the case of sports stores are relatively intense but less significant (0.117*). Sports stores such as Decathlon, Hervis or Intersport launch advertising campaigns during specific events (marathons, sports events/games), at the beginning of the school year or during traditional holidays. Moreover, the sports units have an active presence on social networks like Facebook, Twitter or Linkedin where they also organize various games and competitions. Respondents also perceive the communication that shoe stores perform when regular price discounts and special offers are announced or during some holidays.

Location. The survey results show that location does not exert a significant impact for any of the stores. This is mainly because stores are located in shopping centers where respondents come, not to visit the stores in particular, but to have a nice time for a few hours, meet friends, have a conversation over a glass of wine, watch a film or visit food outlets (Auchan, Carrefour, Cora etc.).

Managerial implications and directions for future research

The present study points to the conclusion that a great number of factors contribute to customers' perception of brand equity. As these factors are closely intertwined, it is difficult to distinguish between each one's impact on brand equity. The practical significance of distinguishing each factor's contribution to the assessment of a brand by customers brings major competitive advantages to the managers of fashion retail chains and, indirectly, to producers.

Brands which the public perceive to be strong affect significantly the options of purchasing the products marketed under the said brands. The research results clearly highlight the major significance of assortment on how customers perceive a fashion brand. This factor should be dealt with differently according to the retail format through which a brand is marketed. Specialized stores, mainly the shoe stores (classical or sports shoes), have the advantage of a polarized attraction towards a particular product brand (for instance, Otter, Adidas, Nike etc.). Through their wide assortments, the big stores (H&M, Zara, C&A etc.) allow customers to draw a comparison between the marketed brands. This could help the said retail chains to establish a management direction to follow. The specialized stores marketing a single brand could strengthen their market presence by means of a policy to gain the loyalty of already attracted customers. This is an instance of applying relationship marketing, where efforts are made to go from customer retention to customer loyalty [39] whose climax, otherwise difficult to reach, is exclusivity. At the same time, large area stores marketing multiple brands can focus on attracting new customers, an attempt typical of transactional marketing. Store ambiance is another notable element that has some "say" in determining the brand value. One should not consider only the deciding element triggering demand for a particular brand (awareness and/or the best quality-price ratio) but also the other factors that trigger demand, most of which can be incorporated into the concept of ambiance. The quality customer service in a pleasant, harmoniously styled ambiance that matches nicely the usage destination of the marketed brands persuades customers to express their purchasing decision. One should not overlook that most customers of fashion stores do not pursue the sole satisfaction of their own need for body protection. The elements that decide the purchase may be related to the status achieved by wearing a particular brand or the satisfaction of giving someone a clothing item sold under a fashionable brand name.

The other factors analyzed within the proposed model (point of sale advertising, service, location) are highly interconnected and distinguishing the role played by each factor could represent a topic for further research. As an element shaping the brand value of fashion items, price also ought to be researched individually to better identify its contribution in this regard. More than in the case of the other factors of the model, in the case of the 'price' factor the contemporary customer weighs the relation quality-price-degree of need satisfaction. This is a reason for marketing research to focus more carefully on the clear delineation of the content of the customer need when he or she wishes to purchase a fashion product marketed under a famous brand name. Certainly, the regional and the historical specificities can by no means be neglected in explaining this impact of price. The authors believe that the impact of price on shaping a particular behavior towards fashion stores may vary across regions.

However, this research was focused on highlighting the main vectors that contribute to building brand equity and not on the comparative analysis of socio-economic indicators that may affect consumers' motivation when selecting a particular type of store. These aspects will be subject to an in-depth analysis as part of a future piece of scientific research conducted by the authors.

BIBLIOGRAPHY

[1] Aaker, D. A. *Building strong brands*. The Free Press, New York, 1996

[2] Aaker, D. A., Joachimsthaler, E. *Brand leadership*. The Free Press, New York, 2000

[3] Aaker, D. A., Landrevie, J. *Le management du capital-marque.* Dalloz, Paris, 1995

[4] Aaker, D. A. *Managing brand equity.* The Free Press, New York, 1991

[5] Anselmsson, J. *Sources of customer satisfaction with shopping malls: A comparative study of different customer segments*. In: International Review of Retail, Distribution and Consumer Research, 2006, vol. 16, issue 1, pp. 115-138

[6] Basu Monga, A., Gürhan-Canli, Z. *The influence of mating mind-sets on brand extensión evaluation*. In: Journal of Marketing Research, August 2012, vol. XLIX, issue 4

[7] Bogdan, A. *Brandingul pe frontul de est. Despre reputație, împotriva curentului.* Brandient, București, 2010

[8] Bruhn, M., Köhler, R. *Wie Marken wirken. Impulse aus der Neuroökonomie für die Markenführung.* Vahlen Verlag, München, 2010

[9] Cătoiu, I. (coord.) *Cercetări de marketing.* Tratat, editura Uranus, București, 2009

[10] Chaudhuri, A., Holbrook, M. B. *The chain of effects from brand trust and brand affect to brand performance: the role of brand loyalty*. In: *Journal of Marketing*, 2001, vol. 65, issue 2, pp. 81-93

[11] Chowdhury, J., Reardon, J., Srivastava, R. *Alternative modes of measuring store image: an empirical assessment of structured versus unstructured measures.* In: Journal of Marketing Theory and Practice, 1998, vol. 6, issue 2, pp. 72-86

[12] Churchill, G. A. *Marketing research: Methodological foundation*. 5th edition. The Dryden Press: Fort Worth, 1991

[13] Coca, V., Dobrea, M., Vasiliu, C. *Towards a sustainable development of retailing in Romania.* In: Amfiteatru Economic, 2013, special issue 7, pp. 583-602

[14] Popescu, D., Popa. I, Cicea. C, Iordănescu M. *The expansion potential of using sales promotion techniques in the Romanian garments industry.* In: Industria Textilă, 2013, vol. 64, issue 5, pp. 293-300

[15] Dabija, D. C. *Marketingul întreprinderii de comerț.* Risoprint, Cluj-Napoca, 2010

[16] Dabija, D. C., Pop, N. Al. *Typological aspects of retailers on the background of market concentration*. In: Management & Marketing, Spring 2008, vol. 3, issue 1, p. 19

[17] Dabija, D. C. *Organizational culture and reputation – vectors in shaping successful retail brand value*. In: Tăchiciu, L., Ioncică, M., Iosif, A. & Pantelescu, A. (Eds). The 22nd RESER International Conference – Services and Economic Development Local and Global Challanges, European Association for Research on Services, 2012, p. 240

[18] del Rio, B., Vasquez, R., Iglesias, V. *The effects of brand associations on consumer response*. In: Journal of Consumer Marketing, 2001, vol. 18, issue 5, pp. 410-425

[19] du Plessis, E. *The branded mind. What neuroscience really tells us about the puzzle of the brain and the brand.* Kogan Page Ltd., London, 2011

[20] Esch, F. R. *Strategie und Technik der Markenführung.* 5th edition. Vahlen: München, 2007

[21] Forza, C., Filippini, R. *TQM impact on quality conformance and customer satisfaction: a causal model*. In: International Journal of Production Economics, 1998, vol. 55, pp. 1-20

[22] Grewal, D., Krishnan, R., Backer, J., Borin, N. *The effects of store name, brand name and price discount on consumers evaluations and purchase intentions.* In: Journal of Retailing, 1998, vol. 74, issue 3, pp. 331-352

[23] Hälsig, F. *Branchenübergreifende Analyse des Aufbaus einer starken Retail Brand*. Wiesbaden: Gabler, 2008

[24] Hansen, R., Deutscher, T. *An empirical investigation of attribute importance in retail store selection*. In: Journal of Retailing, 1977/1978, vol. 53, issue 4, pp. 59-74

[25] Harris, L. C., Goode, M. M. H. *The four levels of loyalty and the pivotal role of trust: a study of online service dynamics*. In: Journal of Retailing, 2004, vol. 80, issue 2, pp. 139-58

[26] Ju, T. L., Lin, B., Lin, C., Kuo, H. J. *TQM critical factors and KM value chain activities*. In: Total Quality Management, 2006, vol. 17, issue 3, pp. 373-93

[27] Keller, K. L. *Strategic brand management: building, measuring, and managing brand equity*. Second edition, Pearson education, Harlow, 2003

[28] Keller, K. L., Apéria, T., Georgson, M. *Strategic brand management.* A European Perspective, Pearson Education Ltd., Harlow, 2008

[29] Keller, K. L. *Conceptualizing, measuring and managing customer based brand equity*. In: Journal of Marketing, 1993, vol. 57, issue 11, pp. 1-22

[30] Lambin, J. J., Chumpitaz, R., de Moerloose, Ch. *Marketing stratégique et opérationnel: Du marketing à l`orientation marché*, 6e édition, Dunod, Paris, 2005

[31] Luo, X., Raithel, S., Wiles, M. A. *The impact of brand rating dispersion on firm value*. In: Journal of Marketing Research, June 2013, vol. L, issue 3

[32] Martin, D., Schouten, J. *Sustainable marketing*. Pearson Education, Prentice Hall, 2012

[33] Merbold, C. *Unternehmen als Marke*. In: Bruhn, M. Handbuch Markenführung, Schäffer-Poeschel, Stuttgart, 1994

[34] Metha, N., Ma, Y. *A multicategory model of consumers` purchase incidence.* Quantity and brand choice decision: methodological issues and implications on promotional decisions. In: Journal of Marketing Research, August 2012, vol. XLIX, issue 4

[35] Omar, N. A., Alam, S. S., Aziz, N. A., Nazri, M. A. *Retail loyalty programs in Malaysia: The relationship of equity, value, satisfaction, trust, and loyalty among cardholders*. In: Journal of Business Economics and Management, 2011, vol. 12, issue 2, pp. 332-352

[36] Oppewal, H., Timmermans, H. *Retailer self-perceived store image and competitive position*. In: International Review of Retail, Distribution and Consumer Research, 1997, vol. 7, issue 1, pp. 41-59

[37] Plăiaș, I. (coord.) *Cercetări de marketing.* Risoprint, Cluj-Napoca, 2008

[38] Pop, N. Al., Dabija, D. C., Dumitru, I., Pelău, C. M., Petrescu, E. C. *Marketing internațional. Teorie și practică*. Editura Uranus, București, 2011

[39] Pop, N. Al. *A new paradigm in contemporary marketing: relationship marketing.* Management & Marketing, 2006, vol. I, issue 3

[40] Pop, N. Al., Iorga, A. M. *A new challenge for contemporary marketing – neuromarketing*. Management & Marketing. Challenges for the Knowledge Society, Winter 2012, vol. 7, issue 4, p. 28

[41] Rajh, E., Dosen, D. O. *The effects of marketing mix elements on service brand equity*. In: Ekonomska Istravivanja – Economic Research, 2010, vol. 22, issue 4, pp. 69-83

[42] Rajic, T., Dado, J., Taborecka-Petrovicova, J. *Linking retail service quality, satisfaction and perceived value to customer behavioral intentions: evidence from Serbia*. In: E & M Ekonomie a Management, 2013, vol. 16, issue 2, pp. 99-112

[43] Sirdeshmkh, D., Singh, J., Sabol, B. *Consumer trust, value, and loyalty in relational exchanges.* In: Journal of Marketing, 2002, vol. 66, pp. 15-37

[44] Stahl, F., Heitmann, M., Lehmann, D. R., Neslin, S. A. *The impact of brand equity on customer acquisition, retention andprofit margin*. In: Journal of Marketing, July 2012, vol. 76, issue 4

[45] Torelli, C. J., Özsomer, A., Carvalha, S. W., Tat Keh, H., Maehle, N. *Brand concepts as representations of human values: do cultural congruity and compatibility between matter*? In: Journal of Marketing, July 2012, vol. 76, issue 4

[46] Walsh, G., Beatty, S. E. *Customer-based corporate reputation of a service firm: scale development and validation*. In: Journal of the Academy of Marketing Science, 2007, vol. 35, issue 1, pp. 127-143

[47] Yoo, B., Donthu, N., Lee, S. *An examination of selected marketing mix elements and brand equity*. In: Journal of the Academy of Marketing Science, 2000, vol. 28, issue 2, pp. 195-211

[48] Yun, Z. S., Good, L. K. *Developing customer loyalty from e-tail store image attributes*. In: Managing Service Quality, 2007, vol. 17, issue 1, pp. 4-22

Authors:

Conf. univ. dr. DAN-CRISTIAN DABIJA
Universitatea "Babeş-Bolyai"
Str. Mihail Kogălniceanu nr. 1
400084 Cluj-Napoca
e-mail: dabijadancristian@gmail.com

Prof. univ. dr. NICOLAE AL. POP
Academia de Studii Economice
Piața Romană nr. 6
010374 București
e-mail: nicolae_al_pop@yahoo.com

Prof. univ. dr. SILVIU G. SZENTESI
Universitatea "Aurel Vlaicu"
B-dul. Revoluţiei nr. 77
310130 Arad
e-mail: silviuszentesi@yahoo.com

DOCUMENTARE

Materii prime

FIBRE DE VISCOZĂ CU SISTEM DE SECURITATE PE BAZĂ DE AMPRENTĂ

Protejarea produselor împotriva falsificării, urmărirea şi controlul produselor de-a lungul lanţului de aprovizionare şi protecţia legală privind reclamaţiile legate de garanţie devin probleme din ce în ce mai importante într-o economie globalizată.

Ca răspuns la aceste cerințe, compania ***Kelheim Fibres*** – specializată în fosfor anorganic, în colaborare cu compania ***Tailorlux*** a dezvoltat o fibră din viscoză cu sistem de securitate pe bază de amprentă.

Pentru a obţine această fibră, pigmenţii luminescenţi de la Tailorlux sunt încorporaţi în matricea fibrei de viscoză, în timpul procesului de filare. În acest fel, pigmenţii sunt legaţi intrinsec de fibră şi au o durabilitate mare. Tailorlux produce pigmenţi personalizaţi, într-o gamă de peste 300 de miliarde de combinaţii, fiecare având propriul său spectru.

Fibrele care încorporează acești pigmenți poartă o amprentă spectroscopică caracteristică, permiţând atât fibrelor, cât și produselor realizate să fie identificate cu precizie și, prin urmare, imposibil de falsificat.

Validarea se face prin metoda spectroscopiei, o metodă aplicată pe scară largă și care nu creează complicații.

Pigmentul poate fi detectat printr-o examinare distructivă sau nedistructivă, de exemplu în cenușa unui produs.

Pentru realizarea unor verificări rapide, Tailorlux oferă un scaner portabil simplu.

Ultimele realizări ale companiei Kelheim vizează, în principal, industria hârtiei. Fibrele din viscoză împreună cu pigmenții încorporaţi în ele pot fi integrate cu uşurinţă în procesul de fabricare a hârtiei.

Sunt prevăzute și alte aplicații în industria textilă, în special în domeniul nețesutelor, atunci când este necesară o marcă de identificare invizibilă, dar unică. Aceste fibre pot asigura trasabilitatea filtrelor sau a altor produse, ori pot ajuta la controlul conformităţii lanțurilor de aprovizionare din industria textilă.

Compania Kelheim Fibres produce diverse tipuri de fibre de viscoză, în care sunt încorporaţi pigmenți luminescenţi Tailorlux, în funcție de nevoile specifice ale clientului și de caracteristicile produsului finit.

__Smart__textiles and nanotechnology, iulie 2013, p. 4

Raising the competitiveness of Romanian enterprises acting in textile industry based on process management modeling

ELENA FLEACĂ ANCA ALEXANDRA PURCĂREA

REZUMAT – ABSTRACT

Creșterea competitivității firmelor românești din industria textilă pe baza modelării procesului de management

Lucrarea își propune să abordeze problematica firmelor românești din industria confecțiilor textile, care se confruntă cu o diminuare accentuată a competitivității. Globalizarea afacerilor a determinat intensificarea luptei concurențiale, iar competitivitatea pe piața producătorilor de confecții textile este câștigată și menținută numai printr-o îmbunătățire continuă a proceselor interne și prin adaptarea la cerințele în permanentă schimbare ale consumatorilor. Printr-o abordare interdisciplinară a domeniilor ingineriei industriale și tehnologiei informației, lucrarea abordează gândirea de tip proces și modelează procesul planificării agregate a producției, proces esențial ce aparține grupului proceselor de management. Se propune, astfel, factorilor de decizie din industria confecțiilor textile o soluție managerială rapidă, corectă și eficientă. Utilizând aplicația informatică SIMPLE BPM, dezvoltată de firma românească AVANTERA, autorii evidențiază modul în care pot fi extrase și utilizate anumite informații utile privind procesul de planificare agregată a producției, într-o manieră simplă și eficientă.

Cuvinte-cheie: industria confecțiilor textile, gândirea de tip proces, procese de management, transdisciplinaritate, inovare managerială

Raising the competitiveness of Romanian enterprises acting in textile industry based on process management modeling

The paper is tackling the practical problem of Romanian enterprises running the operations in the textile industry with respect to the difficulty of raising their business performance. As they are facing with an acerb competition, their competitiveness is won and maintained based on a continuous improvement of internal processes and on the conformation to the changing requirements of the market. The aim of the paper is to address the trans-disciplinary challenge between engineering management and information technology fields by applying the process thinking and by modeling the process of aggregate production planning from the process management group, as an effective solution that allows decisional factors from textile and clothing manufacturing sectors to make managerial decisions rapidly, correctly, and cost effective. The authors have applied the SIMPLE BMP modeling applications developed by the AVANTERA Romanian enterprise and, finally, share their views regarding how using this innovative tool could draw useful information about the aggregate production planning process, in a straightforward and cost-effective manner.

Key-words: textile and clothing manufacturing industry, process thinking, process management, trans-disciplinary approach, and managerial innovation

Globalization, as the leading force, has created a continuously changing business environment in terms of customers and markets requirements. Innovation becomes a crucial capability for enterprises in order to survive on the long term. As reaction, most of the private and public companies around the world have started to develop innovative management systems with the mainstream topic on improving the organizational processes. Moreover, the enterprises aspiring to become high-performance businesses have adopted a value-driven approach to their business processes management.

At the European Level, the market of textile and clothing manufacturing has gradually strengthened, with evolutions turning to positive growth rates during the third quarter of 2013. As official sources stated, the latest data show positive developments for the main short-term indicators, as compared with the third quarter of the previous year [1].

Therefore, improving the competitive environment for enterprises within this sector is of critical importance to ensure that a sound industrial basis is kept in the European Union to allow continuous innovation and wealth creation. This means a strong focus on technological innovation based on three dimension: raw materials, working processes and technology; the products and their markets and, the management.

According to the EUROSTAT statistical yearbook, at the national level the consumption rate concerning wearing apparel and dressing within the textile and clothing industry displayed a small growth rate (7,2% annual growth rate between 2004 – 2010). The situation reveals that for Romanian enterprises from textile and clothing manufacturing sectors the bottlenecks with respect to business performance are quite complex because they arise from different causes such as: types of the products, demographical factors, the economical conjuncture, and the changing attitude of customers in terms of fashion trends [2].

Worthy to mention, the studies highlighted the problems encounter by the Romanian enterprises from the textile sector, in terms of changes frequencies and the impacts on the business performance [3] – [6]. The change factors such as organizational culture and structure, technological advance, quality and human resources policies have created high pressure on textile and clothing manufacturing enterprises with respect to two types of structural changes:

- shift the loan production system with the entire product production system;
- implementing the quality management system ISO 9001 [5].

Moreover, the management of enterprises acting in textile industry is characterized by the following three directions [6]:

- production management with focus on planning manufacturing activities, working processes and production activity control;
- product management with focus on designing new products;
- the marketing process for the products.

Therefore, the authors have taken into account that, any enterprises running its business in textile and clothing manufacturing sector has at least three processes groups:

- G_1 – Manufacturing management processes group;
- G_2 – New product development management processes group;
- G_3 – The marketing management processes group.

A synoptic map of processes groups' taxonomy is illustrated in figure 1.

Manufacturing management processes group, G_1, consists of those processes that coordinate the working processes needed to deliver value to the customer and depend on the company core activities related to the total life cycle of the product, encompassing different activities (weaving mill activities, apparel activities, and garment activities and so on).

New product development management processes group, G_2, consists of those management processes performed to assure a fast reaction of enterprises to the changing customer requirements as effects of the seasonal influence and the fashion trends.

The marketing management processes group, G_3, consists of those processes that coordinate the post production stage that enable enterprise to market efficiently its products in terms of inventory systems and selling activities [7].

Worthy to be mentioned, as studies highlighted, a key element for improving the business performance requires the activities form manufacturing, new product development, and marketing areas to comply with the ISO 9001 family of standards requirements [8].

The glue that holds the three groups of processes management together is the process thinking concept, more exactly the business process management that enables enterprises to react promptly to the changing customers' attitude by delivering high value to them. These processes, related to the well-known Deming Cycle (plan, do, check, and act), are mentioned in the scientific literature as planning, executing, monitoring & controlling, and continuous improvement [9].

MODELING METHOD

Process modeling takes a crucial role in the process management of any company. Process models, as valuable artifacts that link the strategy to implementation, have long been state of the art in the field, and thus there are subject to quality considerations. There is a significant market development in the field of the model-based design of business processes starting with the packaged business application software (SAP, Oracle Applications etc.) and continuing with high-end tools such as ADONIS, ARIS, Casewise and so on [10].

The objective of the practical research was to tackle the enterprises from the textile and clothing manufacturing industry regarding the needs of improving their competitiveness. The authors have applied the

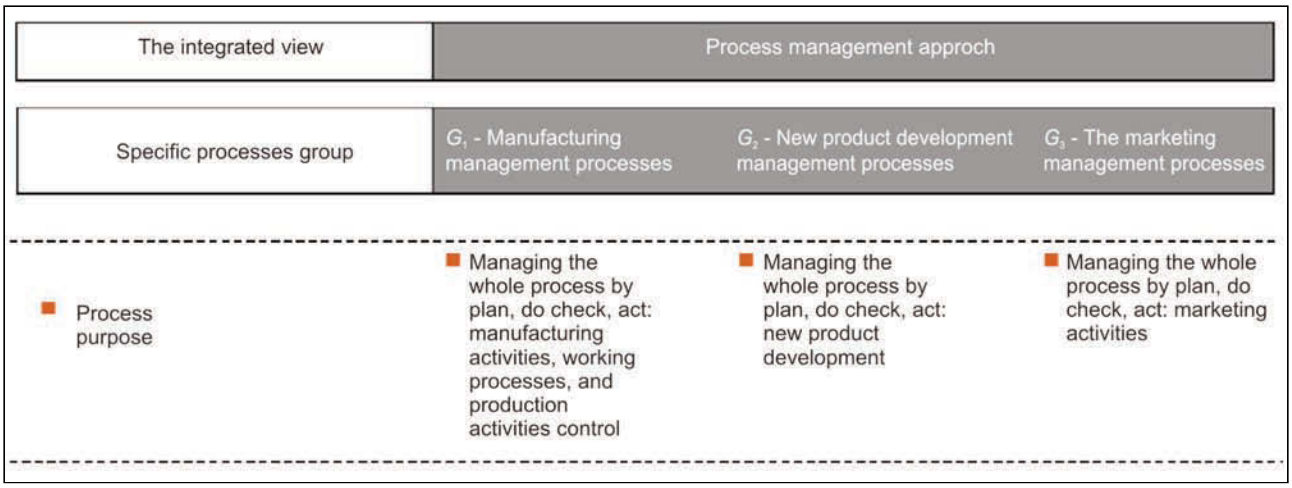


Fig. 1. A synoptic map of the taxonomy of processes groups

effective modeling software tool, named SIMPLE BPM modeling application, developed by the Romanian company AVANTERA with the aim to address the companies' needs on achieving business excellence using modern management tools.
The methodological approach of the practical endeavor was consisted of:
– Designing the process flow diagram using Event-driven Process Chain (EPC) technique from Business Process Modeling – activities, events, and logical connectors;
– Defining activities and assigning the necessary resources – participants, process roles, required documents, and working instruments;
– Drawing useful information about the process from the SIMPLE BPM modeling application, such as process diagram, synthetic table of the process, general and detailed information about the process.

The process flow diagram using Event-driven Process Chain (EPC) technique

The Event-driven Process Chain (EPC) is a modeling language for representing the logical and temporal dependencies of activities encompassed within any type of process. The SIMPLE modeling tool proposes the following key objects flow: activities, events, process interface, and connectors, as syntax elements that enable the conceptual integration of the information systems design [11].
The syntax and semantic aspects of the EPC used by the SIMPLE BPM Software Modeling tool can be described as follows:

- *The activities* (*A*), capture the functioning aspect of the process and describe clearly and concisely the action that has to be performed;
- *The events* (*E*) describe pre-conditions and post-conditions of functions. They do not consume resources of any kind;
- *The process interface* (*P*) is a syntax element that designates the necessity of executing the process in question between the flowchart's predecessor element and the flowchart's successor element;
- *The connectors* describe the precedency relationship between the activities or the process interfaces – AND-split (*A*), OR-split (*O*), and XOR-split (*X*). Connectors have either multiple incoming with one outgoing arcs JOINT-connectors (*J*) or one incoming and multiple outgoing arcs (split connectors). These connectors enable the semantic of the EPC used such as: AND-split triggers the execution of all subsequent branches in concurrency, OR-split triggers the execution of any combination of the multiple subsequent branches, based on the condition of at least one branch execution and XOR-split represents a choice between one of several alternative branches and requires the execution of the selected branch.

The EPC responds to the question "what should be done?" by defining and designing the required activities, the corresponding events, and by creating a modular framework based on the process interfaces [12].

Defining activities and assigning the necessary resources: participants, process roles, required documents, and working instruments

The SIMPLE BPM modeling methodology makes a clear distinction between the objects flow in terms of resources allocation. In this regard, the process activities and the process interfaces could be assigned with resources due to the nature of these objects. Since the events represent only situations or circumstances and connectors define the relationships between activities or branches, they do not use resources [13].
The resources, as objects flow, are characterized by attributes that could be chosen from a dropdown list or could by defined by the user. The assignment of the resources on the activity or the process interface also implies associating resources with appropriate values.
The SIMPLE BPM modeling methodology uses five resources' types as follows:

- *Financial resources* associated as activity "costs", being defined three levels – small, medium, and high costs;
- *Material resources* associated as distinctive objects in relation to an activity, being represented as "Resources";
- *Facilities resources* associated as working instruments, being represented as "Instrument";
- *Informational resources* are approached as two folds: informatics resources being considerate as "Instruments" and documented information represented as "Document" or "Knowledge";
- *Human resources*, generally named as "agents", answer to a key question "Who does what?".

In this regard, the methodology requires two steps. Firstly, it is defined the agents' type: individual jobs or organizational unit, and, secondly, it is specified the role of the agent chosen. The roles of human resources assigned are defined in accordance to RACI matrix (Responsible, Accountable, Consult and Inform) defined in the scientific literature [14]. The SIMPLE modeling tool uses five roles for the agents as follows: performer – the person who executes the activity; contributor – the person who's interference in execution is occasionally and/or is consulted for activity execution; coordinator –the person in charge with coordinating the activity execution; decision maker – the person who is responsible for the activity completion; informed – the person who is informed about the activity results.
This step clearly answers to the question: "who does what?" and also defines the working instruments and documents required for completing the activities from the process flowchart.

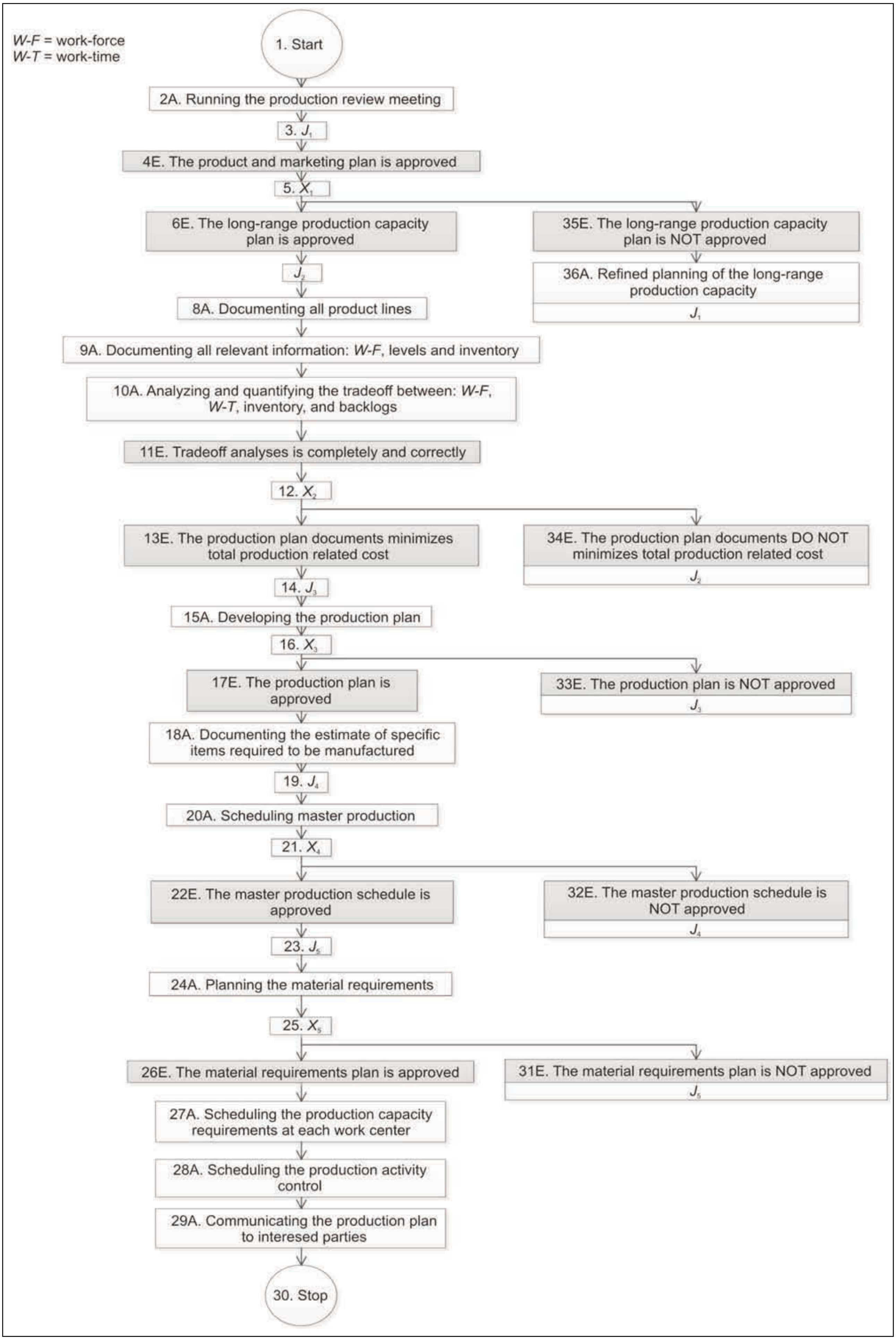


Fig. 2. Aggregate production planning process – process diagram

Table 1

AGGREGATE PRODUCTION PLANNING PROCESS – SYNTHETIC TABLE	
Type	**Planning process from processes management group**
Approved by	Company vice president
Procedure summary	The procedure represents the keys steps for aggregate production planning
Deliverable	The production plan
Deliverable beneficiary	The production division
Process necessity (motivation)	Fostering the company competitiveness based on the standardized processes
Objectives – effectiveness	The correctness of the process content
Performance indicators – effectiveness	According the check list from the SIMPLE application
Target values – effectiveness	100%
Procedure's necessity	Designing the baseline for completing the activities of aggregate production planning
Verified by	Production manager and technical consultant
Developed by	Process architecture

RESULTS AND DISCUSSIONS

Modeling the process of aggregate production planning

In order to address the cross-disciplinary challenge between engineering and management fields and to be within the scope of the practical research that is limited to the planning processes, the authors have modeled the process of aggregate production planning since it represent the major concern for enterprises from the textile and clothing manufacturing industry that struggle to translate their business plans into broad categories of production requirements.

The production planning process is a hierarchical framework of long, medium, and short range of planning activities that enable top management level to use aggregate data for decisions, and also shop-floor management to make decisions using detailed data. Planning the manufacturing activities is linked to other types of planning starting with strategic planning and finishing with the job-shop and/or flow-shop planning and has the aim of determining the optimal combination of production rate, the work-force level, and the inventory on hand [15].

The algorithm followed three steps: designing the process diagram; assigning resources required; drawing meta-information about the process from the operational table of the process. The results of process simulation based on the SIMPLE BPM modeling tool are shown in table 1.

Figure 2 reveals detailed information about the process, showing the process diagram.

CONCLUSIONS

The confluence of management and technology creates an environment with a huge potential of managerial innovation as a key vehicle towards the enterprise competitiveness. Using the powerful IT instruments for knowledge processing, the decisional factors from textile and clothing manufacturing sectors are moving from making decisions based on shallow analysis and weak resources planning to deeply informed, accurate and opportune decisions.

The aggregate production planning process was simulated with the SIMPLE BPM application developed by AVANTERA enterprise and can be executed automatically by the system. The aggregate production planning process models could be customized with minimal efforts by the enterprises form the textile sectors, directly by themselves due to the simplicity and easiness of using the software application, and by developing internal competences.

The processes modeled may be developed for practical use with minimal adjustments in different domains and productive activity types because the functionalities of application support the implementation of the ISO standards suites in quality environment, health and occupational safety, audit, food safety, risk management.

BIBLIOGRAPHY

[1] The European Apparel and Textile Confederation, EURATEX, www.euratex.ro.

[2] *External and intra* – EU trade – statistical yearbook, EUROSTAT, 2011

[3] Popescu, D., Popa, I., Cicea, C., Iordănescu, M. *The expansion potential of using sales promotion techniques in the Romanian garments industry.* In: Industria Textilă, 2013, vol. 64, issue 5, pp. 293-300

[4] Popescu, D., Popa, I., Iordănescu, M. *Organizational change management and innovation IX. Technological innovation*. In: Quality - Access to Success, 2013, vol. 14, issue 135, pp. 79-82

[5] Popescu, D. I., Drăghici, M. S. *Strategic entrepreneurial management - necessity and opportunity.* In: Industria Textilă, 2012, vol. 63, issue 5, pp. 267-276
[6] Ifrim, L., Purcărea, A. A., Dănălache, F. *Determination of change factor¢s weight in garment industry organizations.* Management of Technological Changes Conference Proceedings, Greece, 2011, ISBN 978-960-99486-1-6
[7] Ifrim, L. *Contribuții privind schimbările în organizațiile din industria confecțiilor textile în vederea creșterii competitivității lor.* Teză de doctorat, 2011
[8] Micu, D. M., Purcărea, A. A., Dumitriu, D., Ifrim, L. *Evaluation of marketing performance - importance, current status and future developments.* Management of Technological Changes Conference Proceedings, Greece, 2009, ISBN 978-960-89832-6-7
[9] Ifrim, L., Prisecaru, B. *Purchasing process according to ISO 9001 quality management system standard in the apparel industry.* QUALITA Conference Proceedings, France, 2011. http://www.rufereq.asso.fr/QUALITA/program.html
[10] Fleacă, B., Fleacă, E. *An exploratory study on organization processes taxonomy.* In: Bulletin of University of Agricultural Sciences and Veterinary Medicine, Horticulture, Cluj-Napoca, 2013, vol. 70, issue 2, pp. 310-318. Print ISSN 1843-5254, Electronic ISSN 1843-5394
[11] Schönthaler, F., Vossen, G., Oberweis, A., Karle, Th. *Business processes for business communities. Modeling languages, methods, tools.* Springer-Verlag, Berlin, Heidelberg, London, New York, *2012*
[12] Scheer, A. W., Thomas, O., Adam, O. *Process modeling using event-driven process chains.* Process Aware Information Systems: Bridging People and Software Through Process Technology, Wiley, Chichester, 2005, pp. 119-146
[13] Pascadi, M., Tutunaru, M. *SIMPLE BPM software modeler's manual,* 2011. https://www.avantera.ro/bet/v1.4/manual.pdf
[14] Project Management Institute. *A guide to the project management body of knowledge.* 5th edition, Project Management Institute, Inc. 2013
[15] Vollman, Th., Berry, W., Whybark, C. *Manufacturing planning and control systems.* 4th edition, Mc. Graw-Hill, NY, 1997

Authors:

Chief of works dr. eng. ELENA FLEACĂ
Prof. dr. eng. ANCA ALEXANDRA PURCĂREA
University Politehnica of Bucharest
Faculty of Entrepreneurship, Business Engineering and Management
313 Splaiul Independenței street, Bucharest
e-mail: elena.fleaca@upb.ro; apurcarea@gmail.com

DOCUMENTARE

Textile nețesute

MATERIALE TEXTILE NEȚESUTE PENTRU DOMENIUL MEDICAL

Compania ***Ahlstrom***, din Helsinki – Finlanda, a lansat pe piață un nou material textil nețesut format din trei straturi, destinat producerii halatelor chirurgicale.

Compania a dezvoltat materialele textile nețesute *TenderGuard*, pentru a asigura un echilibru între funcția de barieră şi cea de confort. Materialele au o greutate redusă, un drapaj foarte bun și un tuşeu moale. Ele oferă acelaşi nivel de protecție şi de respingere a unor fluide cu tensiune superficială scăzută, cum ar fi sângele, fluidele din corp şi alcoolii, ca și neţesutele consolidate lansate deja pe piață. În plus, textilele nețesute *TenderGuard* conferă un confort mai ridicat, iar prețul de cost este mai mic.

Materialul este alcătuit din trei straturi: deasupra şi dedesubt se află câte un văl nețesut constituit din fibre speciale legate în rețele prin consolidare la filare, iar stratul de mijloc este un văl nețesut – format, la rândul său, din trei straturi de fibre de mare finețe – obținut prin injectare de topitură.

Aceste materiale sunt realizate în conformitate cu standardul S.U.A. AAMI PB70 și cu standardul european EN 13795. În prezent, compania furnizează aceste materiale în trei variante ale greutăți de bază – 35, 43 și 50 g.m^{-2}. În cazul greutății de 43 și 50 g.m^{-2}, materialul textil este în conformitate cu cerinţele standardului AAMI, iar la greutatea de 35 g.m^{-2} este respectată conformitatea cu standardul EN 13795, în ceea ce privește cerinţele de performanță standard și cele de performanță ridicată în zonele articolelor de îmbrăcăminte mai puțin expuse uzurii.

În plus, aceste materiale sunt durabile și rezistente la manipulare și sterilizare. Având în vedere că gradul de scămoșare este redus, iar scamele sunt purtătoare de microorganisme ce pot infecta pacientul, ele asigură un nivel ridicat de protecție.

Technical Textiles International, octombrie/noiembrie 2013, p. 41

Polymeric composites based on flax wastes and natural rubber

ELENA MĂNĂILĂ MARIA DANIELA STELESCU LILIOARA SURDU
GABRIELA CRĂCIUN CHRISTIAN LAURENȚIU DINCĂ DANA GURĂU

REZUMAT – ABSTRACT

Compozite polimerice pe bază de deșeuri din fibre de in și cauciuc natural

În lucrare sunt prezentate experimentările privitoare la obținerea și caracterizarea unor compozite polimerice pe bază de deșeuri din fibre de in și cauciuc natural. Reticularea cauciucului natural s-a realizat atât prin metoda clasică, cu ajutorul peroxidului de benzoil, cât și prin metoda neconvențională de iradiere cu electroni accelerați. Prin adăugarea în amestecuri a deșeurilor de in mărunțite, s-a constatat o îmbunătățire semnificativă a unor proprietăți fizico-mecanice, cum ar fi duritatea, modulul de alungire, rezistența la rupere. De asemenea, pe măsură ce cantitatea de deșeuri de in din amestecuri și doza de iradiere cu electroni accelerați au crescut, s-a observat o îmbunătățire a gradului de reticulare a probelor, determinat cu ecuația Flory-Rehner. Având caracteristici hidrofile, cantitatea de deșeuri de in din amestecuri, a influențat în mod semnificativ caracteristicile de gonflare în apă ale probelor. Compozitele obținute pot fi utilizate în industria de automobile, industria mobilei, construcții etc.

Cuvinte-cheie: deșeuri de in, cauciuc natural, iradiere, proprietăți fizico-mecanice, densitate de reticulare, gonflare în apă

Polymeric composites based on flax fibre wastes and natural rubber

This paper presents our experiments on obtaining and characterizing polymeric composites based on flax fibre wastes and natural rubber. Natural rubber was cross-linked both through a conventional method – using benzoyl peroxide, and an unconventional method – electron beam irradiation. Physical-mechanical properties such as hardness, 100% elongation modulus and tensile strength indicate a significant improvement as a result of adding ground flax waste to blends. Better results have been obtained using crosslinking by electron beam irradiation. The crosslinking rates of samples, measured using the Flory-Rehner equation increase as the amount of flax waste in blends increases and as the electron beam irradiation dose increases. The swelling parameters of samples significantly depend on the amount of flax wastes in blends, because the latter have hydrophilic characteristics. The obtained composites can be used in manufacturing products with applications in the automotive industry, furniture industry, constructions etc.

Key-words: flax wastes, natural rubber, irradiation, physical-mechanical characteristics, crosslink density, swelling parameters

Natural fibre-reinforced composites have recently received much attention because of their attractive properties such as lightweight, non-abrasive, combustible, non-toxic, low cost and biodegradable. [1]. There is a wide variety of different natural fibres which can be used as reinforcers or fillers. The most important of the natural fibers used in composite materials are flax, hemp, jute, kenaf and sisal, due to their properties and availability. These fibres are composed mainly of cellulose and some lignin and are sometimes called ligno-cellulosic fibres. Generally four main reasons are mentioned which make the use of natural fibers attractive: their specific properties, their price, their health advantages and their recyclability [2].

Natural rubber is a high molecular weight polymer of isoprene in which essentially all the isoprene's have the cis 1–4 configuration. This is an interesting material with commercial success due to its excellent physical properties, especially high mechanical strength, low heat build-up, excellent flexibility, and resistance to impact and tear, and above all its renewability [3]. However, raw dry rubber is seldom used in its original state for any engineering and domestic application. Consequently, rubber manufacture involves the addition to rubber many auxiliary materials called additives to allow the rubber compounds to be satisfactorily processed and vulcanized in order to improve the application properties of the rubber compound. Additives used in rubber manufacture include vulcanizing agents, accelerators, activators and/or retarders, fillers, anti-degradants, among others. Fillers represent one of the most important additives used in rubber compounding. Fillers are added to rubber formulation in order to optimize properties needed for service application [4]. Reinforcement of rubber polymers with particulate fillers is a subject that has captured the interest of a large number of researchers [5] – [6]. Property advantages obtainable from filler reinforced rubber vulcanizates include design flexibility, improved physico-mechanical properties such as tensile properties, hardness, and processing economy. Due to strong environmental regulations worldwide and increased interest in the proper utilization of renewable natural resources, efforts have been made to find alternative reinforcements that are environmentally friendly while providing the same performance as their synthetic counterparts. With their low cost, easy availability, ease of chemical and mechanical modification, and high specific mechanical properties, natural fibers represent a good, renewable and biodegradable alternative to the most common synthetic reinforcement [5] – [7]. The reinforcement of elastomers with short fibers results in composites with a wide variety of properties. The performance and properties are a function of fiber type, fiber content, fiber aspect ratio, fiber orientation, fiber dispersion, fiber-matrix adhesion, processing methods, and properties of the elastomer matrix. A composite with almost any desired property can be obtained by manipulation of these parameters [8].

The most important stage in the rubber processing technology is vulcanization/rosslinking. During crosslinking, rubber molecules with chain configuration are linked by chemical bridges/bonds, and the rubber mass turns from its plastic mass into an elastic one.

This is normally done by sulphur and accelerator for general purpose rubbers. The chemistry of vulcanization is complex and the resulting crosslinks may be mono-, di-, tri- or higher poly-sulphides, with a proportion which is among others largely determined by the vulcanization system, the cure time and the temperature. These compounds and their reaction products could be responsible for cytotoxicity [9] and allergy-causing compounds, such as nitrosamines and nitrosatable materials. Vulcanization with peroxides is done by radical mechanism when bonds form between C-C macromolecules. The chain of free radical reactions is initiated by thermal decomposition of the peroxide into primary radicals formed by scission stable species (acetone and diacetylbenzene) and the second radical that continue the propagation in the presence of rubber. Besides the conventional techniques, crosslinking of natural rubber can also be achieved by means of high energy radiation. This technology has been studied for a long time. Radiation can produce crosslink densities like those obtained by sulfur curing, but the net effects, while similar, are not identical. The type of crosslink formed in this method (–C–C–) give rise to better mechanical properties at higher temperature. This might be reflected in better high temperature performance as higher hot tear strength. Also, it can lead to greater abrasion resistance and superior ozone resistance [10]. In addition, crosslinking by EB also shows a series of advantages such as reduced crosslinking time and power expenditure, no polymer degradation due to high temperature as EB crosslinking occurs at room temperature, the process is very fast and can be controlled precisely; the EB can be steered very easily to meet the requirements of various geometrical shapes of the products to be cured, very high productivity, perfect for thin products, lack of wastes and the resulting products are sterile [10] – [12].

This paper studies the influence of flax fiber amount and electron beam irradiation dose on physical-mechanical properties, crosslinking density and behavior in aqueous environment of polymeric composites based on natural rubber and flax wastes, where the elastomer was cross-linked by both electron beam irradiation and by means of peroxides.

EXPERIMENTAL PART

Materials used

All the raw materials: natural rubber Crep 1X (Mooney viscosity is 74 ML_{1+4} at 100ºC, 0.32% volatile materials content, 0.38% nitrogen content, 0.22% percentage of ash, 0.021% impurities content), antioxidant Irganox 1010, polyethylene glycol PEG 4000 (1,128 g/cm^3 density, 4–8ºC melting point range), ground flax wastes (thread length of max. 3 mm) and dibenzoyl peroxide Perkadox 14-40 B (1.60 g/cm^3 density, 3.8% active oxygen content, 40% peroxide content, *p*H 7) as vulcanizing agent for classical vulcanization.

Sample preparation

Blends were prepared on an electrically heated laboratory roller. For preparation of polymeric composites, the blend constituents were added in the following sequence and amounts: 100 parts natural rubber roll binding (2’), embedding 3 phr (parts to 100 parts rubber) PEG 4000 and 1 phr Irganox 1010 antioxidant (2’), adding 5 and 15 phr ground flax wastes respectively (2–4’), homogenisation of blends and removing from the roll in the form of sheet (4’). Process variables: temperature 25–50 ± 5ºC, friction 1:1.1, and total blending time 8–14’. Plates required for physico-mechanical tests with sizes of 150 x 150 x x 2 mm^3 were obtained by pressing in a hydraulic press at 110 ± 5ºC and 150 MPa. Dibenzoyl peroxide vulcanized samples were prepared similarly to the experimental ones with the following specifications: 8 phr of dibenzoyl peroxide Perkadox 14-4B (2’) as vulcanizing agent was added and the blend vulcanization was achieved in a hydraulic press at 160ºC, the curing time was 19’.

Experimental installations and sample irradiation

The samples were packed in a polyethylene film and were irradiated using the electron beam accelerator called ILU-6M in the dose rang of 15–60 Mrad and at room temperature. The accelerator consists mainly of two systems: the electron acceleration system and accelerated electron scanning system. The ILU-6M is a resonator-type accelerator, operating at 115 ± 5 MHz. This accelerator generates electron beam pulses of 0.375 ms duration, up to 0.32 A peak current intensity and up to 6 mA mean current intensity. The cross-section size of the scanned EB at the ILU-6M vacuum window exit is 1 100 mm x 65 mm. The EB effects are related to the absorbed dose *D*, expressed in Gray or J kg^{-1} (10 Gray = 1 Mrad).

Laboratory tests

Tensile strength tests were carried out with a Schopper strength tester with testing speed 460 mm/min, using dumb-bell shaped specimens according to ISO 37/2012. Hardness was measured by using a hardener tester according to ISO 7619-1/2011 using 6 mm thick samples. Elasticity was evaluated with a test machine of type Schob using 6 mm thick samples, according to ISO 4662/2009.

The sol-gel analysis was performed on cross-linked NR rubber (with and without flax waste) to determine the mass fraction of insoluble NR (the network material resulting from network-forming crosslinking process) samples (gel fraction)**.** The samples were swollen in toluene and extracted after 24 hours in order to remove any scissioned fragments and unreacted materials. The networks were then dried in air for 6 days, and in an oven at 80**°**C for 3 hours, and reweighed. The gel fraction was calculated as:

$$Gelfraction = \frac{m_s}{m_i} \times 100 \qquad (1)$$

where:

m_s and m_i are the weight of the dried sample after extraction and the weight of the sample before extraction, respectively [13] – [17].

The crosslink density, ν, of the samples was determined on the basis of equilibrium solvent-swelling measurements (in toluene at 23–25°C) by application of the well-known modified Flory-Rehner equation for tetra functional networks. The samples were initially weighed m_i and immersed in toluene for 24 hours. The swollen samples were removed and cautiously dried to remove excess solvent before being weighed m_g and, during this operation, the samples being covered to avoid toluene evaporation during weighing. Traces of solvent and other small molecules were then eliminated by drying in air for 6 days and in an oven at 80°C for 3 hours. Finally, the samples were weighed for the last time m_s and volume fractions of polymer in the samples at equilibrium swelling ν_{2m} were determined from swelling ratio G as follows equation (2):

$$\nu_{2m} = \frac{1}{1 + G} \qquad (2)$$

where:

$$G = \frac{m_g - m_s}{m_s} \times \frac{\rho_e}{\rho_s}$$

ρ_e and ρ_s are the densities of elastomer samples and solvent (0.866 g/cm^3 for toluene).

The densities of elastomer samples were determinate by hydrostatic weighing method, according to the SR ISO 2781/2010. The samples crosslink densities, ν, were determined from measurements in a solvent, using the Flory–Rehner relationship:

$$\nu = -\frac{Ln(1 - \nu_{2m}) + \nu_{2m} + \chi_{12}\nu_{2m}^2}{V_1\left(\nu_{2m}^{1/3} - \frac{\nu_{2m}}{2}\right)} \qquad (3)$$

where:

V_1 is the molar volume of solvent (106.5 cm^3/mol for toluene);

ν_{2m} – the volume fraction of polymer in the sample at equilibrium swelling;

χ_{12} – the Flory-Huggins polymer-solvent interaction [13] – [16].

Water uptake test – the effect of water absorption on fiber reinforced natural rubber composites are investigated in accordance with SR EN ISO 20344/2004. The samples were dried in an oven at 80°C for 2 hours and then are allowed them to cool to room temperature in desiccators before weighing. Water absorption tests were conducted by immersing the samples in distilled water in beaker and kept at room temperature (23 ± 2°C). After immersion the samples were taken out from the water at periodic intervals and the wet surfaces were quickly dried using a clean dry cloth or tissue paper. The specimens were weighed regularly at 24, 48, 72, 96 and 120 hours exposures. The moisture absorption was calculated by the weight difference. The percentage weight gain of the samples was measured at different time intervals. The water uptake was calculated as equation (4):

$$Water\ uptake\ (\%) = \frac{W_S - W_1}{W_1} \times 100 \qquad (4)$$

where:

W_S is the weight of the water saturated specimen at 24, 48, 72, 96 and 120 hours;

W_1 – the initial weight of the oven-dried specimen.

Swelling parameters – swelling studies provide information on the strength of interface, degree of dispersion of fibres, and their alignment in the elastomer matrix. Swelling behavior was determined by the change in mass using the following method. For cured rubber blends vulcanized the test pieces of known weight, W_1, were immersed in various solvents (water and toluene) in diffusion test bottles and kept at room temperature for five days. After immersion the samples were taken out from the solvents and the wet surfaces were quickly dried using a tissue paper and re-weighted, W_2. The test samples of the blends were further dried in an oven at 80ºC for 6 hours, cooled in a desiccator and immediately weighed W_3. The swelling parameters [18], [19] of blends were calculated by the following swelling data:

Calculation of Q_t (mol % uptake of the solvent) – the mol % uptake of the solvent, Q_t, for the composite samples was determined using the equation (5):

$$Q_t = \frac{(W_2 - W_1) / M_S}{W_1} \times 100 \qquad (5)$$

Swelling index (*SI*, %) was calculated by the equation (6):

$$SI\ (\%) = \frac{W_2 - W_1}{W_1} \times 100 \qquad (6)$$

Soluble fraction (*SF*, %) was determined by the following relation (7):

$$SF\ (\%) = \frac{W_1 - W_3}{W_1} \times 100 \qquad (7)$$

RESULTS AND DISCUSSIONS

Physical-mechanical characteristics

In table 1 are presented the results of physical-mechanical characteristics of samples cross-linked with peroxide. By introducing ground flax wastes in rubber blends, it is noticed that as the amount of flax waste is increased, the following take place:

– a significant increase in hardness, namely an increase of 11° ShA when introducing 5 phr wastes (from 45 to 56° ShA), when increasing the amount of flax wastes at 15 phr, hardness is 70° ShA;

– an increase in modulus at 100% elongation, tensile strength and elongation at break. These changes indicate that flax wastes have a similar reinforcement effect to mineral fillers, at the same time improving their characteristics.

Physical-mechanical characteristics of samples cross-linked by electron beam irradiation are presented in figures 1–5. It is noticed that hardness (fig. 1) increases with the increase of the irradiation dose and with the introduction of flax wastes in natural rubber blends, because they lead to reinforcement of samples. Elasticity (fig. 2) slightly decreases with the increase of EB dose and varies irregularly when increasing the flax amount; for both characteristics the obtained values are lower than those of blends cross-linked with peroxides. Modulus at 100% elongation (fig. 3) and tensile strength (fig. 4) increase when increasing the irradiation dose and when introducing flax wastes in natural rubber blends, and the obtained values are comparable to those of blends cross-linked with peroxides. Elongation at break (fig. 5) decreases with the increase of EB dose and with the increase of flax waste amount introduced in blends, indicating an increase in crosslink density.

Table 1

PHYSICAL–MECHANICAL CHARACTERISTICS OF SAMPLES CROSS-LINKED WITH PEROXIDE

Characteristics/ Amount of flax wastes	0 phr	5 phr	15 phr
Hardness, °ShA	45	56	70
Elasticity, %	56	56	44
Modulus at 100% elongation, N/mm^2	0.75	1.2	1.7
Tensile strength, N/mm^2	0.90	1.3	1.9
Elongation at break, %	110	126	160

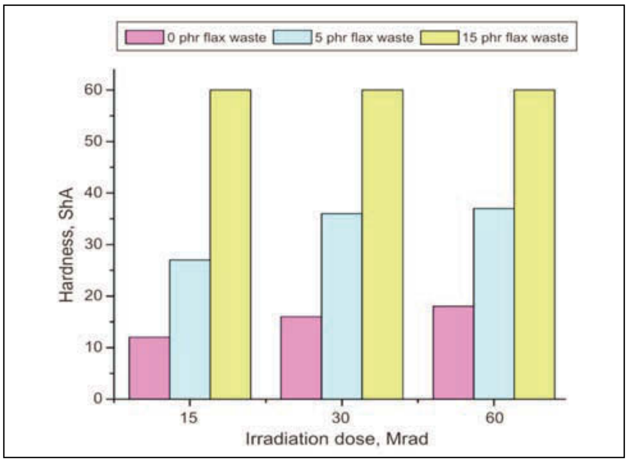


Fig. 1. Hardness versus EB irradiation dose and amount of flax wastes

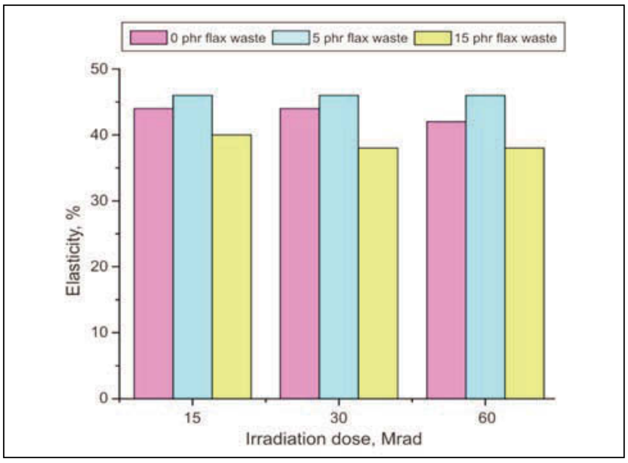


Fig. 2. Elasticity versus EB irradiation dose and amount of flax wastes

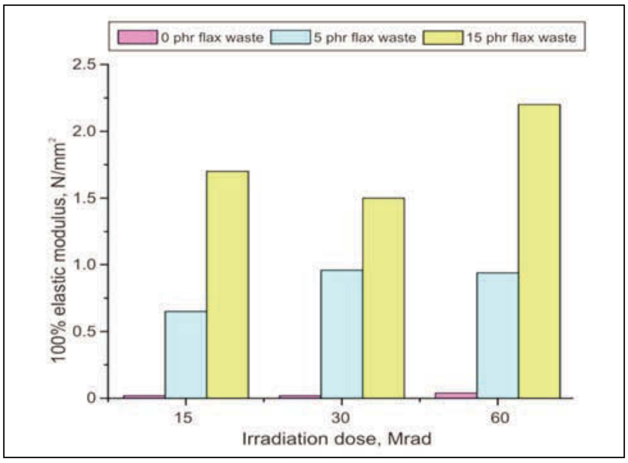


Fig. 3. 100% elastic modulus versus EB irradiation dose and amount of flax wastes

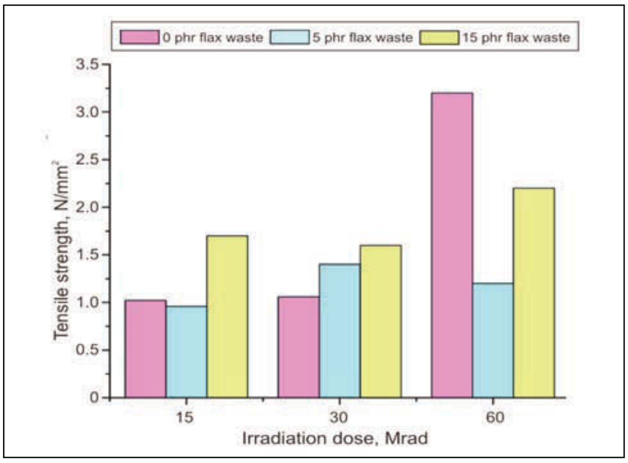


Fig. 4. Tensile strength versus EB irradiation dose and amount of flax wastes

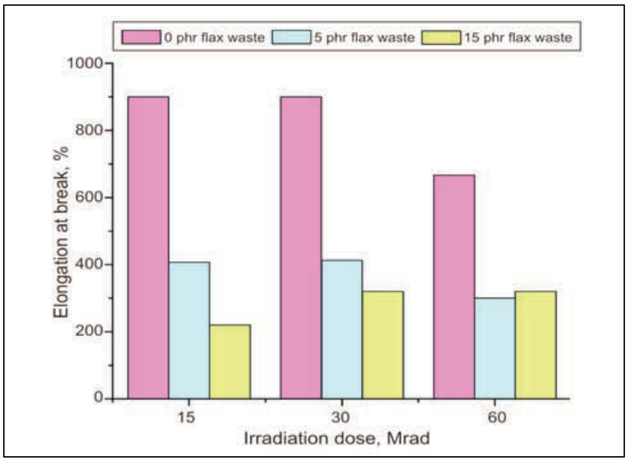


Fig. 5. Elongation at break versus EB irradiation dose and amount of flax wastes

Obtained values are very high compared to those of blends cross-linked with peroxides.

In conclusion, by introducing ground flax wastes in natural rubber blends, an increase in hardness, modulus at 100% elongation and tensile strength of the blends occurs because they have the effect of reinforcing rubber blends. With the increase of EB irradiation dose, an increase of hardness, modulus at 100% elongation and tensile strength of blends occurs because the crosslink density increases. Blends cross-linked by EB irradiation have shown higher values of elongation at break, lower values of hardness and elasticity, and modulus at 100% elongation and tensile strength have comparable values to those of blends cross-linked with peroxides.

Gel fraction and crosslink density of the blends

Table 2 shows the gel fraction (mass fraction of the network material resulting from a network-forming polymerization or crosslinking process; the gel fraction comprises a single molecule spanning the entire volume of the material sample) and cross-link density (number of crosslinks per unit volume in a polymer network) of the samples vulcanized by dibenzoyl peroxide, and EB respectively as a function of the flax content. The determination is based on the absorption of a proper solvent and subsequent swelling of the rubber [15], [16].

Gel fraction value is over 90% for all blends and varies irregularly depending on the amount of flax waste in the blend, the crosslinking method or the irradiation dose.

It is noticed that, as the flax quantity increases, there is an increase of cross-link density, *v*, because flax wastes act as a filler in natural rubber blends and lead to reinforcement of blends. Crosslink density increases as the irradiation dose is increased as a result of a larger number of bonds forming between macromolecular chains. Crosslink density of blends cross-linked with peroxide is higher than that of blends cross-linked with electron beam. The experimental results confirmed by other works [15] – [17] showed that with the increase in crosslink density, modulus at 100% strain, hardness and tensile strength increased, whereas the elongation at break decreased. Analyzing the results of physical-mechanical properties presented in table 2 and figures 1 – 5, one can notice that hardness and elasticity of blends cross-linked with peroxide have higher values than those cross-linked with EB, and elongation at break of blends cross-linked with EB has higher values than those cross-linked with peroxide, in accordance with values of crosslink density in table 2 and literature data. However, modulus at 100% elongation and tensile strength of blends cross-linked with EB have comparable values to those of blends cross-linked with peroxide. This indicates that EB crosslinking can lead to materials with unique properties, which cannot be obtained through other methods. Materials with good tensile strength and elongation at break and also have low hardness and high elasticity values find applications in many economic areas.

Table 2

GEL FRACTION AND CROSSLINK DENSITY OF SAMPLES

Sample	Gel fraction, %	ν, 10^{-4} mol/cm^3
NR + 0 phr flax/ peroxide	94.36	5.5781
NR + 5 phr flax/ peroxide	94.64	10.2366
NR + 15 phr flax/ peroxide	94.77	13.2790
NR + 0 phr flax/15 Mrad	94.47	0.4410
NR + 5 phr flax/15 Mrad	94.20	0.3647
NR + 15 phr flax/15 Mrad	90.95	0.4953
NR + 0 phr flax/ 30 Mrad	93.50	0.8412
NR + 5 phr flax/30 Mrad	95.45	0.8420
NR + 15 phr flax/ 30 Mrad	94.27	1.0335
NR + 0 phr flax/ 60 Mrad	94.93	1.5152
NR + 5 phr flax/ 60 Mrad	95.84	1.7298
NR + 15 phr flax/ 60 Mrad	95.62	2.7228

Swelling parameters

The water uptake results of samples cross-linked with peroxide and by electron beam irradiation (with and without flax waste) are presented in figure 6 and figure 7. From these figures is observed that the percentage of water absorption in the composites NR/flax waste depended on two parameters: flax waste content and irradiation dose. The water uptake increased with increasing fibre content and irradiation dose. The increasing water absorption is due to the hydrophilic nature of fibre and the greater interfacial area between the fibre and the elastomer matrix [20]. In polymer composites with fibres, water is absorbed mainly by the fibres because the rubber material is hydrophobic and its water absorbability can be neglected [21].

A comparison of the Q_t (mol% uptake of the solvent – water) for the samples vulcanized by electron beam

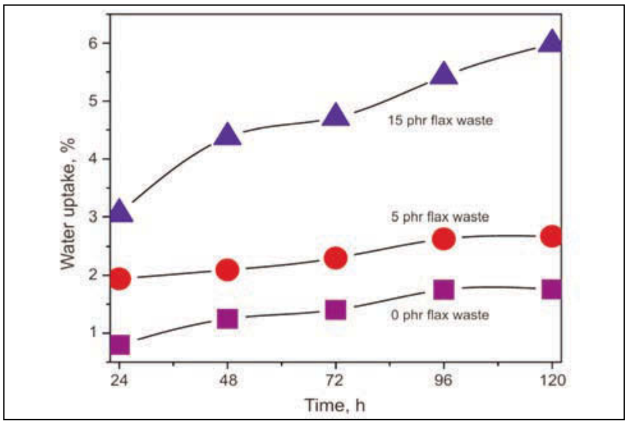


Fig. 6. Water uptake of composites crosslinking with peroxide versus amount of flax wastes

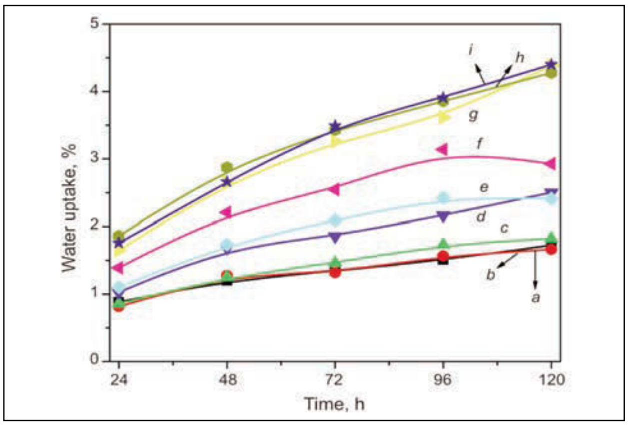


Fig. 7. Water uptake of:
a – NR0/15 Mrad; *b* – NR0/30 Mrad; *c* – NR0/60 Mrad; *d* – NR + 5 phr flax waste/15 Mrad; *e* – NR + 5 phr flax waste/30 Mrad; *f* – NR + 5 phr flax waste/60 Mrad; *g* – NR +15 phr flax waste/15 Mrad; *h* – NR + 15 phr flax waste/30 Mrad; *i* – NR + 15 phr flax waste/60 Mrad

irradiation with and without flax waste is given in figure 8. The uptake of solvent increases with irradiation dose and fibre loading. It may be observed that the uptake of water is high for the composites with 15 phr flax waste for all irradiation doses.

This shows that there is better fiber/rubber adhesion and in this case the samples shows a tendency to degrade [19]. The reinforcement is most effective when the composite contains a small amount of fibre (5 phr) for all irradiation doses. Figure 9 and figure 10 give the variation of % swelling index and solubility with fibre loading and irradiation doses. As also noticed for water uptake and Q_t, swelling index and solubility increases with fibres loading, regardless of the irradiation dose. It is clear from this results that as fibre loading increases, equilibrium solvent uptake increases. Better results were obtained in the case of a reduced fibre loading (5 phr) at irradiation doses of 15 and 30 Mrad. The presence of a reduced fibre loading in the composite exhibits high resistance to swelling compared to a large amount of fibres. At the same irradiation doses, the amount of solvent sorbed

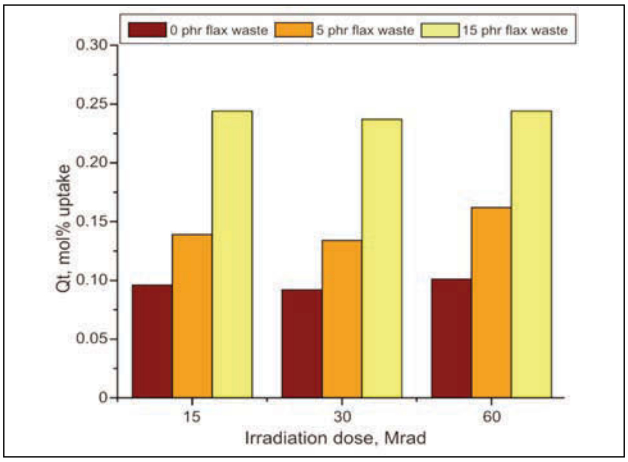


Fig. 8. The mol % uptake of the solvent, Q_t, versus EB irradiation dose and amount of flax wastes

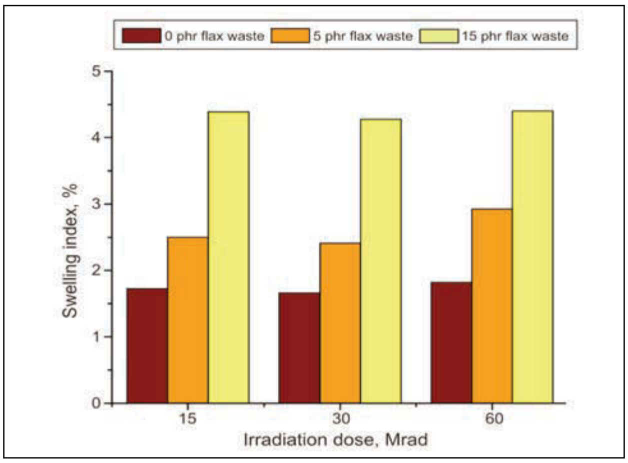


Fig. 9. Swelling index versus EB irradiation dose and amount of flax wastes

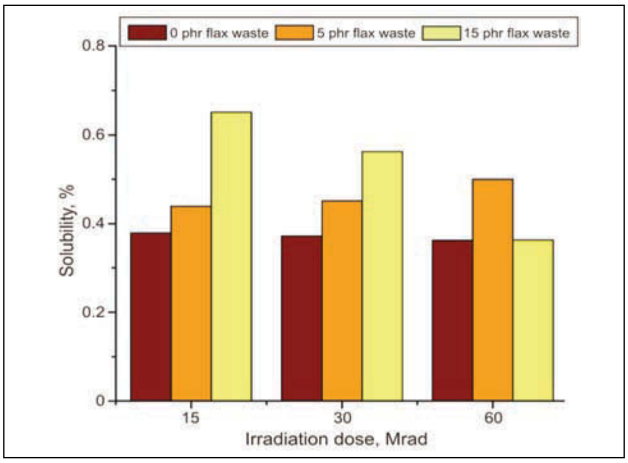


Fig. 10. Solubility versus EB irradiation dose and amount of flax wastes

by a composite at equilibrium is high for the composite with high fibre loading. This is because of the fact that in unbonded fibre rubber composites the solvent can penetrate into the polymer along the thickness direction and also through the weak interfaces parallel and perpendicular to the fibre orientation. The initial driving force for swelling is higher in unbonded composites as a result of large number of voids at the interface. But in the case of composites with less fibre loading the interface is strong and the liquid can penetrate into the composites only through the space between the fibre ends. As a result, the diffusion rate is slow in composites with good bonding [21]. As the composites with higher filler loading exhibit weak adhesion between filler and matrix, more water will be absorbed and consequently higher water loss will be observed during drying [20].

CONCLUSIONS

The study conducted led to the conclusion that by introducing ground flax waste in natural rubber blends an increase in crosslink density, hardness, modulus at 100% elongation and tensile strength of blends occurs because they have a reinforcement effect on rubber blends; when increasing the EB irradiation dose, an increase in crosslink density, hardness, modulus at 100% elongation and tensile strength of blends takes place as a result of a larger number of bonds forming between macromolecular chains; blends cross-linked by EB irradiation have shown higher values for elongation at break, lower values for crosslink density, hardness and elasticity, while modulus at 100% elongation and tensile strength have comparable values to those of blends cross-linked with peroxides. Gel fraction value is over 90% for all blends. The water uptake, swelling index and solubility increased with increasing fiber content. The increasing water absorption is due to the hydrophilic nature of fiber and the greater interfacial area between the fiber and the elastomer matrix**.**

Obtaining polymeric composites based on flax waste and natural rubber is an efficient method of exploiting flax waste from the textile industry. Studies will continue regarding the use of new types of natural fibers and other types of elastomers or polymers, as well as regarding the optimization of characteristics of polymeric composites obtained. The obtained composites can be used in manufacturing products with applications in the automotive, furniture, constructions, light industries etc.

BIBLIOGRAPHY

[1] Njuguna, J., Wambua, P., Pielichowski, K., Kayvantash, K. *Natural fibre-reinforced polymer composites and nanocomposites for automotive applications*. In: Cellulose Fibers: Bio- and Nano-Polymer Composites, 2011, pp. 661-700

[2] Harriëtte, Bos. *The potential of flax fibres as reinforcement for composite materials.* Cip-Data Library Technische Universiteit Eindhoven, Eindhoven: Technische Universiteit Eindhoven, 2004

[3] Daniel, D., Punyanich, I., Quang, N. T., Fredderic, G., Charoen, N. *Graft copolymers of natural rubber and poly(dimethyl(acryloyloxymethyl) phosphate) (NR-g-PDMAMP) or poly(dimethyl (methacryloyl oxyethyl) phosphate) (NR-g-PDMMEP) from photo-polymerization in latex medium*. In: European Polymer Journal, 2009, vol. 45, p. 820

[4] Setua, D. K., De S. K. *Short silk fiber reinforced natural rubber composites*. In: Rubber Chemical Technology, 1983, vol. 56, issue 4, p. 808

[5] Chakraborty, S. K., Setua, D. K., De S. K. *Short jute fiber reinforced carboxylated nitrile rubber*. In: Rubber Chemical Technology, 1982, vol. 55, issue 5, p. 1 286

[6] Egwaikhide, P. A., Akporhonor, E. E., Okieimen, F. E. *Effect of coconut fibre filler on the cure characteristics, physico-mechanical and swelling properties of natural rubber vulcanizates*. In: International Journal of Physical Sciences, 2007, vol. 2, issue 2, p. 39

[7] Lovely, M., Joseph, K. U., Joseph, R. *Swelling behavior of isora/natural rubber composites in oils used in automobiles*. In: Bulletin of Materials Science, 2006, vol. 29, issue 1, p. 91

[8] O'Connor, J. E. *Short-fiber-reinforced elastomer composites*. In: Rubber Chemistry and Technology, 1977, vol. 50, issue 5, p. 945

[9] Ikarashi, Y., Toyoda, K., Ohasawa, N., Uchima, T., Tsuchiya, T., Kaniwa, M. A., Sato, M., Takahashi, M., Nakamura, A. *Comparative studies by cell culture and* in vivo *implantation test on the toxicity of natural rubber latex materials*. In: Journal of Biomedical Materials Research, 1992, vol. 26, issue 3, p. 339

[10] Basfar, A. A., Silverman, J. *Improved ozone resistance of styrene butadiene rubber cured by a combination of sulfur and ionizing radiation*. In: Polymer Degradation and Stability, 1994, vol. 46, issue 1, p. 1

[11] Zuga, M. D., Iovu, H., Trandafir, V., Mănăilă, E., Martin, D., Stelescu, M. M. *Study on the preparation of some biocompostes based on silicone elastomers and collagen.* In: Journal of Optoelectronic and Advanced Materials, 2007, issue 9, p. 3 325

[12] Stelescu, M. D., Manaila, E., Zuga, N. *The use of polyfunctional monomers in the radical cure of chlorinated polyethylene*. In: Polymer Journal, 2011, vol. 43, p. 792

[13] Stelescu, M. D. *Characteristics of silicone rubber blends*. In: Leather Footwear Journal, 2010, vol. 10, issue 3, p. 51

[14] Lopez-Manchado, M. A., Herrero, B., Arroyo, A. *Preparation and characterization of organoclay nanocomposites based on natural rubber*. In: Polymer International, 2003, vol. 52, p. 1 070

[15] Arroyo, M., Lopez-Manchado, M. A., Herrero, B. *Organo-montmorillonite as substitute of carbon black in natural rubber compounds*. In: Polymer, 2003, vol. 44, p. 2 447

[16] Chenal, J. M., Chazeau, L., Guy, L., Bomal, Y., Gauthier, C. *Molecular weight between physical entanglements in natural rubber: A critical parameter during strain-induced crystallization*. In: Polymer, 2007, vol. 48, p. 1 042

[17] Stelescu, M. D., Mănăilă, E., Crăciun, G. *Vulcanization of ethylene-propylene–terpolymer-based rubber mixtures by radiation processing.* In: Journal of Applied Polymer Science, 2013, vol. 128, issue 4, pp. 2 325-2 336

[18] Ahmed, K., Nizami, S. S., Raza, N. Z., Shirin, K. *Cure characteristics, mechanical and swelling properties of marble sludge filled epdm modified chloroprene rubber blends*. In: Advances in Materials Physics and Chemistry, 2012, issue 2, p. 90

[19] Mathew, L., Joseph, K. U., Joseph, R. *Swelling behaviour of isora/natural rubber composites in oils used in Automobiles*. In: Bulletin of Materials Science, 2006, vol. 29, issue 1, p. 91

[20] Ismail, H., Edyham, M. R., Wirjosentono, B. *Dynamic properties and swelling behaviour of bamboo filled natural rubber composites : the effect of bonding agent*. In: Iranian Polymer Journal, 2001, vol. 10, issue 6, p. 377

[21] Mathew, L. Thesis. *Short isora fibre reinforced natural rubber composites*. Department of Polymer Science and Rubber Technology Cochin University of Science and Technology, Kochi 22, Kerala, India 2006, pp. 173-174

Authors:

ELENA MĂNĂILĂ
GABRIELA CRĂCIUN
National Institute for Laser Plasma and Radiation Physics
409 Atomistilor Street, 077125 Magurele
e-mail: elena.manaila@inflpr.ro

MARIA DANIELA STELESCU
DANA GURĂU
The National Research & Development Institute for Textiles and Leather
Leather and Footwear Research Institute Branch
93 Ion Minulescu Street, Bucharest

CHRISTIAN LAURENŢIU DINCĂ
LILIOARA SURDU
The National Research & Development Institute for Textiles and Leather
16 Lucreţiu Pătrăşcanu Street, 030508 Bucharest
e-mail: certex@ns.certex.ro

Correspondence author:

PhD. eng. MARIA DANIELA STELESCU
e-mail: dmstelescu@yahoo.com

DOCUMENTARE

Confecţii textile

JACHETA INTERACTIVĂ *ZEGNA SPORT ICON*

Ermenegildo Zegna, brandul italian de renume în domeniul modei, a revenit la domeniul tehnologiilor purtabile, prin lansarea noii jachete *Icon* (fig. 1), care reprezintă un prim pas spre o îmbrăcăminte sport cu adevărat interactivă.

Fig. 1

Jacheta este echipată cu sistemul BTM, dezvoltat de compania britanică ***Fibretonic***, care îi permite utilizatorului să se conecteze wireless la un smartphone și să controleze apelurile telefonice și muzica de la comenzile joystickului CONNECTEDwear, încorporat în manecă.

„*Suntem încântaţi că tehnologia noastră purtabilă este utilizată la această jachetă frumos proiectată... Ea oferă purtatorilor ușurința de a-şi controla telefonul și muzica, printr-o simplă apăsare pe mânecă*“ – declara Steve Leftly, directorul general executiv al companiei Fibretonic.

Lansarea jachetei *Zegna Sport Icon*, care în prezent este disponibilă la nivel mondial, confirmă încrederea companiei italiene în eficiența acestei tehnologii.

În anul 2007, Zegna a lansat, pentru prima dată, *iJacket,* cu ajutorul tehnologiei Eleksen, ajungând la o vânzare de aproximativ 8 000 de bucăţi, în primele șase luni de la lansare, la un preţ cu amănuntul de 1 000 de dolari S.U.A. Pe măsură ce tehnologia s-a dezvoltat, au fost lansate produse îmbunătăţite, cum ar fi jacheta *BT* şi jacheta *Iconic.*

Următoarea lansare a companiei Zegna a fost *Solar Jacket*, realizată pe bază de celule solare integrate, destinate încărcării dispozitivelor aflate în gulerul acesteia. Jacheta a avut un succes imediat şi o vânzare de 3 000 de bucăţi, în primele şase luni de la lansare, la un preţ de aproximativ 1 000 de dolari S.U.A.

Cea de-a doua generaţie, *Solar Ski*, s-a vândut, în primele şase luni de la lansare, într-un număr de 2 000 de bucăţi, la un preţ de 1 500 de dolari S.U.A. pe bucată. Cea de-a treia generaţie *Solar Jacket*, destinată sezonului de iarnă 2009/2010, a avut parte de un succes similar.

Toate aceste produse, realizate în ediţie limitată, pe lângă faptul că sunt profitabile, au generat o promovare foarte mare a companiei Zegna, fără ca aceasta să facă vreo investiţie în campanii publicitare.

Cu toate acestea, în perioada 2011 – 2012, Zegna nu a mai lansat astfel de produse, întreaga atenție concentrându-se asupra unor concepte prietenoase mediului, ceea ce a făcut ca noile componente electronice integrate să fie promovate atât în Europa, cât și în S.U.A.

__Smart__textiles and nanotechnology, octombrie 2013, p. 1

O NOUĂ GAMĂ DE COMPOZITE DIN FIBRE NATURALE

Compania ***Composites Evolution***, din Chesterfield – Marea Britanie, a lansat un nou sortiment de materiale texile din fibre de iută, pentru ranforsarea compozitelor. În figura 1 este prezentat un material textil din iută, destinat ranforsării compozitelor, ca alternativă mai ieftină la cel din fibre de in.
Biotex Jute sunt realizate din materiale durabile, ce posedă bune proprietăți mecanice, cum ar fi raportul optim între greutate și rigiditate. Aceste proprietăți sunt similare cu cele ale fibrelor naturale de cea mai bună calitate, cum ar fi cele de in. Costurile de realizare a acestora sunt aproximativ la fel cu cele ale materialelor din fibră de sticlă.
Noua gamă, care include ţesături cu legătură pânză şi diagonal 2 x 2, are o serie de avantaje: menține scăzută greutatea pieselor compozite, asigură o bună izolare termică şi fonică și contribuie la amortizarea vibraţiilor. Cu toate că greutatea materialelor din iută este cu 50% mai mică decât cea a materialelor din fibre de sticlă, rigiditatea specifică este similară acestora.

Fig. 1

Biotex Jute sunt 100% ecologice, datorită faptului că fibrele de iută se extrag din tulpinile lemnoase ale unor plante liberiene anuale, prin procese de prelucrare prietenoase mediului, iar la sfârșitul duratei de viaţă a materialului compozit, iuta poate fi reciclată.
În funcție de cererea de pe piață, compania Composites Evolution furnizează, în cadrul gamei Biotex, și alte materiale compozite realizate din fibre naturale, cum ar fi cele de in, sau din in în combinaţie cu acidul polilactic (PLA) sau cu polipropilena (PP), dar și cu alte materiale, dacă clienții le solicită.

Technical Textiles International, octombrie/noiembrie 2013, p. 39

MATERIALE TEXTILE IMPLANTABILE DE ULTIMĂ GENERAȚIE

Cu structuri personalizate, noile materiale textile biocompatibile şi absorbabile (fig. 1) înlocuiesc din ce în ce mai mult materialele tradiționale rigide, fiind folosite la producerea unor dispozitive medicale – grefe, valve cardiace, ligamente de stabilizare a coloanei vertebrale și ligamente artificiale.
Noile opțiuni de tratament, mult mai sofisticate, necesită instrumente și tehnologii medicale de înaltă performanţă. De exemplu, pentru procedurile cardiovasculare şi ortopedice de înlocuire sau reconstrucție a țesuturilor, cartilajelor, oaselor etc., chirurgii apelează la metode minim invazive, care necesită materiale de dimensiuni mai mici, mai rezistente şi mai flexibile. Compania ***Biomedical Structures***, din Warwick – S.U.A., este un important furnizor de materiale pentru producătorii de dispozitive medicale. Ea utilizează toată gama de tehnologii textile pentru realizarea unor produse personalizate, inclusiv structuri împletite, țesute, tricotate şi nețesute. Alegerea firelor este o etapă importantă, de aceea compania BMS se implică în controlul tuturor componentelor încă din faza de polimer. De exemplu, în producerea structurilor biomedicale tricotate sunt utilizate polipropilena, poliesterul, acidul poliglicolic/acidul polilactic, poliuretanul, politetrafluoroetilena, polieterul ceton cetonă, polieterul eter cetonă, firele metalice etc. În ceea ce priveşte firele speciale, compania BMS colaborează cu firma ***DSM Dyneema***, care a dezvoltat fibra *UHMWPE Purity*.
O altă colaborare importantă a fost realizată cu compania ***TissueGen***, din Dallas – S.U.A., care a elaborat un nou sortiment de fibre biodegradabile, *Elute*, încărcate cu medicamente. Legat de aceasta, Christopher Knowles, director general executiv al TissueGen afirma: *„Fibrele Elute conferă un plus de performanță dispozitivelor medicale implantabile, ducând la o vindecare mai rapidă, o adaptabilitate și o toleranță mai bună a organismului pacientului şi mai puține rezultate negative, cu costuri relativ mici... Fibrele biodegradabile pot fi încărcate cu cea mai variată gamă de medicamente și agenți terapeutici, datorită procesului*

Fig. 1

brevetat de extrudare la temperatura camerei, care are ca rezultat o distribuție controlată și localizată în organism".
TissueGen are capacitatea de a livra aceste fibre la diferite dimensiuni și rezistențe, în funcție de cerințele pieței. Ele sunt disponibile, prin compania BMS, sub formă de fibre, țesături, tricoturi sau textile împletite, pentru diferite aplicațiile medicale: cardiologie, vindecarea rănilor cutanate, regenerarea nervilor periferici, suturi, stenturi vasculare, grefe, ortopedie și chirurgie generală.
Un avantaj semnificativ față de alte mijloace de livrare a medicamentelor, cum ar fi microsferele și nanoparticulele, este conferit de faptul că tehnologia TissueGen oferă suportul mecanic și farmacologic din aceeași fibră. Geometria cilindrică lungă asigură o eliberare mai lentă a medicamentului, comparativ cu geometria sferică cu aceeași rază, având ca rezultat o fereastră terapeutică mai mare pentru concentrații similare de medicamente. Fibrele sunt uşor de implantat și îşi mențin stabilitatea pozițională, oferind un avantaj de neegalat atunci când vizează anumite locuri din țesuturi, cum ar fi tumorile solide. Extrudarea fibrei este un proces bine controlat, care oferă o distribuție granulometrică uniformă. Fibrele multistratificate coaxiale oferă posibilitatea ca fiecare strat să conțină o combinație unică de medicament şi polimer, permițând eliberarea adaptată a unui număr mare de medicamente într-o singură fibră. Spre deosebire de microsfere şi nanoparticule, fibrele nu prezintă risc pentru pacienți, deoarece ele pot fi îndepărtate în cazul rar al unei reacții adverse.
TissueGen a încheiat deja parteneriate importante cu dezvoltatori de dispozitive medicale pentru inimă, ochi, artere periferice şi nervi.

*Smart**textiles** and nanotechnology, octombrie 2013, p. 6*

INDEX DE AUTORI pe anul 2013