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Sumar

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Biosynthesis of silver nanoparticles using Reseda Luteola L. and their antimicrobial activity

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REZUMAT – ABSTRACT

Biosinteza nanoparticulelor de argint pe bază de Reseda Luteola L. şi activitatea antimicrobiană a acestora

Dintre diferitele metode sinteză a nanoparticulelor de argint, cea mai mult utilizată a fost metoda biologică. În cadrul acestui articol este prezentată o metodă facilă şi rapidă pentru biosinteza nanoparticulelor de argint, care se bazează pe folosirea unui colorant natural extras din rezeda de câmp (Reseda Luteola L.). Extractul apos de colorant a fost folosit ca agent de reducere a ionilor de argint. Caracterizarea acestor nanoparticule s-a efectuat prin diverse tehnici. S-a analizat atât formarea şi dezvoltarea nanoparticulelor, cu ajutorul spectroscopiei de absorbție UV-VIS, cât şi forma, dimensiunea şi morfologia acestora prin microscopie electronică de transmisie (TEM). De asemenea, a fost evaluată influența cantității de colorant asupra procentului de argint şi a timpului de contact, pentru a descoperi efectele acestora asupra eficacității sintezei nanoparticulelor de argint. Distribuția dimensiunii nanoparticulelor de argint a fost evaluată prin tehnica DLS. De asemenea, a fost investigat şi potențialul antibacterian al nanoparticulelor de argint biosintetizate.

Cuvinte-cheie: colorant natural, nanoparticule de argint, efect antibacterian, pH

Biosynthesis of silver nanoparticles using Reseda Luteola L. and their antimicrobial activity

Among different methods to synthesize silver nanoparticles (SNPs), the biological method has been the most extensively investigated. This study presents a facile and rapid method for biosynthesis of silver nanoparticles from Weld (Reseda Luteola L.) as a natural dye. An aqueous extract of the dye was used as a reducing agent for silver ions. The evaluation of these nanoparticles was made by various methods. The formation and growth of the nanoparticles were studied using UV-Vis absorption spectroscopy, while their shape, size and morphologies were monitored by transmission electron microscopy (TEM). Moreover, the influence of the dye amount to silver ratio and contact time were evaluated to find their effects on synthesis' efficacy. Size distribution of SNPs were evaluated by means of Dynamic light scattering (DLS) measurements. Antibacterial potential of biosynthesized SNPs was investigated.

Key-words: natural dye, silver nanoparticles, antibacterial effect, pH

Nanoparticles play an important role in pharmaceutical, industrial and biotechnological applications. In particular, silver nanoparticles are proved to have antibacterial, antifungal, antiplasmodial and larvicidal properties [1–2]. Silver ion is highly toxic to bacteria such as Escherichia coli B (E. coli) and Staphylococcus aureus but has a low toxicity to animal cells. Linens and clothing can provide a suitable environment for many bacteria, fungi and viruses to grow when in contact with the human body, allowing transmission of infectious disease. Silver nanoparticle is one of the most antibacterial agents which are preferred to apply in textile industry [3]. Antibacterial efficacy on textile fabrics can easily be achieved by applying nanosized silver colloids to the fabrics [4–6]. Among different methods to synthesize silver nanoparticles, the biological method has been extensively investigated. Biosynthesis provides advancement over chemical and physical method as it is cost effective, environment friendly, easily scaled up for large scale synthesis and in this method there is no need to use high pressure, energy, temperature and toxic chemicals. From recent results, researchers inspired on biological systems to develop benign nanoparticles using microorganisms, yeast and plant or plant extracts termed as green chemistry approaches [7]. Silver nanoparticles being extensively synthesized using various plant leaf extracts such as Geranium [8], Neem [9], Ocimum [10], Cassia auriculata [11], Mahogany [12], Chenopodium album [13], Cassia fistula [14] and Avicennia marina [15]. Weld (Reseda Luteola L.) is a plant which produces a yellow colour from its foliage and flowers. Luteolin and apigenin are the two main flavonoids present in the Weld [16]. Since prehistoric times, natural dyes have been used for coloring natural fibers such wool, cotton and silk. They also served to color cosmetic products and to produce inks, watercolors and artist's paints. This paper reports a facile and rapid biosynthesis of silver nanoparticles from Weld as a natural dye. The aqueous extract of the dye was used as reducing agent to silver nanoparticles synthesis from silver nitrate.

EXPERIMENTAL PART

Materials and chemicals

Weld (Reseda Luteola L.) was collected during the flowering period (May/June 2008) in Iran. The foliage and flowers parts of plant collected and after drying, were grounded in a laboratory mill. Silver nitrate was obtained from Merck (Germany). High salt Luria Bertani Broth (LB) was purchased from Sigma Aldrich. All the chemicals and reagents used in this study were of analytical grade. *p*H was adjusted to the required value with a 0.1 N NaOH aqueous solution.

Extraction of dye

10 grams of dried Weld was weighed in a round bottom flask. A magnetic stirring-bar and 400 mL of methanol–water 8:2 (v/v) were added to the flask. The flasks were placed on a heater with a stirrer and refluxed for 15 minutes at boiling temperature. The extracts were then filtered (Whatman no. 541, 22 μm) and put in a Petri dish into an oven at 45°C for 24 hours for a powder state. The powder was kept in a refrigerator and used for further experiments.

Synthesis of silver nanoparticles

The broth used for reduction of Ag^+ ions to Ag^0 was prepared by taking 0.5 g of extracted dye with 100 mL of deionized water and then stirring the mixture for 5 minutes at room temperature. After stirring, the solution was filtered using a HPLC syringe filter (0.45 μm, 25 mm). A required dye amount of the broth was mixed with pure water to adjust the final volume of 5 mL. At last step, 5 mL of a 100 ppm aqueous $AgNO_3$ was added drop wise to the dye solution at room temperature, while vigorously stirring for 1 hour. Water, silver solution and dye solution was separately adjusted to *p*H = 8 before mixing together. In this paper the amount of *K* represents the dye to silver concentration ratio.

Characterization of silver nanoparticles

The bio reduction of Ag^+ ions in solutions was monitored by measuring UV-Vis spectra of the solution after a specific time and several times dilution with deionized water. UV-VIS spectral analysis was performed using a Cary 100 Bio UV/Vis spectrophotometer (Varian). The dye solution without $AgNO_3$ at the same concentration of each sample was used for the baseline correction. Transmission Electron Microscopy (TEM) measurements were performed using a Libra 200 (Carl Zeiss SMT). Samples were prepared by placing solution droplets of a 2 μL volume on the carbon-coated copper TEM grids and followed by slowly evaporating at room temperature. The size distribution of particles was characterized by dynamic light scattering (DLS) using a Zetasizer Nano HPPSv420 (Malvern Instruments, UK).

Qualitative antibacterial testing

In this method antibacterial activity is defined as the antibacterial agent that inhibited the growth of tested bacteria in around. In order to determine antibacterial activity of synthesized SNPs, qualitative bacteriostatic tests against E. coli (ATCC 8739) were used by the agar-based test method and expressed in term of the size of inhibition zone (in mm). Surfaces of Petri dishes, containing 25 mL of Mueller-Hinton agar, were seeded individually with bacterial suspensions (equivalent to 0.5 McFarland standard, 1.5×10^8 CFU/mL), using a sterile cotton swab. Wells were done by punching a stainless-steel cylinder (80 mm in diameter) onto the agar plates and removing the agar. 80 μL aliquots of each prepared sample were placed individually in the wells. The Petri dishes were incubated at 37°C for 24 hours, thereafter, the zones of inhibition were determined.

Quantitative antibacterial test method

The antibacterial properties were quantitatively evaluated against E. coli, according to test method FC-TM-19-2001, which was designed by laboratory accord for exact antibacterial evaluation of colloidal solutions. 10 μl of bacteria was added to 10 ml fresh LB medium and grown in 37°C till the amount of bacteria reach 10^8 CFU/ml. This solution was diluted using LB medium to 10^7 CFU/ml. 0.1 ml of the solution was added to 40 mL of synthesized SNPs and biological serum as a control and after inoculation for 24 hours in 37°C was diluted in test tubes with the biological serum solution at 10^1, 10^2, 10^3 and 10^4 times. 0.1 mL of solution from each test tube was placed on agar plates and incubated for 24 hours. Finally, the average number of colonies was calculated from 3 repeating.

RESULTS AND DISCUSSIONS

Reduction of $AgNO_3$ solution

Figure 1 shows the UV-Vis spectrum for the 50 ppm silver ions containing solution and extract of Weld at *p*H 8 with *K* = 10. Upon stirring at room temperature (25°C) for 1 hour, a prominent peak appeared at 450 nm, which could be attributed to the Surface

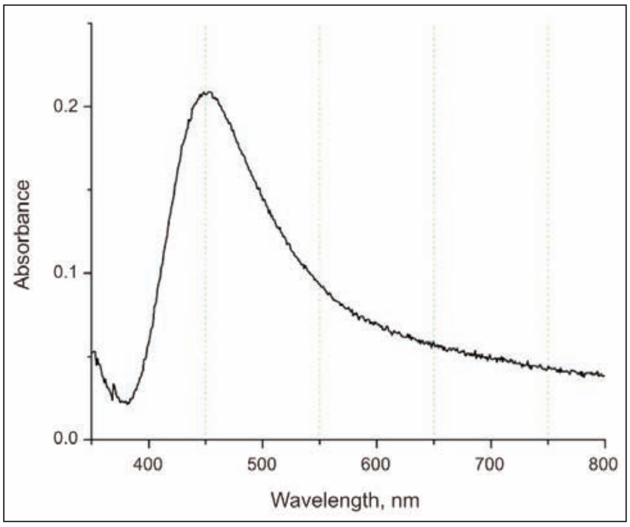


Fig. 1. UV-Vis spectra of synthesized SNPs after 1 hour in solution with *K* = 10 and *p*H = 8

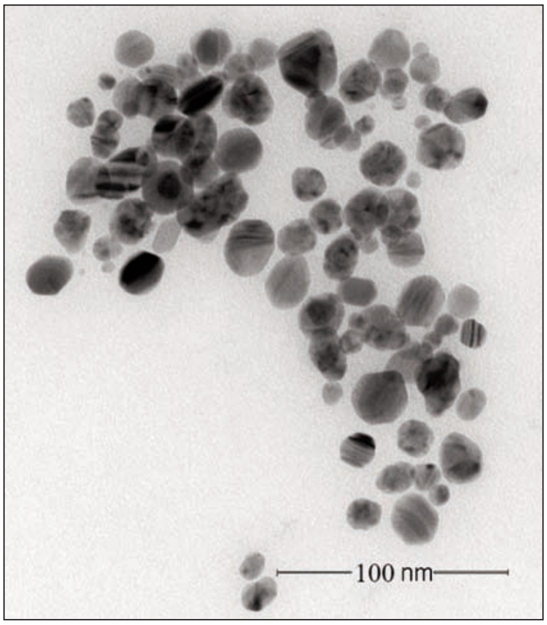
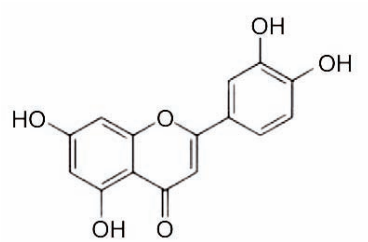


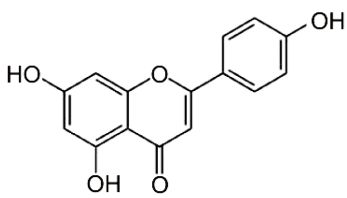
Fig. 2. TEM image of synthesized SNPs after 1 hour in solution with K = 10 and pH = 8

Plasmon Resonance band of SNPs [17]. TEM images confirmed existence of SNPs in solution (fig. 2).

Chemical constituents in the dye extract may act as a biological reducing agent. The main biomolecules responsible for nanoparticle synthesis are polyphenols or flavonoids, which are present in the comparable amount concentrations in Weld. Oxidation-reduction abilities are primarily owing to phenolic antioxidant compounds, i.e. their ability to act as reducing agents, hydrogen donors and singlet oxygen quenchers [18]. Luteolin and Apigenin are two major polyphenols present in Weld [19]. Molecular structure of Luteolin is presented in formula (1) and of Apigenin in formula (2).



(1)



(2)

Polyphenols which have two ortho or para-dihydroxy group in their phenolic ring can easily be oxidized to related quinones [20]. Therefore, Luteolin is the most important polyphenol acting as a reducing agent in SNPs synthesis. Tentative mechanism of SNPs synthesis in the present of Luteolin is illustrated in formula (3).

It can be seen, that one molecule of Luteolin can cause a reduction of two silver ions to SNPs. In this mechanism, Luteolin is oxidized to α, β-unsaturated carbonyl groups. Resulted Quinone is not stable and is rapidly hydrated to unreactive species [21].

Effect of dye extracts quantity on synthesis of silver nanoparticles

Figure 3 shows the UV-Vis spectra for synthesized SNPs with several different silver to dye ratio after one hour in pH = 8. Increasing ratio of dye extract up to K =15 led to an increase in absorbance intensity at 450 nm corresponded to SNPs formation. With K = 20, the sharpness of absorption peak was less than K = 15. At low amount of K, the number of dye molecules may be not enough to reduce all silver ions to SNPs. An increase of the dye amount could cause a complete reduction of any silver ions to SNPs and therefore an increase in absorption intensity at 450 nm. A decrease in UV-Vis absorbance intensity with K = 20 could be due to surrounding of SNPs by extra dye molecules. It seems, after achievement the required amount of dye molecules as a reducing agent, a reaction between extra dyes and synthesized SNPs can happen and lead to surrounding of SNPs by dye molecules. A small pick at 368 nm

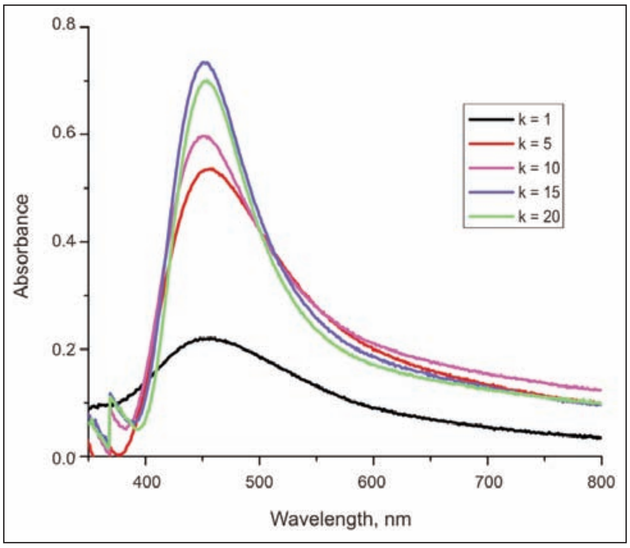
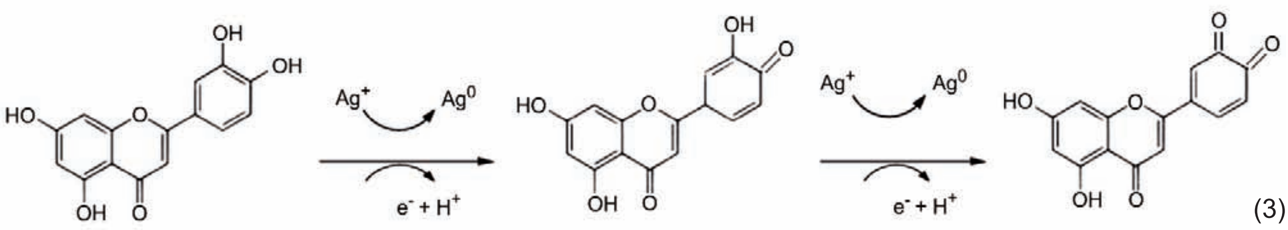
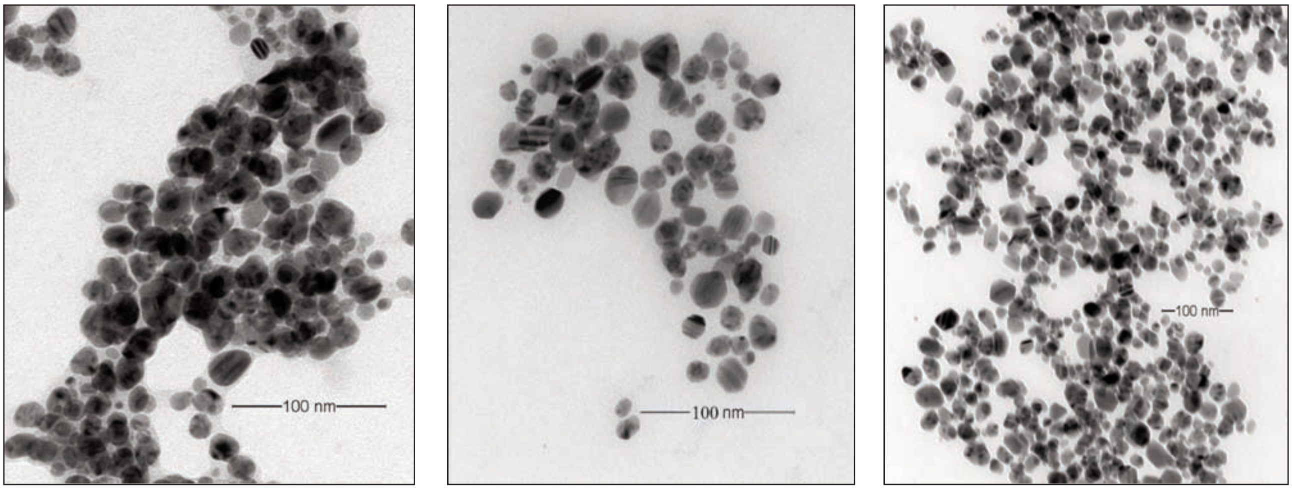


Fig. 3. UV-Vis spectra for synthesized SNPs with several different silver to dye ratio after one hour in pH = 8

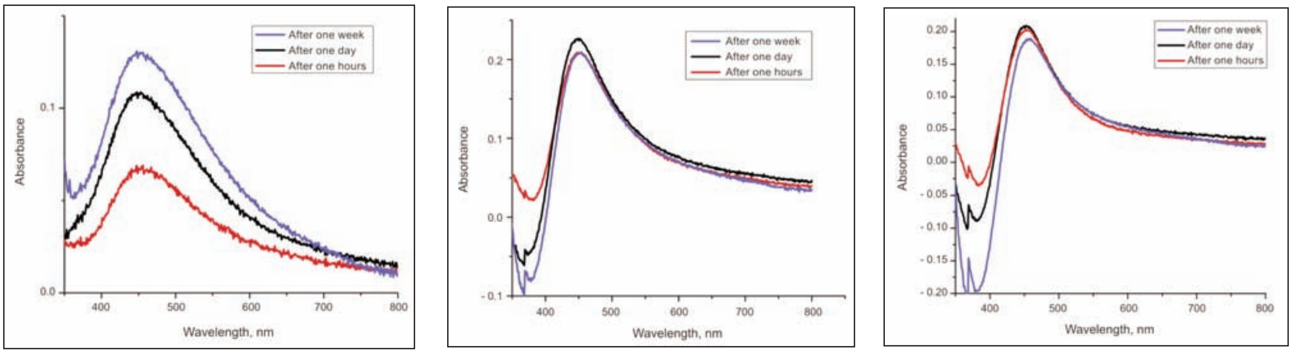


(3)



a *b* *c*

Fig. 4. TEM images of the synthesized SNPs after 1 hour in solution with *p*H = 8 and:
a) *K* = 1; ***b)*** *K* = 10; ***c)*** *K* = 20



a *b* *c*

Fig. 5. UV-Vis absorption spectra of solution of synthesized SNPs in different time in solution with *p*H = 8 and:
a) *K* = 1; ***b)*** *K* = 10; ***c)*** *K* = 20

is related to presence of some unreacted dyes that can be observed in in UV-Vis spectra for samples with *K* larger than 10.

The mean value of hydrodynamic diameter (Z-average) and polydispersity indices of silver nanoparticles for *K* 1, 10 and 20 are summarized in table 1. The Z-average for nanoparticles was reduced by increasing dye to silver ratio up to *K* = 10. An increase of *K* up to 20 caused an increase in the particle hydrodynamic diameter. It is probably because of dye molecules attachment to SNPs in a high concentration of dye in solution.

Table 1

EFFECT OF K ON Z AVERAGE AND POLYDISPERSITY INDEX OF SNPs AFTER 6 HOURS

K	**1**	**10**	**20**
Z **average,** nm	30.8	12.1	20.6
Polydispersity index	0.207	0.545	0.512

The lowest value of polydispersity indices of produced nanoparticles led to a narrow size distribution. An increased amount of dye to silver ratio from 1 to 10 led to an increase in polydispersity indices of SNPs. This indicated that a more difference in size of synthesized SNPs will be by a higher concentration of the dye. Weld is made of different flavonoids able to reduce silver ions to SNPs. Different reducing agent with different redox potential could cause synthesis of SNPs in different size.

A correlation between *K* and the size of synthesized SNPs can be noted by TEM images depicted in figure 4. With an increase of K from 1 to 20, a decrease in the particle size was revealed. An increase of *K* up to 20 resulted in a smaller SNPs size. It is due to that dye acts as a reduction agent and any increase of reduction agent will lead to a smaller SNPs.

Stability of silver nanoparticles

The effect of dye extracts quantity on synthesis time and stability of SNPs in an aqueous solution was evaluated at different dye to silver ratio using UV-VIS spectroscopy and the zeta size analyzer. UV-Vis spectroscopy results indicated that at a low ratio of dye-to-silver, even after one day, an increase in maximum absorbance intensity was revealed (fig. 5). With an increase of *K* to 10, no increase in peak intensity was noticed after one day. It can be concluded that with an increase of dye concentration, less time was needed to achieve a maximum of UV-Vis absorption intensity at 450 nm. It is due to that dye acts as a reduction agent and any increase of reduction agent will lead to a faster synthesis of SNPs. However, an increase of the dye-to-silver ratio up to 20, caused less stability in UV-Vis absorption spectra. A decrease in UV-Vis absorbance in the range of 350 – 400 is because of a decrease in dye concentration in solution and can be explained by dye aggregation. At high dye concentrations, molecules have tendency for attach to each other to larger particles. At k = 20, some of SNPs might be surrounded by the dye and therefore were agglomerate accompanied by dye aggregation.

A comparison of DLS results shown in tables 1 and 2 revealed that stability in all cases is sufficient. When amount of the dye-to-silver ratio is 20, the hydrodynamic diameter of particles was reached to a double size after one month. It can confirm that stability of the particles at this concentration of dye was decreased.

Results on antibacterial activity

An antibacterial is an agent that inhibits bacterial growth or kills bacteria [22]. The results of qualitative antibacterial assay are presented in table 3. The best antibacterial properties, leading to the larger inhibition zone of bacterial growth, were achieved with K = 1. With an increase of the dye amount to K = 10, a small decrease in the inhibition zone diameter was observed The SNPs prepared by using dye to silver ratio 20 gave the smallest inhibition zones. It could be because of the surrounding and encapsulation of synthesized SNPs with dye so, there are less free to diffuse on the agar plate and inhibits growth of bacteria. In quantitative antimicrobial method, the antimicrobial activity was evaluated by calculating the percent reduction of bacteria after incubation with SNPs using equation (4):

$$R\,(\%) = \frac{M_a - M_b}{M_a} \cdot 100 \qquad (4)$$

where:

R is percentage of the bacteria reduction;

M_a – average number of bacterial colonies on the agar plate including the diluted solution of the control after 24 hours incubation;

M_b – average number of bacterial colonies on the agar plate including the diluted solution of bacteria containing SNPs after 24 hours incubation.

Results in table 4 show that in all cases synthesized SNPs could kill all of the bacteria. It means that synthesized SNPs show excellent bactericidal properties in quantitative test. Comparison between qualitative and quantitative tests shows encapsulated SNPs can separate from dye molecules in liquid phase and kill all of bacteria. It means complex between dye and SNPs was not too strength to cause the loss of antimicrobial activity of synthesized SNPs.

Table 2

EFFECT OF K ON Z AVERAGE AND POLYDISPERSITY INDEX OF SNPs AFTER 30 DAYS

K	**1**	**10**	**20**
Z average, nm	36.92	17.73	41.88
Polydispersity index	0.298	0.446	0.435

Table 3

THE DIAMETER OF GROWTH INHIBITION ZONE IN QUALITATIVE METHOD FOR SYNTHESIZED SNPs AT DIFFERENT AMOUNTS OF *K*

K	**1**	**10**	**20**
Inhibition zone diameter, mm	18.18	17.45	10.36

Table 4

RESULTS OF QUANTITATIVE ANTIBACTERIAL TEST FOR SYNTHESIZED SNPs AT DIFFERENT AMOUNT OF DYE TO SILVER RATIO

K	**1**	**10**	**20**
M_a	1×10^7	1×10^7	1×10^7
M_b	0	0	0
Percent reduction of bacteria	100	100	100

CONCLUSIONS

The biosynthesis of silver nanoparticles from Weld (Reseda Luteola. L) as a natural dye was investigated. The aqueous extract of the dye was used as a reducing agent for silver nanoparticles synthesis from silver nitrate. The amount of dye-to-silver ratio was the decisive factor for size, polydispersity, stability and antibacterial properties of synthesized nanoparticles. Synthesized SNPs showed an excellent antimicrobial activity in liquid phase by the quantitative antimicrobial test. From a technological point of view, this method may have potential applications to obtain antibacterial properties of textiles, especially which can be dyed with natural dyes.

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BIBLIOGRAPHY

[1] Saxena, A., Tripathi, R. M., Singh, R. P. *Biological synthesis of silver nanoparticles by using onion (Allium Cepa) extract and their antibacterial activity*. In: Digest Journal of Nanomaterials & Biostructures, 2010, vol. 5, issue 2, p. 427

[2] Elumalai, E. K., Prasad, T., Hemachandran, J., Therasa, S. V., Thirumalai, T., David, E. *Extracellular synthesis of silver nanoparticles using leaves of Euphorbia hirta and their antibacterial activities*. In: Journal of Pharmaceutical Sciences and Research, 2010, vol. 2, issue 9, p. 549

[3] Dastjerdi, R., Montazer, M. *A review on the application of inorganic nano-structured materials in the modification of textiles: Focus on anti-microbial properties*. In: Colloids and Surfaces B: Biointerfaces, 2010, vol. 79, issue 1, p. 5

[4] Lee, H. J., Yeo, S. Y., Jeong, S. H. *Antibacterial effect of nanosized silver colloidal solution on textile fabrics*. In: Journal of Material Science, 2003, vol. 38, p. 2 199

[5] Lee H. J., Jeong, S. H. *Bacteriostasis of nanosized colloidal silver on polyester nonwovens*. In: Textile Research Journal, 2004, vol. 74, p. 442

[6] Durán, N., Marcato, P. D., De Souza, G. I. H., Alves, O. L., Esposito, E. *Antibacterial effect of silver nanoparticles produced by fungal process on textile fabrics and their effluent treatment*. In: Journal of Biomedical Nanotechnology, 2007, vol. 3, p. 203

[7] Ghorbani, H. R., Safekordi, A. A., Attar, H., Sorkhabadi, S. M. *Biological and non-biological methods for Silver nanoparticles synthesis*. In: Chemical and Biochemical Engineering Quarterly, 2011, vol. 25, issue 3, p. 317

[8] Shankar, S. S., Ahmad, A., Sastry, M. *Geranium leaf assisted biosynthesis of silver nanoparticles*. In: Biotechnology progress, 2003, vol. 19, issue 6, p. 226

[9] Shankar, S. S., Rai, A., Ahmad, A., Sastry, M. *Rapid synthesis of Au, Ag, and bimetallic Au core–Ag shell nanoparticles using Neem (Azadirachtaindica) leaf broth,* In: Journal of Colloid and Interface Science, 2004, vol. 275, issue 2, p. 496

[10] Malikarjuna, K., Dillip, G. R., Praveen, B., Shreedhar, B., Lakshmi, C. S., Reddy, B. V. S. P., Raju, B. D. P. *Green synthesis of silver nanoparticles using Ocimum leaf extract and their characterization.* In: Digest Journal of Nanomaterials and Biostructures, 2011, vol. 6, issue 1, p. 181

[11] Udayasooian, C., Kumar, K., Jayabalakrishnan, R. M. *Extracellular synthesis of silver nanoparticles using leaf extract of Cassia auriculata*. In: Digest Journal of Nanomaterials and Biostructures, 2011, vol. 6, issue 1, p. 279

[12] Mondal, S., Roy, N., Laskar, RA, SK, I., Basu, S., Mandal, D., Beguma, N. A. *Biogenic synthesis of Ag, Au and bimetallic Au/Ag alloy nanoparticles using aqueous extract of mahogany (Swieteniamahogani JACQ.) leaves*. In: Colloids and Surfaces B: Biointerfaces, 2011, vol. 82, p. 497

[13] Dwivedi, A. D., Gopal, K. *Biosynthesis of silver and gold nanoparticles using Chenopodium album leaf extract*. In: Colloids and Surfaces A: Physicochemical and Engineering Aspects, 2010, vol. 369, p. 27

[14] Lin, L., Wang, W., Huang, J., Li, Q., Snu, D., Yang, X., Wang, H., He, N., Wang, Y. *Nature factory of silver nanowires: Plant-mediated synthesis using broth of Cassia fistula leaf.* In: Chemical Engineering Journal, 2010, vol. 162, p. 852

[15] Gnanadesigan, M., Anand, M., Ravikumar, S., Maruthupandy, M., Vijayakumar, V., Kumaraguru, A. K. *Antibacterial potential of biosynthesised silver nanoparticles using Avicennia marina mangrove plant*. In: Applied Nanoscience, 2012, vol. 2, issue 2, p. 143

[16] Cristea, D., Bareau, I., Vilarem, G. *Identification and quantitative HPLC analysis of the main flavonoids present in weld* (*Reseda luteola* L.). In: Dyes and Pigments, 2003, vol. 57, p. 267

[17] Grijalva, A. S., Urbina, R. H, Silva., J. F. R., Borja, M. A., Barraza, F. F. *Assessment of growth of silver nanoparticles synthesized from an ethylene glycol-silver nitrate-polyvinyl pyrrolidine solution.* In: Physica E, 2005, vol. 25, p. 439

[18] Leopoldini, M., Pitarch, I. P, Russo, N., Toscano, M. *Structure, conformation, and electronic properties of Apigenin, Luteolin, and Taxifolin antioxidants, a first principle theoretical study*. In: Journal of Physical Chemistry, A, 2004, vol. 108, issue 1, p. 92

[19] Cristea, D. Bareau, I., Vilarem, G. *Identification and quantitative HPLC analysis of the main flavonoids present in weld (Reseda luteola L.).* In: Dyes and Pigments, 2003, vol. 57, p. 267

[20] Roy, N., Mondal, S., Laskar, R. A, Basu, S., Mandal, D., Begum, N. A. *Biogenic synthesis of Au and Ag nanoparticles by Indian propolis and its constituents*, In: Colloids and Surfaces B: Biointerfaces, 2010, vol. 76, p. 317

[21] Tu, T., Giblin, D., Gross, M. L. *Structural Determinant of Chemical Reactivity and Potential Health Effects of Quinones from Natural Products*. In: Chemical Research in Toxicology, 2011, vol. 24, issue 9, p. 1 527

[22] Barani, H., Montazer, M., Samadi, N., Tolyat, T. *Nano silver entrapped in phospholipids membrane: Synthesis, characteristics and antibacterial kinetics.* In: Molecular Membrane Biology, 2011, vol. 28, issue 4, p. 206

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Preparation of ethanolamine modified micro and new nano acrylic fibers for ion adsorption

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SAYED ALIREZA HASSANI NAJAFABADI
AHMAD MOUSAVI SHOUSHTARI
AMINODDIN HAJI

REZUMAT – ABSTRACT

Prepararea microfibrelor şi a noilor nanofibre acrilice modificate cu etanolamină, pentru adsorbţia de ioni

Microfibrele şi nanofibrele din poliacrilonitril au fost transformate în poliacrilonitril-monoetanolamină, printr-o reacţie cu etanolamina. Fibra PAN modificată a fost obţinută prin transformarea grupurilor nitril în grupuri hidroxil, folosind o soluţie de etanolamină cu concentraţie diferită la reflux, la 91°C. Fibrele acrilice crude modificate, cu diametre submicrometrice de 120-300 nm, au fost produse prin metoda electrofilării în N, N-dimetilformamidă. Micro şi nanofibrele PAN-MEA au fost folosite ca material de chelare într-o serie de experimente de adsorbţie, pe loturi, pentru îndepărtarea ionilor de Cr (III), Pb (II) şi Ni (II). Structura fibroasă a fost investigată prin diferite metode experimentale de caracterizare, cum ar fi spectroscopia în infraroşu cu transformată Fourier, analiza termogravimetrică şi microscopia de scanare electronică. De asemenea, au fost investigate proprietăţile fizice şi mecanice. Nanofibrele au prezentat o capacitate mai mare de absorbţie a ionilor metalici decât fibra obişnuită, datorită raportului mare dintre suprafaţă şi masă.

Cuvinte-cheie: chelare, modificare, nanofibră, adsorpţia ionilor, fibră acrilică

Preparation of ethanolamine modified micro and new nano acrylic fibers for ion adsorption

Polyacrylonitrile micro and nano fibers were converted to polyacrylonitrile-monoethanolamine through reaction with ethanolamine. The modified PAN fiber was prepared by conversion nitrile groups into hydroxyle groups using ethanolamine solution with different concentration under refluxing at 91°C. Modified raw acrylic fibers with sub-micrometer diameters ranging from 120 to 300 nm were produced using electrospinning in N, N-dimethyl formamide. The PAN-MEA micro and nano fibers were examined as chelating material in a series of batch adsorption experiments for removal of Cr (III), Pb (II) and Ni (II) ions. The fiber structure has been investigated by different experimental techniques of characterization such as Fourier transform infrared spectroscopy, thermogravimetric analysis and scanning electron microscopy. Also, the physical and mechanical properties have been investigated. Nano fibers show more ability to adsorb metal ions than the usual fiber because of high ratio of surface to mass.

Key-words: chelation, modification, nanofiber, ion adsorption, acrylic fiber

Contamination of water by toxic heavy metals through the discharge of industrial wastewater is a worldwide environmental problem. Heavy metal toxicity can result in damage or reduced mental and central nervous functions, lower energy levels and damage to other vital organs. Lead is an important pollutant introduced into natural waters. The presence of lead in wastewater is dangerous to aquatic flora and fauna even in relatively low concentration and stringent environmental regulation attracts the attention of chemists and environmental engineers for its control. The major sources containing lead are the wastewater from process industries engaged in lead acid battery, paints, oils, mental phosphate, fertilizer, electronic wood production and also the combustion of fossil fuel, forest fires, mining activity, automobile emission, sewage waste water, sea spray etc. are just few examples [1, 2] Removal of heavy metals is an important problem especially in industrial effluents. Various treatment technologies have been developed for the removal of heavy metals from water and wastewater. The commonly used technologies for removing metal ions from effluents include chemical precipitation, lime coagulation, ion exchange, solvent extraction and adsorption using activated carbon, electrode position and membrane process [2, 3].
The electrospinning technology has attracted a growing scientific interest [5]. In electrospinning processes, electrostatic forces are applied to stretch a polymer jet and produce continuous fibers with diameters ranging from nanometers [4–6]. Electrospun nano fibers possess high specific surface area, high porosity, small fiber diameter and low weight. These unique properties have triggered a broad range of applications including composite materials [7], sensors [8], scaffolds in tissue engineering [9], nanodevices [10] and filteration [3, 11].
The commonly used technologies for removing metal ions from effluents include chemical precipitation, lime coagulation, ion exchange [12–14], electro dialysis, reverse osmosis membrane filtration [15, 16], activated carbon [17], solvent extraction and common adsorption [18, 19].

Ion adsorption onto solid chelating polymer materials is now considered as one of the most promising techniques for selective concentration, removal and recovery of metal ions from a wide variety of sources. Among different types of polymer adsorbent, polymer fibers have attracted great interest in recent years [12]. This can be related to their structure and characteristics, like high specific surface, small cross-section, uniformity in diameter (in macroscopic scale) and long length of fiber to diameter [14]. Raw acrylic fibers (RAF), due to their chemical and termal stability, are a good substrate for the modification. The mentioned advantages are mainly attributed to the high adsorption capacities, fast adsorption equilibrium, high recycling rate and low cost of these polymeric fibers.

The use of commercial fiber and introducing functional groups on its structure are the important methods for producing ion adsorbent fibers. The properties of the fiber can be maintained in this method [14]. In the present study, raw acrylic fiber was modified by ethanolamine to obtain polyacrylonitrile-monoethanolamine (PANF-MEA), which is hydroxy-functionalized fiber. The modified fibers were characterized by FTIR spectroscopy. Then, the effects of treatment conditions on physical properties, termal characteristics, surface morphology, and ion adsorption quantity were investigated.

EXPERIMENTAL PART

Materials and instruments

Commerical acrylic fibers supplied from Iran polyacryl with 3.3 dtex – consist of acrylonitrile (AN) – of 93.5 and 6.5% wt of methyl methacrylate (MMA) were used. All chemicals consisting of ethanolamine, $CuSO_4 \times 5H_2O$, $Pb(NO_3)_2$, $Ni(NO_3)_2 \times 6H_2O$, dimethylformamide (DMF) were obtained from Merck (Germany). Metal solutions were prepared from reagent-grade metal salts.

FT-IR spectra of the samples were obtained by bruker (Equinox 55) spectrometer. TAQ 50 derivatograph was used for thermogravimetric analysis. The samples were heated at the rate of 10ºC/minute under Ar atmosphere, between 25ºC and 800ºC. The mechanical properties of the samples were tested by Vibromat and Fafograph from Textechno. Elongation rate of 20 mm/minute and sample length of 20 mm were selected in all samples. Micrograph of the fibers before and after modification was taken using SEM (Philips XL30). The concentration of ions was determined with a flame atomic absorption (FAA) spectrometer (Philips model PU9100).

Chemical modification of RAF with ethanolamine

Modified polyacrylonitrile fiber was prepared by adding 3 g of acrylic fibers to 300 ml of ethanolamine (MEA) solutions with different concentrations. The reaction mixtures were refluxed at 91ºC under stirring for 2 hours. The reaction product was cooled to room temperature, then the product was washed with acetone and distilled water and then air-dried. The content of the MEA groups in the fiber was calculated as follows:

$$EA = (W_1 - W_0)\, M_0 / (M_1 W_0) \qquad (1)$$

where:

EA is the content of MEA groups in the fiber, mol/g;

W_1 – the weight of the dry fiber after reaction, g;

W_0 – the weight of the dry fiber before reaction, g;

M_0 – the molecular weight chain unit CH_2CHCN (53);

M_1 – the molecular weight of $NH_2(CH_2)_2OH$ [20].

Electrospinning process

The formation of a thin fiber via electrospinning is based on the uniaxial stretching (or elongation) of a viscoelastic jet derived from a polymer solution or melt [3].

PAN is solved in common organic solvents. The solubility of raw acrylic fibers in dimethylformamide (DMF) was (17:83 w/w) but it was observed that the solubility of PANF-MEA was (19:81 w/w) and this is because of modification. The whole solutions were prepared by being dissolved in DMF (14:86 w/w) under stirring for several hours at room temperature. Aluminum plates were used as collector and prepared at 20 630 cm^2. The polymer suspension was delivered to capillary nozzle via a feed line from a syringe pump. The spinneret protruded through the center of the plate. A power supply provided upto 20 kV to the plate and the distance between the capillary nozzle and the plate was adjusted at 20 cm to obtain a stable and continuous jet.

Adsorption and removed processes of metal ions

The adsorption ions onto PANF-MEA for Ni (II), Cr (III), and Pb (II) ions were investigated using the batch method. Experiments were carried out in an Erlenmeyer flask at the desired *p*H and 25ºC temperature. The flasks were agitated on a shaker for 2 hours. The amount of adsorbed metal was determined by the difference between the initial metal ion concentration and the final one after equilibrium [3]. The concentration of ions was determined with a flame atomic absorption (FAA) spectrometer (Philips model PU9100).

The efficiency of metal ions recovery was estimated by the sorption yield R (%) and the q (mg/g) was calculated as:

$$R = (C_0 - C_t)/C_0 \cdot 100 \qquad (2)$$

$$q = (C_0 - C_t)/G \cdot V \qquad (3)$$

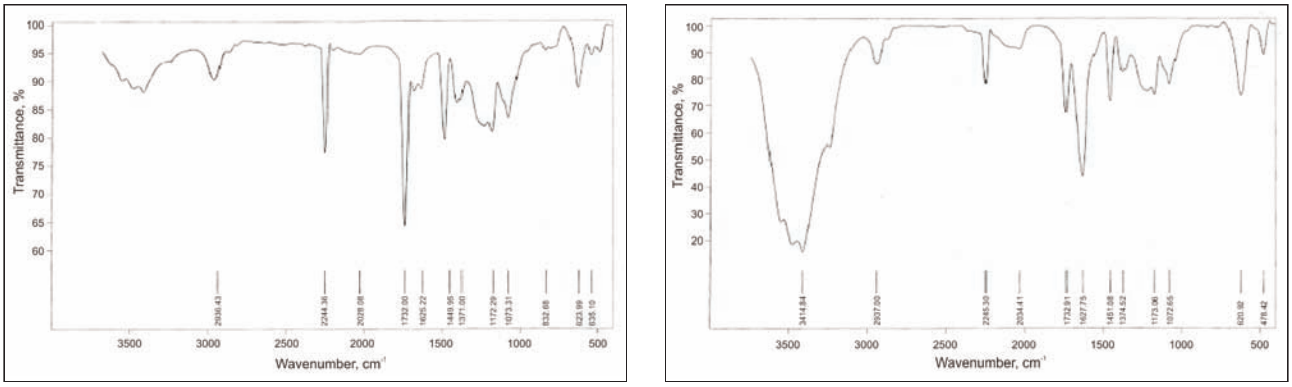
where:

C_0 is the initial metal ion concentration, mg/l;

C_t – the ion concentration after the adsorption period;

V – the volume of solution L and G is the dry mass of the PANF-MEA fiber simple, g.

The metal ions adsorbed on the PANF-MEA were then removed by placing 0.1 g of metal loaded fiber in 10 ml of 1M HNO_3 solution for 30 minutes [12].



a *b*

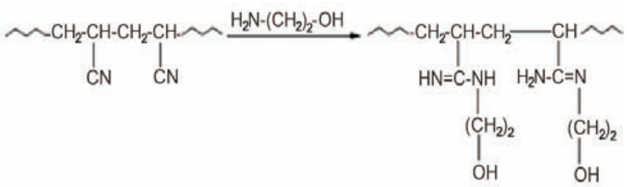
Fig. 1. FT-IR spectra of:
a – raw acrylic fiber (RAF); *b* – modified polyacrylonitrile fiber (PANF-MEA)

RESULTS AND DISCUSSIONS

Characterization of the PANF-MEA

The FT-IR spectra of the raw acrylic (RAF) and modified polyacrylonitril (PANF-MEA) fibers are shown in figure 1.

The FT-IR spectrum of raw acrylic fiber (fig. 1 *a*) shows peaks at 2 242 cm^{-1} (C = N stretching), 2 936 cm^{-1} (CH stretching in CH, CH_2, CH_3 groups), 1 732 cm^{-1} (C=O stretching), 1449 cm^{-1} (CH2 blending), 1371 cm^{-1} (CH scissors vibration), 1 000 – 1 300 cm^{-1} (C-O stretching in ester) confirming that the applied fiber can be a copolymer of acrylonitrile (AN) and methylmetacrylate (MMA) [3]. New peaks at 3 300 – 3 550 cm^{-1} corresponding to stretching vibration of NH and OH. New peak at 1 627 cm^{-1} was corresponding to bending vibration of N-H. The theme appeared in the spectrum PAN-MEA. In the PANF-MEA, it is observed that the intensity of the peaks at 2245 cm^{-1} (C=N) and 1 732 cm^{-1} (C=O) in modified fibers have been reduced. The comparison between the IR spectrums of PANF-MEAwith RAF is shown in table 1. These peaks show hydroxyl group. The chelating functional groups have been attached to the molecular fiber structure. The main reaction between PAN fibers and ethanolamine (MEA) are presented in formule (4).



(4)

Thermal behavior

The thermal behavior of the PANF-MEA in comparison with raw acrylic fibers (RAF) was studied by thermogravimetry. Figure 2 shows the thermoanaliytical TG curves. RAF decomposes in the temperature range of 312–4848°C and PANF-MEA decomposes in the temperature range of 298–4708°C. This decrease is very slight. The thermogravimetric data indicate that the initial termal stability of PANF-MEA is lower than that of RAF due to the conversion of nitrile groups into the hydroxyl groups.

Table 1

THE IR FREQUENCY BANDS OF PAN AND APAN FIBER

RAF	PANF-MEA	Characteristic group
-	3 300–3 550	OH, NH
2 936	2 937	CH, CH_2, CH_3
2 244	2 245	C=N
1 732	1 732	C=O
1 627	-	NH
1 449	1 451	CH_2
1 371	1 374	CH
1 000–1 300	1 000–1 300	C-O Ester

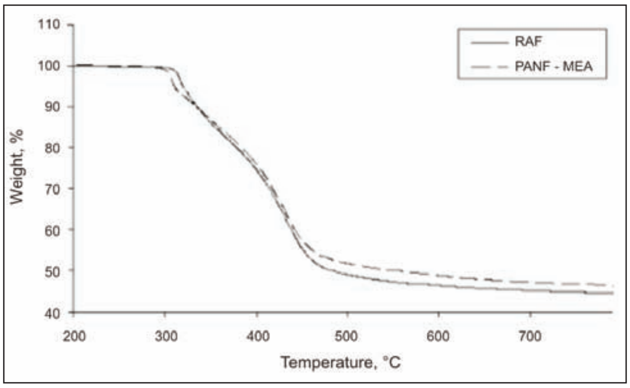


Fig. 2. TG curves of RAF and PANF-MEA

Relationship between reaction conditions and the functional groups

The effects of reaction conditions on the content of the functional groups in the fiber were investigated. Figure 3 presents the effect of the concentration of ethanolamine on the content of the functional group. As can be seen from figure 3, by increasing the concentration, the content of functional group increases with the concentration at the beginning period of

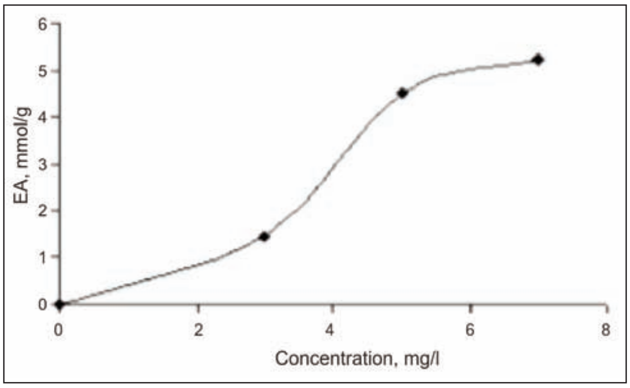


Fig. 3. Effect of concentration of ethanolamine on the content of the functional groups

reaction; however, it tends to steady the values after passing the conditions of 5M.

These results can be related to the high molecular diffusion of $NH_2(CH_2)_2OH$ from the solution into the fiber structure at the mentioned condition of concentration.

Mechanical properties

The effects of functional treatment on the mechanical properties are shown in table 2. By modification of RAF with ethanolamine, some of the properties are increased and some of the properties are reduced. Table 2 shows the changes in the work of rupture (gf/den), modulus (cN/Tex), max stress (cN/Tex) and extension at max load (%) of the modified sample (PANF-MEA) with respect to RAF samples.

Table 2

MECHANICAL PROPERTIES OF MODIFIED FIBER

Sample	Work of rupture, gf/den	Modulus, cN/tex	Max stress, cN/tex	Extension at max load, %
RAF	3.179	309.1	21	25.31
PAN-MEA	3.547	255	19.76	29.3

It is reduction in modulus (14%), and reduction in max stress (6%), but increase in extension at max load (4%), and increase in the work of rupture (10%) were observed. In general, these changes are very slight. This is because of changes which resulted in the molecular structure of raw fibers through modification treatment.

Ion adsorption quantity

The quantities of copper, lead and nickel ions remained in metal solutions after being treated with RAF and the modified acrylic fiber samples were measured. The values of adsorbed ions in PANF-MEA with different concentrations samples are shown in table 3 and figure 4. Moreover, the values of adsorbed ions in PAN-MEA nano-fiber with different concentrations samples are shown in table 4 and figure 5. Experiments were carried out in an Erlenmeyer flask at the desired *p*H and 25ºC temperature. In the sample, the solutions of copper, lead and nickel ions used the concentration of 1 ppm (1 mg/l) of ions. The flasks were agitated on shaker for 2 hours. As can be seen in the raw acrylic fibers, the content of copper, lead and nickel ions adsorbed was negligible; however, in the modified samples, the PAN-MEA nano fiber produced with 7M ethanolamine, high level of ion adsorption was observed, which can be related to the height on the content of the functional group. In addition, among tested samples with PANF-MEA (7M), the adsorption of copper was more than another sample's.

Equilibrium studies

Modified polyacrylonitrile fibers act efficiently for lead (II) ions. Equilibrium adsorption experiments were carried out at *p*H 5, temperature of 25ºC with increasing the amount of lead in the initial solution. The result of them took only about 2 hours. The adsorption isotherms are given in figure 6. Freundrich and Langmuir adsorption isotherm can describe the effect of metal ion concentration after the equilibrium on the PANF-MEA. The Freundrich isotherm model has the form (5):

$$q = KCe^{1/n} \qquad (5)$$

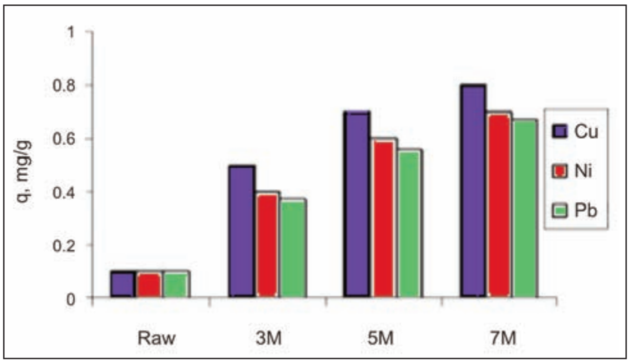


Fig. 4. The quantities of Cu, Ni and Pb ions adsorbed by various fiber samples

Table 3

THE VALUES OF ADSORBED IONS (MOLE %) IN PANF-MEA WITH DIFFERENT CONCENTRATIONS SAMPLES

Sample	RAF	PANF-MEA (3M)	PANF-MEA (7M)	PANF-MEA (5M)
Cu adsorption (mole %)	10	50	70	80
Ni adsorption (mole %)	10	40	60	70
Pb adsorption (mole %)	10	37	56	67

Table 4

THE VALUES OF ADSORBED IONS (mole %) IN NANO PANF-MEA WITH DIFFERENT CONCENTRATIONS SAMPLES				
Sample	**RAF**	**PANF-MEA (3M)**	**PANF-MEA (7M)**	**PANF-MEA (5M)**
Cu adsorption (mole %)	20	90	90	90
Ni adsorption (mole %)	20	80	90	90
Pb adsorption (mole %)	20	71	78	82

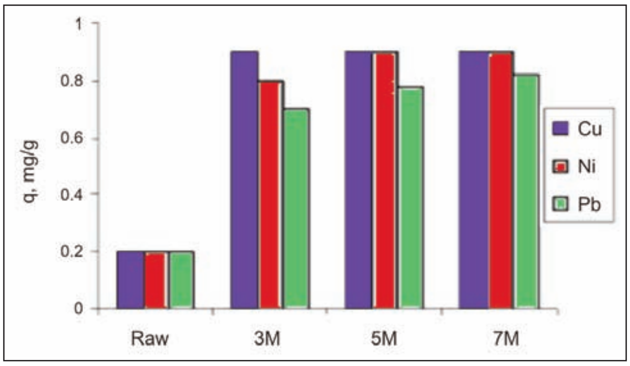


Fig. 5. The quantities of Cu, Ni and Pb ions adsorbed by various nano fiber samples

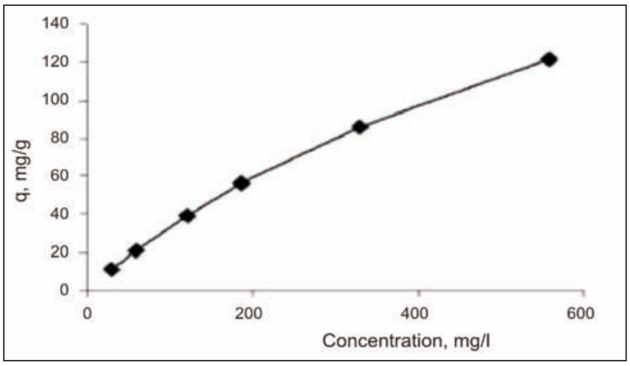


Fig. 6. Isotherms of Pb (II) adsorption on PAN-MEA fiber *p*H 5,25° and 2 hours

where:

K and *n* are Freundrich constants and are indications of adsorption capacity and adsorption intensity;

q – the amount of adsorbate per unit weight of adsorbent in equilibrium with a solution concentration *Ce*.

The variable *q* and *Ce* also show the amount of metal adsorbed on PAN-MEA and the equilibrium concentration of metal, respectively. The Langmuir equation has a general from:

$$q = (q_{max} bCe)/(1 + bCe) \qquad (6)$$

where:

q_{max} is the maximum sorbate (metal) uptake;

b – the Langmuir constant, the ratio of the adsorption rate constant to the desorption rate being constant.

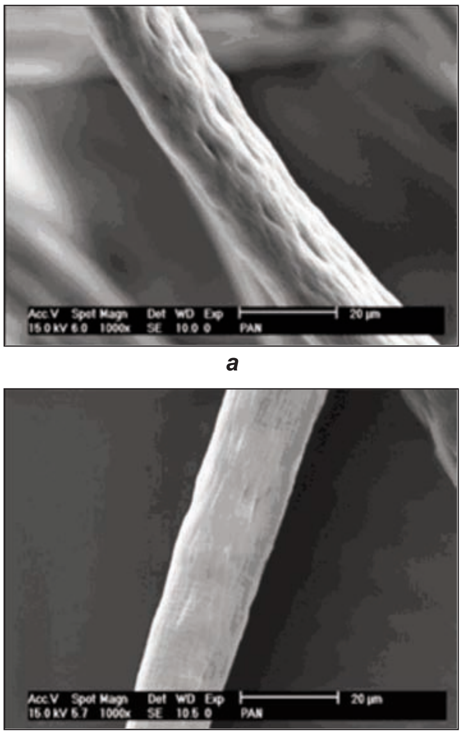
Experimental *Ce* and *q* data were used to evaluate the constant *K, n*, q_{max} and *b* according to the least square fitting method [3]. The values of Freundlich and Langmuir constants resulting from the equilibrium adsorption studies of Pb (II) by PANF-MEA are determined and listed in table 5.

Table 5

FREUNDLICH AND LANGMUIR MODEL PARAMETERS FOR ADSORPTION OF Pb^{+2} IONS BY PANF-MEA			
Metal ion	**Model**	**Parameter**	R^2
Lead (II)	Langmuir	q_m = 294.117; *b* = 0.0013	0.9982
-	Freundlich	*K* = 9.825; *n* = 1.195	0.9956

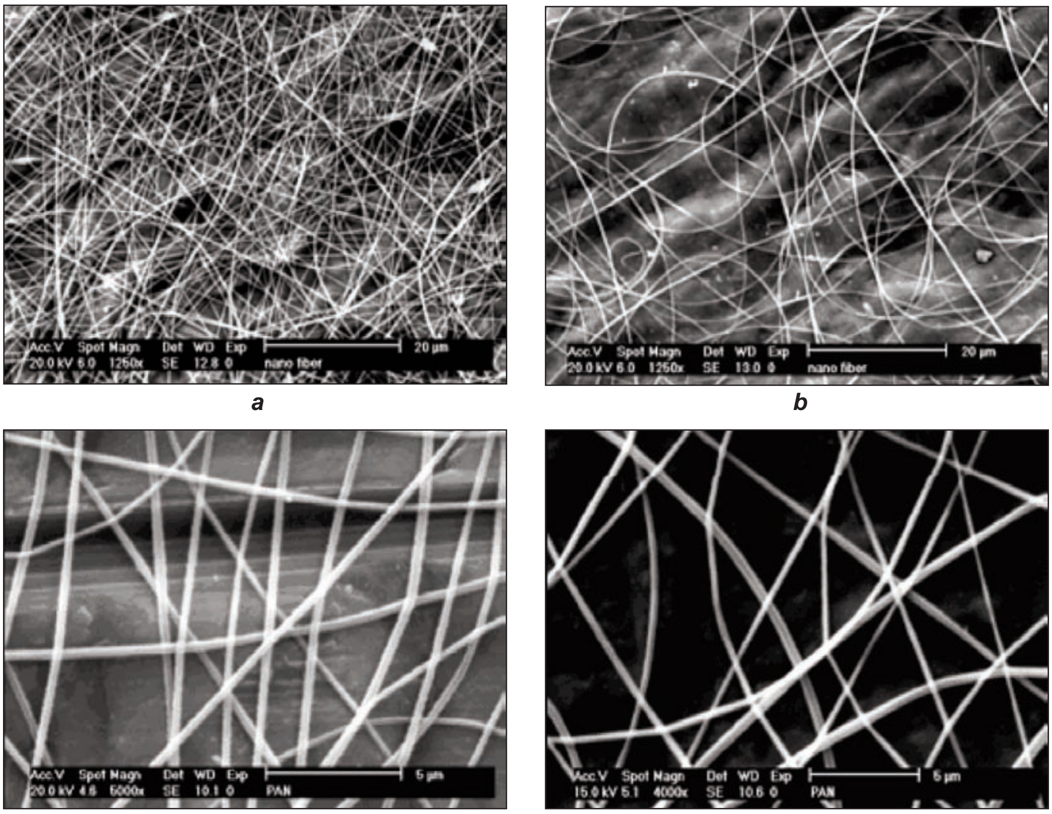
SEM investigations

Scanning electron microscopy (SEM) was used to examine the external surface of the fiber before and after modification. As can be seen from figure 7, original acrylic fiber comparatively surface (fig. 7 *a*) and with modified fiber (PANF-MEA), obvious change comparing to that of the RAF fiber was observed (fig. 7 *b*).



a ***b***

Fig. 7. SEM image of: *a* – raw fiber; *b* – modified PAN fiber



a *b* *c* *d*

Fig. 8. SEM image of:
a, c – the raw nano fiber; ***b, d*** – modified PAN nano fiber

It is clear that changes have occurred in the morphology of the fiber but photographs demonstrated that the surface of PANF-MEA was approximately as smooth, swollen and homogeneous as that of the raw fiber. This can be related to new functional groups that were bigger than (CN) groups. Scanning electron microscopy (SEM) was so used to examine the morphology of the nano fiber before and after modification. As can be seen from figure 8, original acrylic nano fiber comparatively morphology (fig. 8 *a*), and with modified nano fiber (PAN-MEA), obvious change compared to that of the raw fiber was observed (fig. 8 *b*). T modified nano fiber was roundelay as that of raw acrylic nano fiber. This can be related to modification treatment and incorporation of new functional groups into the fiber structure.

CONCLUSIONS

A new type of ion-exchange acrylic nano fiber is successfully prepared by modifying raw acrylic fiber (RAF) with ethanolamine. The results of this study have shown that hydroxyl chelating functional group can be attached to the acrylonitrile fiber by the reaction of nitril groups with ethanolamine. RAF with submicrometer diameters ranging from 120 to 300 nm produced using electrospinning in N, N-dimethyl formamide (DMF). This nano fiber can strongly remove metal ions, such as copper and nickel and lead ions from dilute aquatic solutions. Ions were removed thoroughly by a molar nitric aside solution under the described condition. Therefore, these fibers can be reused with high efficiency.

The FT-IR spectroscopy revealed that chemical bounds were formed between the nitrogen atoms in the amine groups and carbón in the (CN) groups. The SEM showed the fibers have become smooth and swollen by the modification treatment and the modified nano fiber was roundelay as that of raw nano fiber. This phenomenon probably caused the tensile properties of fiber after modification to reduce slightly and also give rise to higher chemical resistance of modified PAN fibers.

BIBLIOGRAPHY

[1] Yavuz, M., Gode, F., Pehlivan, E., Ozmert, S., Sharma, Y. C. *An economic removal of Cu_2+ and Cr_3+ on the new adsorbents: Pumice and polyacrylonitrile/pumice composite.* In: Chemical Engineering Journal, 2008, vol. 137, issue 3, p. 453

[2] Popa, A., Davidescu, C. M., Negrea, P., Ilia, G., Katsaros, A., Demadis, K. D. *Synthesis and characterization of phosphonate ester/phosphonic acid grafted styrene−divinylbenzene copolymer microbeads and their utility in adsorption of divalent metal ions in aqueous solutions.* In: Industrial & Engineering Chemistry Research, 2008, vol. 47, issue 6, p. 2 010

[3] Chen, L., Bromberg, L., Hatton, T. A., Rutledge, G. C. *Catalytic hydrolysis of p-nitrophenyl acetate by electrospun polyacrylamidoxime nanofibers.* In: Polymer, 2007, vol. 48, issue 16, p. 4 675

[4] Reneker, D. H., Yarin, A. L., Fong, H., Koombhongse, S. *Bending instability of electrically charged liquid jets of polymer solutions in electrospinning*. In: Journal of Applied Physics, 2000, vol. 87, issue 9, p. 4 531

[5] Yarin, A. L., Koombhongse, S., Reneker, D. H. *Taylor cone and jetting from liquid droplets in electrospinning of nanofibers.* In: Journal of Applied Physics, 2001, vol. 90, issue 9, p. 4 836

[6] Fridrikh, S. V., Yu, J. .H., Brenner, M. P., Rutledge, G. C. *Controlling the fiber diameter during electrospinning.* In: Physical Review Letters, 2003, vol. 90, issue 14, p. 144 502

[7] Wang, M., Hsieh, A. J., Rutledge, G. C. *Electrospinning of poly (MMA-co-MAA) copolymers and their layered silicate nanocomposites for improved thermal properties*. In: Polymer, 2005, vol. 46, issue 10, p. 3 407

[8] Wang, X., Kim, Y., Drew, C., Ku, B., Kumar, J. *Electrostatic assembly of conjugated polymer thin layers on electrospun nanofibrous membranes for biosensors.* In: Nano Letters, 2004, vol. 4, issue 2, p. 331

[9] Jin, H. J., Chen, J., Karageorgiou, V., Altman, G. H., Kaplan, D. L. *Human bone marrow stromal cell responses on electrospun silk fibroin mats.* In: Biomaterials, 2005, vol. 25, issue 6, p. 1 039

[10] Pinto, N. J., Johnson, J. A. T., MacDiarmid, A. G., Mueller, C. H., Theofylaktos, N., Robinson, D. C., Miranda F. A. *Electrospun polyaniline/polyethylene oxide nanofiber field-effect transistor.* In: Applied Physics Letters, 2003, vol. 83, issue 20, p. 4 244

[11] Gibson, P., Schreuder-Gibson, H., Rivin, D. *Transport properties of porous membranes based on electrospun nanofibers.* In: Colloids and Surfaces A: Physicochemical and Engineering Aspects, 2001, vol. 187–188, p. 469

[12] Tahaei, P., Abdouss, M., Edrissi, M., Shoushtari, A. M., Zargaran, M. *Preparation of chelating fibrous polymer by different diamines and study on their physical and chemical properties.* In: Materialwissenschaft und Werkstofftechnik, 2008, vol. 39, issue 11, p. 839

[13] Gode, F., Pehlivan, E. *Adsorption of Cr(III) ions by Turkish brown coals.* In: Fuel Processing Technology, 2005, vol. 86, issue 8, p. 875

[14] Zargaran, M., Shoushtari, A. M., Abdouss, M. *Diametric swelling and hydrophilic characteristics of fibrous acrylic ion exchanger.* In: Journal of Applied Polymer Science, 2008, vol. 110, issue 6, p. 3 843

[15] Dragan, E. S., Mihai, M., Schauer, J., Ghimici, L. *PAN composite membrane with different solvent affinities controlled by surface modification methods.* In: Journal of Polymer Science Part A: Polymer Chemistry, 2005, vol. 43, issue 18, p. 4 161

[16] Juang, R. S., Shiau, R. C. *Metal removal from aqueous solutions using chitosan-enhanced membrane filtration.* In: Journal of Membrane Science, 2000, vol. 165, issue 2, p. 159

[17] Kadirvelu, K., Faur-Brasquet, C., Cloirec, P. L. *Removal of Cu(II), Pb(II), and Ni(II) by adsorption onto activated carbon cloths.* In: Langmuir, 2000, vol. 16, issue 22, p. 8 404

[18] Deng, S., Bai, Chen J. P. *Aminated polyacrylonitrile fibers for lead and copper removal.* In: Langmuir, 2003, vol. 19, issue 12, p. 5 058

[19] Yu, L. J., Shukla, S. S., Dorris, K. L., Shukla, A., Margrave, J. L. *Adsorption of chromium from aqueous solutions by maple sawdust.* In: Journal of Hazardous Materials, 2003, vol. 100, issue 1–3, p. 53

[20] Shin, D. H., Ko, Y. G., Choi, U. S., Kim, W. N. *Design of high efficiency chelate fibers with an amine group to remove heavy metal ions and pH-related FT-IR analysis.* In: Industrial & Engineering Chemistry Research, 2004, vol. 43, issue 9, p. 2 060

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Aspects of the behavior to cyclic tensioning for the woven filters with simple structure

LUCICA CIOARĂ IOAN CIOARĂ

REZUMAT – ABSTRACT

Aspecte ale comportamentului la tensionarea ciclică a filtrelor țesute cu structură simplă

Țesăturile filtrante sunt, prin excelență, produse cu funcționalitate determinată. Caracterizarea şi estimarea valorii de utilizare a filtrelor țesute cu structură simplă poate fi realizată pe baza caracteristicilor structurale şi fizico-mecanice. Uniformitatea dimensională şi stabilitatea porilor, în timpul utilizării filtrelor, influențează în mod direct performanțele procesului de filtrare. În lucrare este studiată influența solicitărilor ciclice de tensionare, apărute în timpul utilizării, asupra caracteristicilor fizico-mecanice ale filtrelor. Sunt analizate țesăturile filtrante cu finețea de 50 mesh, realizate din fire monofilamentare poliamidice. Metoda de testare utilizată este cea cu gradient de alungire constant. Programul cuprinde trei experimente. Fiecare epruvetă este supusă la 20 de cicli de solicitare. Sunt apeciate modificările proprietăților tensionale ale țesăturii, apărute în urma solicitărilor ciclice.

Cuvinte-cheie: filtru țesut, funcționalitate, tensionare ciclică, caracteristici structurale

Aspects of the behaviour of the woven filters with simple structure subjected to cyclic stress

Woven filter fabrics are characterized by a fixed functionality. The characterization and the estimation of the value of the filter fabrics with simple structure can be made on the basis of specific structural and physical-mechanical characteristics. During the use of the filters, dimensional uniformity and the pore stability directly influence the performance of filtering process. The paper presents the influence of cyclic stress occurred during use on the physical-mechanical characteristics of filters. Filter fabrics with the fineness of 50 mesh made of monofilament polyamide yarns were tested. The testing method used is based on constant elongation gradient. The program comprises three experiments. Each specimen was subjected to 20 stress cycles. The modifications of the fabric stress arising from cyclic stress were studied.

Key-words: woven filter, functionality, cyclic tensioning, structural characteristics

Filtering, as a distinct phase of the technological process, covers a large domain in both industry and research activities. If considering the complexity of the phenomena involved in filtering, along with the large diversity of the industrial branches, which apply filtering processes, the special importance of filters and, equally, of their quality, may be exactly understood.

Due to their structural rheological properties, fabrics are frequently employed as filtering planes. Among them, of special importance are the simple fabrics, made of monofilament yarns, utilized for surface filtering.

Surface filtering implies that particles larger than the pore size are retained on the filter medium surface. Due to the adsorption forces particles smaller than pore size can be retained along the pore wall, reducing its transverse dimension causing blocked pores and filter medium clogging as a result. In the first phase of the clogging nominal fineness of filtration is reduced, the pressure difference increases and a combination of surface filtration with a pseudo-depth filtration take place (occurs). Later on, as the degree of clogging increases, fluid flow through the filter medium is significantly reduced. At the same time due to the extensions that the woven filter is stressed during use, appear pores deformations which modify the filter finesse. The process parameters are maintained constantly because of occurred pseudo-filtering due to the residual layer on filter surface. For this reason it is important to study and evaluate the behaviour of fabric to stretches that appear during utilization. In this paper, we propose to study the behaviour of woven filters with simple structure to the stretches to which they are stressed during use.

For woven filter fabrics with simple structures, obtained with a warp and a weft, a series of conditions – on character and repartition of pores – should be considered; thus the pores should be open, to avoid warping, while shape of pores and their distribution are expected to be as uniform as possible. Also, the position of pores in the fabric should be stable, which assures the maintenance of the initial pore sizes along the whole filtering process. Consequently, the quality certificates for such woven fabrics should include data regarding the following parameters: the pore sizes and their geometrical shape, the distribution of pores on the filter surface and the thickness of the fabric.

Table 1

PRIORITY FUNCTIONS OF THE FILTER MEDIA AND THEIR ASSESSMENT CRITERIA			
Symbol	**The name of the function**	**Specific technical dimension**	**Structural characteristics of fabric**
F_1	to separate the phases of a heterogeneous mixture	pore size	fineness and density of yarns
F_2	to ensure filtration fineness	pore shape and distribution, filter medium fineness	fineness and density 3of yarns, weave
F_3	to ensure filtering velocity	adequate filtering active area	fineness and density of yarns
F_4	to be dimensionally stable during operation	structural and mechanical characteristics of yarn and fabric	the mechanical characteristics of the of yarns
F_5	to withstand the action of mechanical factors during operation	tensile strength burst resistance	the mechanical characteristics of the of yarns
F_6	to withstand the erosive effects of the environment	chemical resistance	the nature of raw material

The woven filtration fabrics are characterized by a fixed functionality. The characterization and the estimation of the use value of the filter fabrics with simple structure can be made with the help of specific structural and functional characteristics.

The porosity, a filters feature, is their property of having pores in their structure. The filter media create uniform or non-uniform spaces for fluid flow. The keeping quality of filtration, the efficiency and finesse of filtration, as well as the filtering capacity are aspects directly related to the porosity of filter media. The textile filter media are generally heterogeneous because the filter permeability is changed during use. The dimensional uniformity and the pore stability of one filter media influence directly the performance of filtering process.

Starting from these considerations in table 1 are present the functions, which have been identified as necessary to filter media and the technical elements of function appreciation. As seen from the table with specific functions of fabric filter media, a foreground function is to be dimensional stable during lifetime to maintain the finesse and the efficiency of filtration. This function is achieved by structural and mechanical characteristics of yarns and fabric and is appreciate by the fatigue strength of filter fabric. In this paper we propose to study the behaviour of filter fabrics with simple structure to cyclic stretch applications. There are a number of filter fabrics which are subject to this type of applications, for example, filter fabrics, which work in industrial installations as vibrating bolters or are processed to pressure pulsations of filtering.

EXPERIMENTAL PART

Materials and methods

Were analyzed the woven filters 50 mesh. The fabrics were made from monofilament polyamide. The filters of this type are used in hydraulic and pneumatic industrials, in the oil industry to filtration of drilling fluid etc. The structural and functional characteristics of the analyzed woven filters are presented in table 2.

Table 2

STRUCTURAL CHARACTERISTICS OF THE ANALYZED WOVEN FILTRATION FABRICS		
Type of analyzed woven filtration fabric		**Filter 50 mesh**
Parameter	***UM***	***Value***
Yarns diameter	mm	0.14
Filtering active surface	%	51.84
Thread density	threads/cm	20
Filter finesse	pores/cm	20
Filter finesse mesh	pores/inch	50
Pore side	mm	0.36
Pore area	mm^2	0.1296
Yarns count	tex	12.76
Woven fabric mass	g/m^2	53.73

The experimental program involved the cyclic stretch applications of woven fabrics. On each specimen were performed 20 cyclic stretch applications. It is method of test with constant strain gradient. The program included three experiments: application of stretch to values of 20 mm, 30 mm and 40 mm. The applications were made on a dynamometer Metefem with constant movement of the lower clamp, so that, the specimen stretch was controlled to each application cycle. On the dynamometer were recorded the loading/unloading hysteresis curves during each application cycle.

For all three experiments, the stretch intensity is high, even extreme, to the experiment with 40 mm extension. A stretch of 20 mm is 32% of break elongation of woven filter and a stretch of 40 mm is 64% of it. These intense stretches appear to the filters used in industrial installations in which the flow of filtered fluid and its pressure on filter have high values. In many of these installations to ensure the optimal filtering

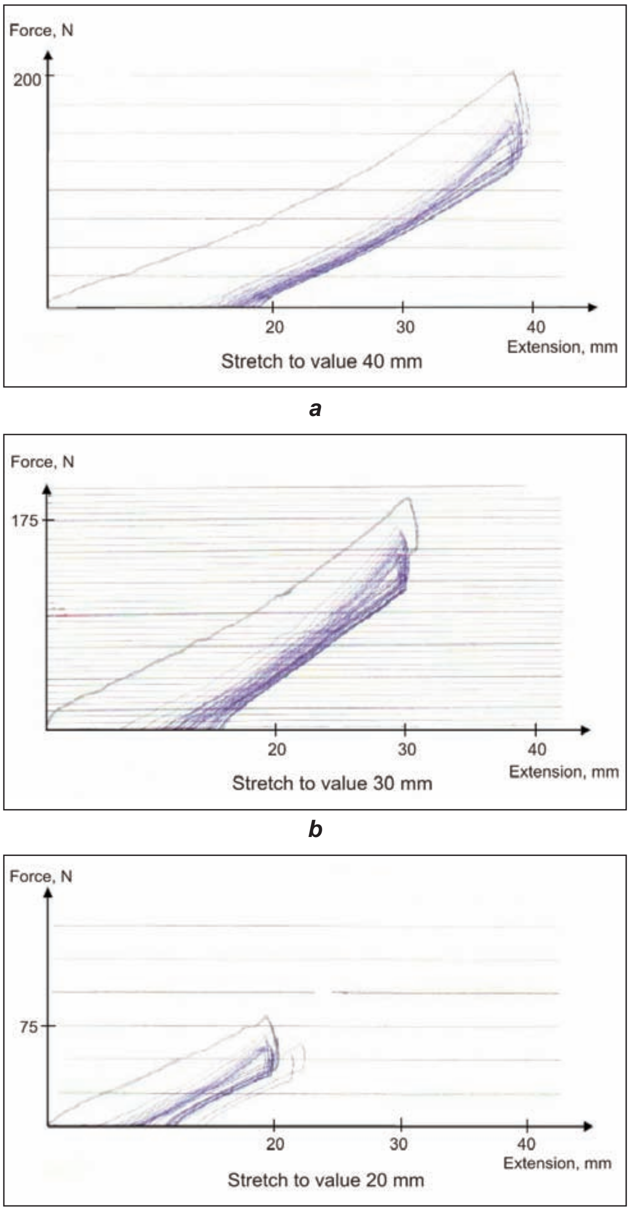

Fig. 1. Hysteresis curves of the cyclic stretch for woven filter 50 mesh

speed, the sieve has a vibrating motion that amplifies the stretch.

On the dynamometer Tinus Olsen H5kT were determined the breaking-force and elongation at break, as well as the stress-strain diagram for the unsolicited woven fabrics and the specimens after application of cyclic tension.

RESULTS AND DISSCUSIONS

The hysteresis curves recorded at each stage of the experimental program are presented in figure 1. The stress-strain diagrams of the unsolicited woven fabrics and the solicited woven fabrics are presented in figure 2.

The experimental data recorded on the dynamometer Tinus Olsen H5kT were processed by QMAT Pro software, which allowed the calculation of work of rupture and the determination of loaded force on the specimen at a certain elongation. The values with

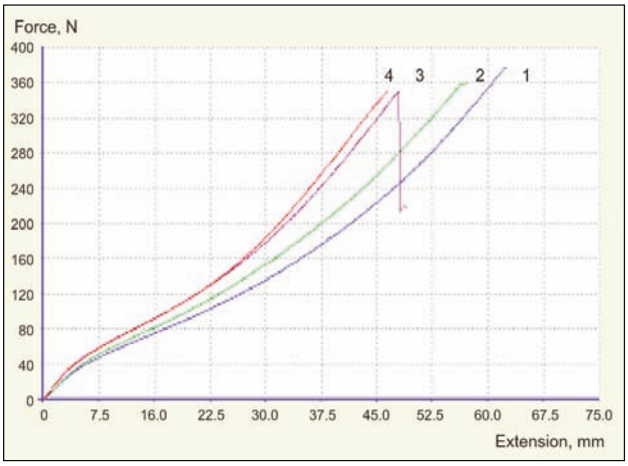

Fig. 2. The strain-stretch diagram for woven filter

tensional characteristics recorded in conducted experiments are presented in table 3 and table 4.

The hysteresis curves of the cyclic stretch application recorded for three experiments of woven filter 50 mesh are presented in figure 1.

On all three diagrams are observed that the first cycle stretch is detached to the rest of the 20 cycles. The explanation is simple: occurs the remanent elongation. Most part of the remanent elongation is achieved from the first cycle stretch application. The remanent elongation increases slightly after each cyclic stretch and the hysteresis curves, plotted on the diagram, are moving on abscissa. The residual elongation is higher in specimens to which the stretch intensity has the highest value – 40 mm. On the hysteresis loop for the stretch of 20 mm elongation is observed that the load curve does not overlap with the relaxation curve. In this case it is considered that the fabric still preserves some elastic properties. The hysteresis loops of the most intense stretch of 40 mm indicate that the relaxation curves are very close by the loading curves, the fabric elasticity being significantly affected by the cyclic stretch (hysteresis loop is less).

The following hysteresis curves after the first cycle stretch have all approximately the same allure. In addition, on hysteresis curves are observed that, the stress that is loaded onto specimen is becoming less, according as increases the number of stretch cycles on the specimen. Technically, woven fabrics with lower hysteresis loop are particularly important because they have elastic properties. In figure 2 are presented the stress-strain diagrams of the unsolicited woven fabric to stretch (curve *1*) and three samples of solicited woven fabric, according the experimental program (curves *2, 3* and *4*, as per the notation from table 3). The four diagrams differ significantly.

The stress-strain diagram of woven filtration fabric solicited at 20 mm stretch is close by the curve of unsolicited woven fabric to stretch. The stretch application at 20 mm leads to changes of technical characteristics in restricted limits for woven filtration fabrics. Comparative with unsolicited woven fabric to

Table 3

MECHANICAL CHARACTERISTICS OF ANALYZED WOVEN FILTRATION FABRICS				
Type of analyzed woven filtration fabric	**Maximum force**, N	**Relative elongation at break**, %	**Absolute elongation at break**, mm	**Energy at break**, joules
Woven filtration fabric after 20 cycles of 20 mm stretch	360.8	28.54	57.3	9.27
Changes after fatigue, %	4.5	8.7	-	1.3
Woven filtration fabric after 20 cycles of 30 mm stretch	350	24	49	7.48
Changes after fatigue, %	7.4	23.17	-	26.0
Woven filtration fabric after 20 cycles of 40 mm stretch	351.2	23.25	46.5	7.2
Changes after fatigue, %	7	25.57	-	28

Table 4

CHANGES OF MECHANICAL CHARACTERISTICS AFTER FATIGUE			
Type of analyzed woven filtration fabric	**Absolute extension of the nominal force (on the strain-stretch diagram)**		
	160 N	***200 N***	***240 N***
Woven filtration fabric unsolicited	35.2	41.25	47.75
Woven filtration fabric after 20 cycles of 20 mm stretch	33	37.5	42.5
Changes after fatigue, %	6.25	10.7	10.9
Woven filtration fabric after 20 cycles of 30 mm stretch	27,5	33	37.5
Changes after fatigue, %	21.8	20.0	21.8
Woven filtration fabric after 20 cycles of 40 mm stretch	27	32	36
Changes after fatigue, %	26.2	22.3	24.6

stretch, this stretch determines the decrease with 4.5% of tensile stress, with 8.7% of strain and with 1.33% of work of rupture.
Similar, the curves of solicited wove filtration fabric at 30 mm stretch, respectively at 40 mm, are very close together and are detached of witness curve. By comparison with the witness test specimen, the tensile stress decreases with 7.4%, respectively 7.0%, the strain decreases with 23.17%, respectively 25.17% and the work of rupture decreases with 26.04%, respectively 28.42%. The cyclic stretch application at 30 mm, respectively at 40 mm, determines the significant deterioration of the tension characteristics of the woven fabric. To the same strain, the loaded tensile of test specimens is higher in solicited woven fabrics to stretch, being the highest in woven fabrics with the most intense load. The explanation is given by the fact that, the woven fabrics lose some part of elasticity and the proportional region is reduced on stress-strain diagram because the proportional limit decreases.
The percentage change of tensional characteristics for the specimens subjected to cyclic tension is presented in table 4. The elongation values for the forces of 160 N, 200 N and 240 N are read on the stress-stretch diagram in figure 2. It is found that the elongation decreases comparative with the control specimen all the more as the stretch is higher (22–26%).
The rate of curves shows that the proportional limit of stress-stretch diagram for analysed fabrics becomes smaller. The decession of proportional limit is not beneficial for the behaviour of woven fabric filter during use. The difference between a woven fabric filter and a metallic mesh is given just the elastic behaviour of textile fabric. The elastic behaviour of woven fabric filter to cyclic tensions creates the conditions for an effective filtering with maintaining the fineness of filtration and increasing the duration of use. A stretch representing 25–30% of break elongation not causes changes which to affect catastrophic the elastic properties of the woven fabric filter.
The changing of the tensional properties of woven filtration fabrics after a stretch application period reveals that technical characteristic of filter changes. The appearance of remanent strain modifies the fineness and quality of filtration and also, the changing of the process parameters, respective of the flow speed. After remanent strain installing, the filter not allowing elastic flow of fluid, appear the premature break and

decreases the duration of use. The observation that remanent strain appears after first cyclic stretch applications should be considered in choosing filter for a particular process.

It can be considered a safety margin which to undersized the filter pore area so that the fineness of filtration to maintain a longer period in use, even if to the start of the filtration there is an over-filtration.

This undersize is made according the intensity of applications. As a result, at 20 mm stretch the strain decrease with 8% comparative with witness test specimen, is recommended an undersize pore with 8–10%. Therefore, instead of choosing a filter with pore side of l_p = 0.36 mm, is choosing one lower pore side with 10%, respectively l_p = 0.324 mm. To the same yarn count, the recommended filter to be used will have the finesse 55 mesh instead of 50 mesh.

CONCLUSIONS

- Woven filtration fabrics are textile products with broad industrial use, which have functional properties determined by the requirements process of filtering.
- Woven filtration fabrics are tested predominant for cyclic stretch applications, which produce significant changes in their structural characteristics and functionality.
- The experiments for monofilament woven filtration fabrics highlight the occurrence of remanent strain after the first loading cycles, which determine the change of the shape and size of pores with negative implications on the quality of filtering.
- A stretch representing 25–30% of break elongation of the filter not cause catastrophic changes of elastic properties of the woven fabric filter.
- In practice conditions, is recommended the preference of some woven filtration fabrics with adequate undersized of pore side correlated with the level of application during the operation, because the effects of cyclic stretch.

BIBLIOGRAPHY

[1] Adanur, S. *Handbook of Industrial Textiles.* Technomic Publishing Company. Lancester, U.S.A., 1995, ISBN 1-56676-340-1

[2] Behera, B. K., Hari, P. K. *Woven textile structure*. Woodhead Publishing Limited, Cambridge, UK, 2010, ISBN 978-1-84569-514-9

[3] Cioară, I., Cioară, L., Onofrei, E. *Aspects regarding the architecture of the filtering woven fabrics.* In: Unitex, Belgium, 2003, no. 1, pp. 28-30

[4] Cioară, I., Cioară, L. *Criteria for estimating the functionality of the filtering media obtained by weaving*. In: Industria Textilă, 2009, vol. 60, no. 1, pp. 21-25, ISSN 1222-5347

[5] Cioară, L., Cioară, I., Marchiş, O. *The influence of certain technologic parameters on the capacity of filtering the woven textile planes*. In: Industria Uşoară, 1991, no. 4, pp. 239-241, ISSN 1222-5347

[6] Condurache, G., Ciobanu, R., Niculae, M. *Analiza şi ingineria valorii*. Performantica Publishing House, 2004, Iasi, ISBN 973-730-022-x

[7] Harracks, A. R., Anand, S. C. *Handbook of technical textiles.* Woodhead Publishing Limited, 2000, ISBN 1-85573- 385-4

[8] Medar, S., Ionescu, F. *Filters for hydraulic and pneumatic drives*. Technical Publishing House, Bucharest, 1986

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Prediction of random-velour needle punching force using artificial neural network

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REZUMAT – ABSTRACT

Prestabilirea forței de interțesere a velurului, utilizând rețeaua neurală artificială

Tehnologia de interțesere a velurului este o versiune modificată a procesului de interțesere clasic. Proprietățile țesăturii din velur sunt controlate prin reorientarea fibrelor în interiorul ansamblului fibros preconsolidat, utilizând ace speciale. Această interacțiune are ca rezultat crearea unei structuri duble, care cuprinde stratul de fond şi cel de pluş. În lucrare au fost analizate efectele parametrilor de interțesere şi ale caracteristicilor fibrei asupra forței medii totale exercitate asupra acelor, folosind o rețea neurală artificială bazată pe un algoritm multistrat cu transmitere înainte şi retro-propagare. Validitatea modelului a fost confirmată folosind metoda celor mai mici pătrate, iar coeficientul de corelație obținut s-a dovedit a fi unul acceptabil. De asemenea, s-a calculat eroarea medie absolută a datelor de testare, aşa încât datele de intrare ale F_{rms} au condus la rezultate experimentale ale caracteristicilor fibrelor şi parametrilor de interțesere ai F_{rms} similare celor estimate prin model. Rezultatele obținute au confirmat importanța desimii de interțesere şi a adâncimii de pătrundere a acelor, în timpul operației de interțesere. S-a constatat că, prin folosirea rețelei neurale, procesul de interțesere a velurului poate fi modelat matematic, cu o siguranță statistică acceptabilă, astfel încât un asemenea model să poată fi utilizat în proiectarea diverselor tipuri de structuri.

Cuvinte-cheie: velur, forță de interțesere, fibre, ac, rețea neurală artificială, modelare

Prediction of random-velour needle punching force using artificial neural network

Random-velour needling technology is a modified version of conventional needling process. Properties of the random-velour needled fabric are controlled by re-orientation of fibers within the pre-consolidated fibrous assembly using special fork needles. This interaction results in creation of a dual structure, comprising base and pile layers. In this work the effect of needling parameters and fiber characteristics on total average force exerted on the fork needle was investigated using an Artificial Neural Network modeling based on a multi-layered feed-forward back-propagation algorithm. The validity of model was confirmed by least squares method and an acceptable correlation coefficient was obtained. Moreover, mean absolute error of test data was also calculated so that input parameters of F_{rms} led to experimental results of fiber characteristics and needling parameters of F_{rms} similar to those estimated by the model. The results obtained confirmed the importance of punch density and barbed needle penetration depth during the needling operation. It was observed that by the use of neural network, random-velour needling process can be subjected to mathematical modeling, with an acceptable statistical certainty so that such a model can be used in designing various types of structures.

Key-words: random-velour, punching force, fibers, needle, artificial neural network, modeling

Random-velour needled fabrics are produced by a modified needling operation on a machine depicted in figure 1 known as random-velour needle loom. Moveable brush conveyor and structuring fork needles have replaced the conventional lamella bedplate and barbed needles employed on conventional felting needle looms depicted in figure 1*a* respectively. Figure 2 shows both types of needles.

Properties of the final velour fabric are controlled by the structural alteration that takes place during random-velour needling operation. The fork needles not only serve as the principal element in occurrence of the structural alterations, but also both transmit and influence the penetration forces that eventually have to be absorbed by the main frame of the loom [1–3]. Therefore, interaction of fork needle and fibers results in re-orientation of fibers within the initial pre-consolidated fibrous assembly which in turn leads to fundamental structural alteration in terms of creation of a dual structure comprising base and pile layers.

From engineering design aspect of fork needle and random-velour loom, quantification of force exerted on fork needles during fiber re-orientation is of vital importance. Thus, in the present work, a purposely designed force measuring system [4] has been used to measure forces exerted on the individual fork needle during random-velour needling in relation to fibrous assembly characteristics and needling parameters. All previous studies in the field of needle punching force measurement are limited to the effect of fiber and needle loom related parameters during conventional needle-felting process using barbed needles and so far no study in relation to forces experienced by fork needles has been reported.

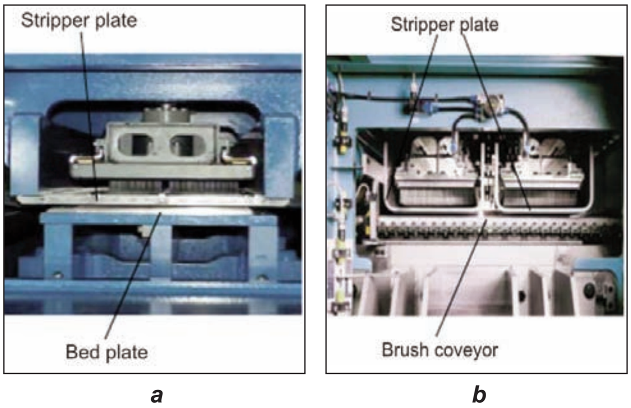


Fig. 1. Needle looms:
a – conventional felting loom; ***b*** – random-velour loom

Fig. 2. Needles:
a – conventional barbed needle; ***b*** – structuring fork needle

Hearle et al. in their pioneering work found that, increase in parameters such as mass of fibrous assembly, fiber coefficient of friction and needle penetration depth, leads to corresponding increase in magnitude of statically measured force exerted on barbed needles of a fully needled needle-board.

It was also reported that, in case of heavy fibrous assembly, increase in needle penetration depth results in excessive fiber breakage during needling [5] which in turn tends to reduce the penetration force on the needle. It was confirmed that, dynamically measured punching force on single needle decreases after an initial increase as mass of fibrous assembly increases [6]. Goswami used a laboratory needle loom and reported that, fiber fineness and crimp are the pivotal factors among parameters affecting the static force experienced by the needles of a fully needled needle-board [7].

Sarin in his 1994 review of pertained researches reported that according to Luenenschloss's studies, total forces exerted on barbed needles of a fully needled needle-board are directly proportional to stroke frequency of the needle board [8]. Seyam studies was concerned with the cumulative contributions of various factors such as needle vibration and inertia on the dynamically measured force experienced by individual barbed needle. Seyam was also successful in determining the location of the needle subjected to the highest force in relation to variation in fiber staple length and amount of punch density [9–13].

Cislo investigations showed that, quasi-static force on the barbed needle increases as both fineness and tensile strength of fiber are increased [14]. Kapusta has concluded that, at very high needling stroke frequency, force experienced by barbed needle decreases. This was considered to be due to excessive fibre breakage and process generated heat [15]. Watanabe showed that provided both needling and fiber related parameters are held invariant, then the force exerted on the needle increases with increases in geometry of barb parameters [16].

Advances in Artificial neural network (ANN) have created great potential for modeling of complex engineering behaviors such as signal processing and engineering control. ANN has also been used in the various fields of textile researches such as prediction of pilling tendency of wool knits, seam performance of woven apparels and structural behaviors of nonwoven fabrics. Present study employs artificial neural network modeling to predict forces experienced by individual fork needle during random-velour needling.

ARTIFICIAL NEURAL NETWORK MODELING

An artificial neural network is a computational structure, consisting of a number of complex networks of processing elements, known as nodes, that dynamically responses to an external input. The neural network learns the governing relationships in the data set by adjusting the weights among nodes. A neural network essentially functions as a tool that maps input vectors to output vectors [17]. Figure 3 shows a fully-connected feed-forward neural network used in this study. This model comprises of an input, a hidden and an output neuron layers.

The transfer functions are logistic sigmoid and linear respectively, as shown in figure 4, where n and m are number of input parameters and number of hidden layer respectively.

The vector values of hidden-layer neurons, h_j, is calculated using continuously valued input vector $q_1, q_2, \dots q_n$ and a transfer function that acts in relation to W_{ij} values which are the weights between the input, hidden layers and b_j values (bias) between the input and hidden layers according to equation (1).

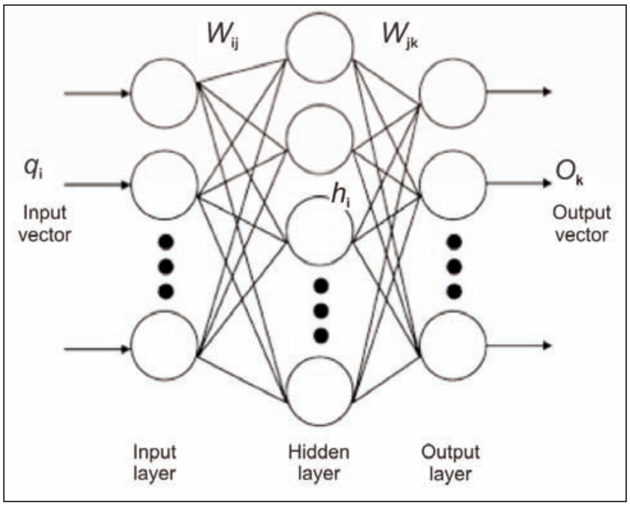


Fig. 3. A fully-connected three-layers feed-forward neural network

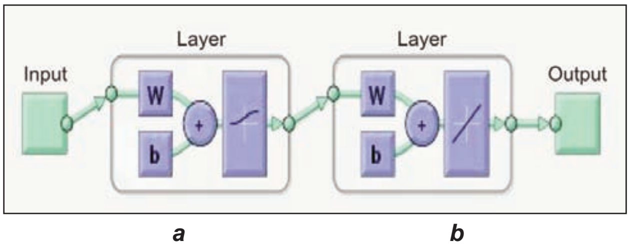


Fig. 4. Transfer functions:
a – logistic sigmoid function; ***b*** – linear function

$$h_j = f\left(\sum_{i=1}^{n} W_{ij}\, q_i - b_j\right) \quad (1)$$

where:

f(x) is a logistic sigmoid function: $f(x) = \dfrac{1}{1 + e^{-x}}$

The unique desired output value, Q_k, is obtained in terms of equation (2) by continuation of the equation (1) operations among hidden and output layers. Figure 4 depicts logistic sigmoid and linear transfer functions. *m* and *n* denote number of hidden layer and input parameters respectively.

$$O_k = g\left(\sum_{j=1}^{m} W_{jk}\, q_j - b_k\right) \quad (2)$$

where:

k represents the number of output layer;

W_{jk} are the hidden and output layers connecting weights;

b_k denotes the bias connecting the hidden and output layers and *g* is a linear function.

DESIGN OF FORCE MEASUREMENT SYSTEM

Block diagram of the designed force measuring system is depicted in figure 5. The system precisely displays needling stroke frequency by incorporation of a precision Rotary Variable Differential Transformer (RVDT). Cyclic angular position of the main shaft in relation to vertical position of the needle board is also displayed.

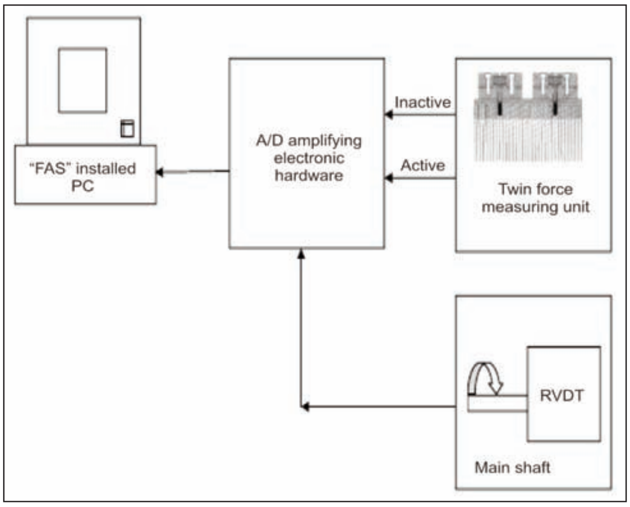


Fig. 5. Force measuring system block diagram

Based on elimination principle, the twin load cell shown in figure 6 precisely measures the contribution of the factors such as vibration, inertia, frictional resistances of brush conveyor, dwell of the needle board at bottom dead center and characteristics of consolidated fibrous assembly to total force. However, since the present study deals with the effect of fiber and needling related parameters on the total force only data acquired from one load cell is cumulatively analyzed. Data acquisition and analysis are carried out using a purposely designed MATLAB R2010a based Force Analysis Software (FAS). The FAS capabilities include alteration of sampling start time and inputting of calibration equation of the load cell in the software.

EXPERIMENTAL PART

It has been established that fiber characteristics together with needling adjustments, during both needle felting and random-velour needling operations are pivotal not only as far as physical and mechanical behavior of random-velour needled fabric is concerned, but also can probably affect the force exerted on the fork needle [18].

In this work, a total of sixty four different random-velour needled fabrics were prepared. In order to achieve the most comprehensive analysis, a large number of fiber and needling related independent variables (X_1 to X_9) as described in table 1, were defined. Variables X_1 to X_3 denote fineness, mean staple length and crimp frequency of the fiber respectively. X_4 represents mass per unit area of felted fibrous assembly. X_5 and X_6 denote barbed needle penetration depth and punch density during needle-felting operation respectively. The measured magnitudes of total average force, F_{rms}, was selected as dependent or output variable, *Y*, by manipulation of three independent variables X_7, X_8 and X_9, represent fork needle penetration depth, stroke frequency and punch density during random-velour needling respectively. Total average force represents root mean value

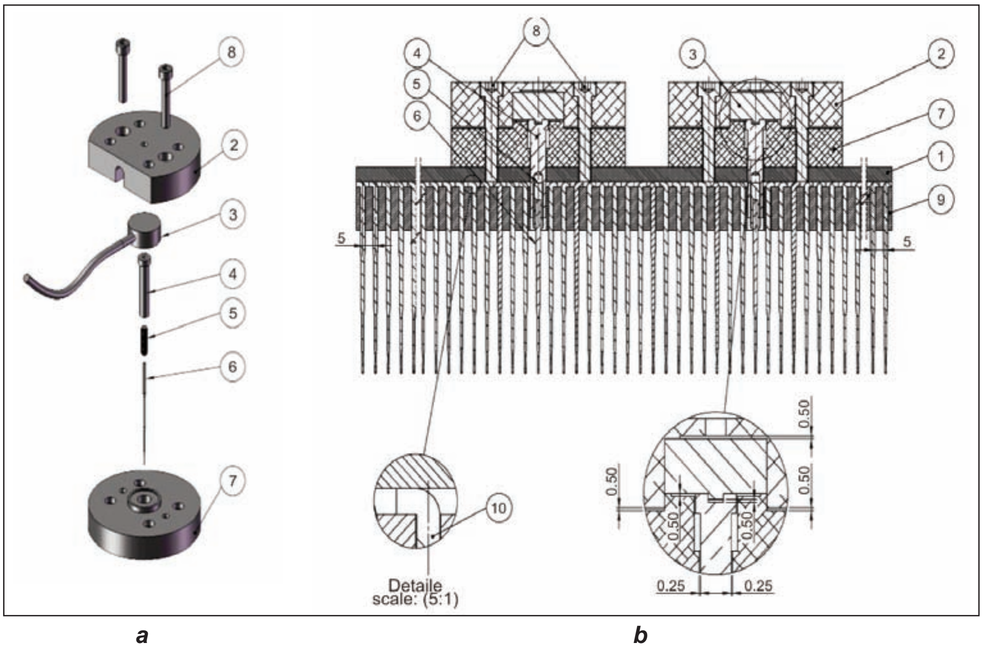


Fig. 6. Force measuring unit:
a – off machine; ***b*** – on machine;
1 – needle beam; *2* – top cell bracket; *3* – load cell; *4* – needle connector tube;
5 – needle connector screw; *6* – fork needle; *7* – bottom cell bracket;
8 – linking screws; *9* – needle board; *10* – needle shank

of the squared discrete force signal of individual fork needles acquired during given stroke cycles, according to equation (3).

$$F_{rms} = \sqrt{\frac{\sum_{i=1}^{n} F_i^2}{n}} \qquad (3)$$

where:

F_{rms} is root mean value of the squared discrete force signal;

F_i – i^{th} value of the force signal;

n – total numbers of force signal.

Magnitude of F_{rms} for an individual needle is in fact power of force signal for the needle. F_{rms} can be needle loom energy consumption index, provided F_{rms} encompass all fork needles then.

Carded 25 g/m^2 polyester web was delivered to a horizontal cross-folding unit and fiber mean staple length for each experimental sample was calculated [19]. Cross-folded batt was fed to a conventional felting needle loom, equipped with GROZ-BECKERT 15*18*32*3 R333 G1002 barbed needles. Mass per unit area of each consolidated felted fibrous assemblies was determined. The felted materials were fed to a laboratory random-velour needle loom, shown in figure 7. This loom was equipped with Groz-Beckert 15*17*25*38*63.5 DG1000 structuring fork needles [20]. In order to predict the total average force, an artificial neural network model based on a multi-layered feed-forward back-propagation algorithm with nine inputs and one output neuron was used. In this study, input–output pairs were presented to the network and weights were adjusted to minimize the error between the network generated output and the actual values. The output corresponded to total average force exerted on the fork needle during random-velour needling. As can be seen in table 2, variables numerically are scattered. Therefore, input and output data were normalized in a pre-processing step. The conversion is based on the normal function using "Prestd" order in neural network toolbox of MATLAB R2010a software [21–22]. Realistic prediction total average force is

Table 1

MODEL VARIABLES										
Parameters	**Fiber fineness,** denier	**Fiber length,** mm	**Fiber crimp frequency,** 1/cm	**Felted fibrous assembly mass,** g/m^2	**Penetration depth - felt,** mm	**Punch density - felt,** 1/cm^2	**Penetration depth - velour,** mm	**Stroke frequency - velour,** s/min.	**Punch density - velour,** 1/cm^2	$F_{rms,}$ g
Model variables	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	Y

Table 2

VARIABLES VALUE (64 EXPERIMENTAL SAMPLES)										
Sample code	**Variable**									
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	Y
1	11	121	4.5	320	7	50	8	231	100	**75.44**
2	11	125	4.5	321	7	50	8	463	200	**97.43**
3	11	128	4.5	322	7	100	8	581	300	**119.69**
4	11	120	4.5	335	7	125	8	696	400	**121.75**
5	11	129	4.5	330	9	50	10	347	200	**132.51**
6	11	122	4.5	333	9	75	10	233	300	**108.42**
7	11	129	4.5	322	9	100	10	461	100	**131.77**
8	11	128	4.5	334	9	125	10	579	400	**151.51**
9	11	126	4.5	324	11	50	12	697	300	**178.92**
10	11	123	4.5	332	11	75	12	463	400	**150.57**
11	11	124	4.5	330	11	100	12	231	100	**93.30**
12	11	120	4.5	318	11	125	12	582	200	**147.71**
13	11	128	4.5	336	13	50	12	346	400	**126.92**
14	11	129	4.5	319	13	75	12	462	200	**136.16**
15	11	120	4.5	327	13	100	14	581	100	**146.71**
16	11	125	4.5	329	13	125	14	695	300	**173.95**
17	13	90	2.3	550	7	50	8	230	100	**134.13**
18	13	95	2.3	540	7	75	8	462	200	**148.68**
19	13	87	2.3	545	7	100	8	578	300	**152.34**
20	13	93	2.3	548	7	125	8	691	400	**164.03**
21	13	92	2.3	550	9	50	10	346	200	**134.50**
22	13	97	2.3	554	9	75	10	231	300	**120.43**
23	13	93	2.3	541	9	100	10	461	100	**143.90**
24	13	90	2.3	549	9	125	10	693	400	**164.61**
25	13	85	2.3	552	11	50	12	699	300	**177.92**
26	13	88	2.3	564	11	75	12	462	400	**147.96**
27	13	92	2.3	561	11	100	12	231	100	**137.47**
28	13	89	2.3	538	11	125	12	585	200	**165.76**
29	13	96	2.3	562	13	50	12	346	400	**136.33**
30	13	89	2.3	547	13	75	12	463	200	**149.88**
31	13	91	2.3	549	13	100	14	579	100	**155.58**
32	13	90	2.3	559	13	125	14	695	300	**208.10**
33	9	124	2.7	425	7	50	8	230	100	**134.42**
34	9	129	2.7	420	7	75	8	462	200	**143.64**
35	9	127	2.7	422	7	100	8	576	300	**155.45**
36	9	125	2.7	430	7	125	8	695	400	**166.56**
37	9	126	2.7	438	9	50	10	346	200	**135.74**
38	9	129	2.7	440	9	75	10	233	300	**129.15**
39	9	127	2.7	429	9	100	10	461	100	**139.28**
40	9	121	2.7	438	9	125	10	579	400	**196.23**
41	9	120	2.7	428	11	50	12	696	300	**197.91**
42	9	122	2.7	441	11	75	12	462	400	**189.50**
43	9	124	2.7	442	11	100	12	231	100	**148.51**
44	9	123	2.7	434	11	125	12	581	200	**169.43**
45	9	125	2.7	445	13	50	12	346	400	**145.33**
46	9	127	2.7	427	13	75	12	462	200	**153.63**
47	9	126	2.7	424	13	100	14	580	100	**165.08**
48	9	129	2.7	430	13	125	14	695	300	**192.48**
49	9	71	4.0	640	7	50	8	230	100	**106.10**
50	9	73	4.0	650	7	75	8	462	200	**133.40**
51	9	75	4.0	647	7	100	8	576	300	**159.57**
52	9	72	4.0	652	7	125	8	695	400	**162.79**
53	9	74	4.0	642	9	50	10	346	200	**134.55**
54	9	75	4.0	652	9	75	10	233	300	**124.98**
55	9	76	4.0	637	9	100	10	461	100	**138.11**
56	9	78	4.0	647	9	125	10	579	400	**191.41**
57	9	79	4.0	636	11	50	12	696	300	**177.82**
58	9	77	4.0	645	11	75	12	462	400	**184.27**
59	9	75	4.0	644	11	100	12	231	100	**132.41**
60	9	78	4.0	637	11	125	12	581	200	**184.82**
61	9	76	4.0	662	13	50	12	346	400	**137.82**
62	9	78	4.0	641	13	75	12	462	200	**145.71**
63	9	79	4.0	649	13	100	14	579	100	**172.16**
64	9	75	4.05	650	13	125	14	695	300	**183.51**

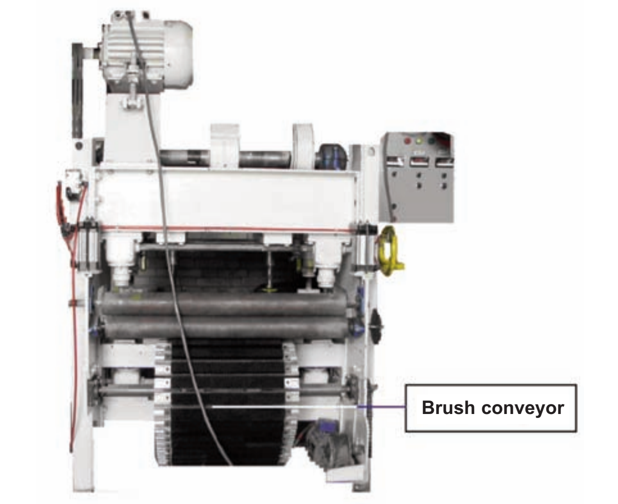


Fig. 7. Laboratory random-velour needle-loom

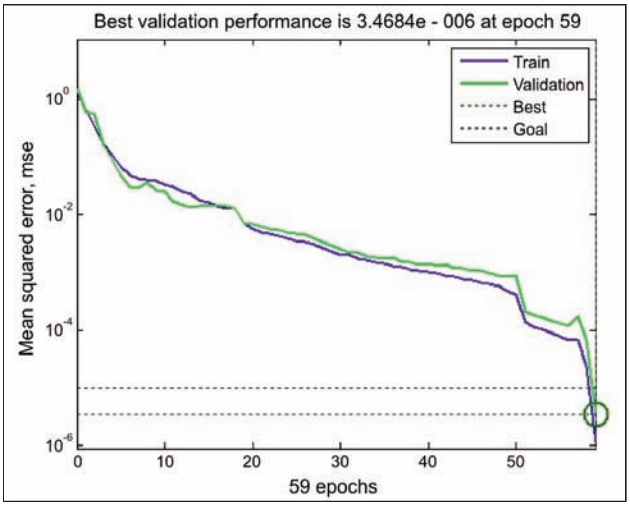


Fig. 8 Minimum value of MSE in 59th epoch of training and validation stages

made by "Prestd" preprocessing the network training set by normalizing the inputs and outputs so that each have zero mean and standard deviations of 1. The pertaining data sets of 42, 14 and 8 of the samples were randomly selected for training, validation, and test sets respectively. Non occurrence of over fitting in the final result was assured using validation set. The model error can also be evaluated using the test set.

The model used in this work is one hidden layered multilayer Perceptron ANN as shown in figure 3. The hidden layer contained various numbers of neurons. Extensive training and testing of the model revealed that existence of 6 neurons in the hidden layer minimize the value of mean square error (MSE) of the model.

As shown in figure 4, the Logistic Sigmoid function (logsig) for the first layer and the Linear function (purelin) for the last layer are used as the transfer functions. Lerenberge-Marquarte back-propagation technique was used as training algorithm of the model. This is an iterative gradient algorithm which minimizes the MSE value between predicted and desired output results.

RESULTS AND DISCUSSIONS

The developed feed-forward ANN was used to map the total average force F_{rms} and input parameters. Acceptable compatibility between predicted and experimental results was achieved by minimization of error due to successive modeling trials, which led to selection of the trained model. During training, model weight and biases are varied in a manner that minimum value of model perform function are reached. By definition the perform function of the feed-forward model is mean square error (MSE) among predicted and targeted results. An ultimate MSE value of approximately $3.4 \cdot 10^{-6}$ was obtained after performing simultaneous stages of training and validation in the 59th epoch, as shown in figure 8.

Table 3

PREDICTED AND EXPERIMENTAL VALUES OF EIGHT TESTS DATA

No. of test data	Predicted value, y_i', g	Experimental value, y_i, g
1	150.5687	151.51
2	166.7048	173.95
3	177.4509	164.61
4	224.1523	208.10
5	201.1091	196.23
6	218.2833	192.48
7	189.4479	191.41
8	213.2968	183.51

Error (%) = 6.68%

The selected model is tested by 8 of 64 actual data. Figure 9 shows correlation values among predicted and experimental data of training (R = 1) and test (R = 0.87589) stages.

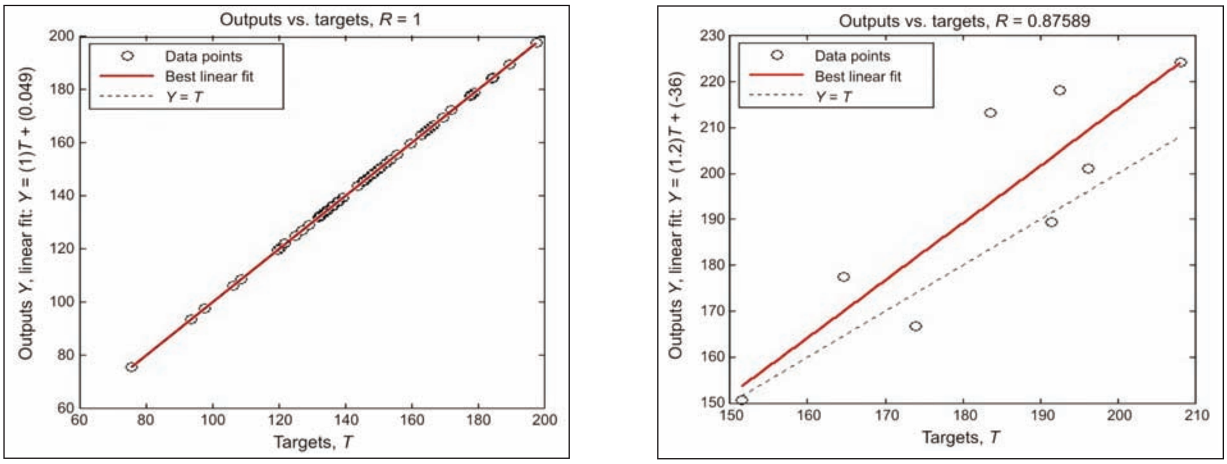
Training of neural network was achieved using nine input parameters. Model was tested by feeding the inputs into the network. The model generated values of total average force F_{rms} were compared with experimentally obtained results. Equation (4) gives the percentage average of absolute error of eight test data.

$$Error\,(\%) = \frac{\sum_{i=1}^{8} \left| \frac{(y_i - y_i')}{y_i} \right|}{8} \cdot 100 \qquad (4)$$

where:

y_i' and y_i as stated in table 3 are predicted and experimental values respectively.

Equation (5) gives the significance percentage effect of each parameter on F_{rms} using neuron weights in the hidden and output layers. The results based on extraction of neurons weight in hidden and output layers from the model in relation to tables 4 and 5 are shown in table 6.



a ***b***

Fig. 9. Predicted and experimental data:
a – training; ***b*** – test

Table 4

W_{ij} VALUES (BETWEEN INPUT AND HIDDEN LAYERS)									
	W_{1j}	W_{2j}	W_{3j}	W_{4j}	W_{5j}	W_{6j}	W_{7j}	W_{8j}	W_{9j}
***j* = 1**	-10.2209	3.0422	-3.3809	-0.8074	3.3465	4.7798	-2.2070	-5.1939	-0.3095
***j* = 2**	-0.4273	-3.0007	-0.4542	-2.9269	2.6639	0.7045	-2.0218	-1.4483	0.9492
***j* = 3**	1.2983	1.2056	-4.6878	6.2337	5.4000	6.1853	-9.7229	-2.2089	-0.8152
***j* = 4**	-0.3361	0.3726	-1.2828	0.9146	-1.6754	0.3344	0.0938	-0.1564	-1.1032
***j* = 5**	1.2963	1.9592	-6.6960	5.2698	5.0740	-5.5554	1.7063	-3.5660	6.1474
***j* = 6**	-0.4100	5.4505	2.5951	3.9631	-2.8666	-5.9653	-0.1712	-1.3026	-9.2166

Table 5

W_{jk} VALUES (BETWEEN HIDDEN AND OUTPUT LAYERS)						
	W_{1j}	W_{2j}	W_{3j}	W_{4j}	W_{5j}	W_{6j}
***K* = 1**	1.4044	-4.7716	2.4427	-3.9633	1.8466	-0.8262

Table 6

SIGNIFICANCE PERCENTAGE OF INPUT PARAMETERS ON F_{rms} VALUE									
Parameters	**Fiber fineness,** denier	**Fiber length,** mm	**Fiber crimp frequency,** 1/cm	**Felted fibrous assembly mass,** g/m^2	**Penetration depth - felt,** mm	**Punch density - felt,** 1/cm^2	**Penetration depth - velour,** mm	**Stroke frequency - velour,** s/min.	**Punch density - velour,** 1/cm^2
Effects, %	9.79	10.15	11.52	11.86	12.16	12.99	10.45	9.76	11.32

$$Effect_i\,(\%) = \frac{\sum_{j=1}^{6} W_{ij}}{\sum_{i=1}^{8}\sum_{j=1}^{6}\sum_{k=1} W_{ij} + W_{jk}} \cdot 100 \qquad (5)$$

Table 6 indicates that fiber characteristics and needling parameters percentage effect more or less equally affect F_{rms}. Results also emphasized the importance of factors such as punch density and needle penetration depth pertaining to initial felt needling. In this regard the influence of mass per unit area of random-velour needled fabric and fiber crimp on F_{rms} must not be ignored.

CONCLUSIONS

The artificial neural network has great potential for modeling of complex nonlinear textile processes. The back-propagation network model was used to predict F_{rms} behavior when the relative importance of inputs was known. A general model capable of predicting the combined effect of fiber characteristics, mass per unit area of initial pre-consolidated fibrous assembly together with needling adjustment during both needling stages on total average force exerted on the fork needle was developed. Validity of the model was confirmed by small value of mean square error and the relatively high coefficient of correlation of the test data. The use of validation technique as well as small error % among predicted and experimental test data further verified that the ANN model is in fact the generalized mapping of the inputs and output parameters.

BIBLIOGRAPHY

[1] Mrstina, V., Fejgl, F. *Needle punching textile technology*. Elsevier, USA, 1990, ISBN 0 444 988041

[2] Purdy, A.T. *Needle-punching*. The Textile Institute, Manchester, U.K., 1980, ISBN 0 900739 32 0

[3] Tyas, T. *Needle-felted fabrics*. P. Lennox-Kerr. Ed. Textile Trade Press. Chapter 1: *The design of needle looms,* Manchester, U.K., 1972

[4] Mashroteh, H., Zarrebini, M. *Analysis of punching force during random-velour needling*. In: Textile Research Journal, 2010, vol. 81, issue 5, pp. 471–481

[5] Hearle, J. W. S., Sultan, M. A. I. *A study of needled fabrics:* Part VI: *The measurement of punching force during needling*. In: Journal of Textile Institute, 1968, vol. 59, pp. 237–242

[6] Hearle, J. W. S., Purdy, A. T. *A technique for the measurement of the punching force during needle-felting*. In: Journal of Textile Institute, 1972, vol. 63, pp. 363–374

[7] Goswami, B. C., Beck, T., Scardino, F. L. *Influence of fiber geometry on the punching-force characteristics of webs during needle felting*. In: Textile Research Journal, 1972, vol. 42, pp. 605–612

[8] Sarin, S., Meng, J., Seyam, A. M. *Mechanics of needle punching process and products.* Part I: *Critical review of previous work on forces experienced by needles during needling of nonwoven fabrics*. In: International Nonwoven Journal, 1994, vol. 6, issue 2, pp. 32–36

[9] Seyam, A. M., Meng, J., Mohamed, A. *Mechanics of needle punching process and products*. Part II: *An on-line device to measure the punching forces experienced by individual needles*. In: International Nonwoven Journal, 1995, vol. 7, issue 3

[10] Seyam, A. M., Sarin, S. *Effect of needle position and orientation on forces experienced by individual needles during needle punching*. In: Textile Research Journal, 1997, vol. 67, pp. 772–776

[11] Seyam, A. M., Mohamed A., Kim H. *Signal analysis of dynamic forces experienced by individual needles at high speed needle punching*. In: Textile Research Journal, 1998, vol. 68, pp. 296–301

[12] Seyam, A. M. *Application of on-line monitoring of dynamic forces experienced by needles during formation of needled fabrics*. In: International Nonwoven Journal, 1999, vol. 8, issue 5, pp. 55–60

[13] Seyam, A. M. *Impact of needling parameters on the locations of maximum needle force due to fiber web/ needle interaction.* The Association of the Nonwoven Fabrics Industry (Inda). Proceeding of Needlepunch Conference, USA, 2000

[14] Cislo, R., Kapusta, H. *Analysis of forces transmitted by needles in the process of web needling in quasi-static conditions*. In: Fibers & Textiles in Eastern Europe, 2002, pp. 76–80

[15] Kapusta, H. *Analysis of values of punching forces in the process of web needling in dynamic conditions*. In: Fibers & Textiles in Eastern Europe, 2003, vol. 11, issue 1, p. 40

[16] Watanabe, A., Miwa, M., Yokoi, T., Merati A. A. *Predicting the penetrating force and number of fibers caught by a needle barb in needle punching*. In: Textile Research Journal, 2004, vol. 74, issue 5, pp. 417–425

[17] Menhaj, M. B. *Computational intelligence*. 3rd Ed., Amirkabir University of Technology (AUT), Tehran, Iran, 2000

[18] Mashroteh, H., Zarrebini, M., Alimoradi, S. *Estimation of properties of random-velour polypropylene needled fabrics using multivariate regression models*. Proceeding of the 4th ITC&D, Croatia, 2008

[19] Mashroteh, H., Zarrebini, M. *Effect of carded web weight on some properties of random-velour nonwoven floor coverings using polypropylene fibers.* Proceeding of the 6th Conference on Textile Engineering, Iran, 2007

[20] GROZ-BECKERT. *Needles – General Catalogue*. Groz-Beckert, Germany, 2009

[21] Haykin, S. *Neural network, a comprehensive foundation*. MacMillan College Publishing Company, New York, USA, 1994

[22] Demuth, H., Beale, M., Hagan, M. *Neural network toolbox user's guide*. MATLAB R2010a, The Math Works Inc., Copyright 1984 – 2010

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A research on the properties of various types of commonly used lining fabrics

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REZUMAT – ABSTRACT

Cercetări privind proprietăţile diferitelor tipuri de căptuşeală, cu diverse destinaţii

Materialele de căptuşeală sunt concepute pentru a acoperi, în interior, un articol de îmbrăcăminte. Ele sunt elemente funcţionale ale articolului de îmbrăcăminte, având rolul de a-i dubla interiorul cu o structură complexă şi de a-i menţine forma, pentru a-i conferi purtătorului un confort mai bun. În scopul analizei şi comparării unor proprietăţi ale materialelor de căptuşeală, s-au folosit nouă tipuri de ţesături. S-a realizat o analiză comparativă a efectelor densităţii ţesăturii, fineţii firului şi tipului de material asupra proprietăţilor materialelor de căptuşeală. Materialele cu densitate mai mare, din fire mai groase, prezintă suprafeţe mai netede, permeabilitate mai mică la aer şi o rezistenţă crescută la rupere. S-a observat că ţesăturile din 100% acetat sunt mai netede decât cele din 100% poliester, în timp ce rezistenţa la rupere este mai mică. Valorile mai mari ale densităţii şi fineţii firului din structura ţesăturii au dus la creşterea grosimii materialelor de căptuşeală.

Cuvinte-cheie: materiale de căptuşeală, proprietăţi mecanice, rugozitatea suprafeţei, permeabilitate la aer

A research on the properties of various types of commonly used lining fabrics

Linings are textiles used to cover the inner side of the garments. They are functional parts of the garment, and are used to maintain the shape of the garment, to improve the comfort of the wearer, to cover the inside of the garment of complex construction. In order to investigate and compare physical properties of commonly used lining fabrics, 9 different lining fabrics were supplied for the experiment. The data obtained from the experiments was evaluated statistically. In the scope of the results, the effects of fabric density, yarn count and material type on properties of the lining fabrics were analyzed and compared. Lining fabrics which are denser and include thicker yarns have smoother surfaces, lower air permeability and higher tensile strength. 100% acetate fabrics were found smoother than 100% polyester fabric, whereas the tensile strength results were found opposite. Increasing density and yarn count in lining fabric structure caused an increase in the thickness values of linings.

Key-words: lining, mechanical properties, surface roughness, air permeability

Lining can be defined as the fabric sewn inside of a garment to provide different functional properties. They are used in suits, trousers, skirts, dresses, jackets and outdoor apparel.

The roles of lining can be classified as follows:

- to improve comfort in terms of thermal or wetness properties;
- to prevent sensory discomfort from prickliness or roughness of garment fabrics;
- to help garments maintain good shape or silhouette;
- to reduce wrinkling or residual deformation of the outer fabric and to provide durability;
- to reduce friction when putting on and taking off clothing and moving;
- to cover seams or interfacing inside lining;
- to prevent transparency of the garment;
- to extend garment life by preventing hanger stress and body contact with the shell fabric;
- to make a barrier between the body and the garment, therefore, preventing absorption of perspiration and body oils that may deteriorate or stain shell fabrics [1, 2].

Performance expectations of linings vary with product type and end use. The factors that affect the quality and performance of linings include fabric properties, design and structure of the lining, compatibility with other materials and garment structure. The choice of lining material depends upon the intended end use, the characteristics of the piece goods, the performance requirements for the product, the quality level, and the cost [1].

There are various studies, which investigate seam strength and tensile properties of lining fabrics. Surface properties of lining fabrics have not been studied by the previous researchers, although they influence the usage performance and abrasion properties of linings.

In order to investigate and compare physical properties of commonly used lining fabrics, 9 different fabrics were tested and the effects of fabric density, yarn count and material type on the properties of the lining fabrics were compared and statistically analyzed.

Table 1

THE STRUCTURAL PROPERTIES OF THE LINING FABRICS								
Group no.	**Fabric code**	**Material type**	**Yarn type**	**Fabric construction**	**Weft density,** picks/cm	**Warp density,** ends/cm	**Weft yarn count,** tex	**Warp yarn count,** tex
1	1	65% PES - 35% Co	Staple	Plain weave	28	45	14	9
	2	65% PES - 35% Co	Staple	Plain weave	38	45	14	9
2	3	100% PES	Filament	Plain weave	31	38	14	9
	4	100% PES	Filament	Plain weave	31	76	14	9
3	5	100% PES	Filament	Twill (2/1)	28	50	14	8.3
	6	50% PES-50% CA	Filament	Twill (2/1)	28	50	14	8.3
	7	100% CA	Filament	Twill (2/1)	28	50	14	8.3
4	8	100% PES	Filament	Plain weave	38	90	5	3.5
	9	100% PES	Filament	Plain weave	38	90	8	5.8

MATERIALS AND METHODS

The structural properties of the selected lining fabrics, which are made of polyester (PES)-cotton (Co), polyester, polyester-acetate (CA) and acetate fibers, are given in table 1.

In this study, lining fabrics were grouped according to their warp and weft densities, warp and weft yarn counts and material types. 4 groups were generated by considering their warp density, weft density, yarn count and material type, while the other parameters were kept constant.

Surface roughness (friction coefficient), air permeability, thickness, breaking force, tear resistance and seam strength properties of lining fabrics were tested and all measurements were performed after conditioning of the fabrics for 24 hours under the standard atmosphere conditions (20 ± 2°C temperature, 65 ± 4% relative humidity).

Surface roughness was determined by FricTorq instrument. Air permeability was measured according to TS 391 EN ISO 9237 standard by Textest FX 3300 instrument. The measurements performed with a sample size of 20 cm^2 at 100 Pa. Thickness values were measured according to TS 7128 EN ISO 5084 standard by SDL ATLAS Digital Thickness Gauge. Breaking strength tests were performed on Lloyd LRX Plus device in accordance with TS EN ISO 13934-1 standard. The distance between the jaws was 200 mm, and the gauge speed of the Lloyd was 100 mm/minute. Five samples for each specimen were taken from both directions, and averages of the test results were calculated. Tear resistance was measured by Elmatear tester according to ISO 13937-1:2000 standard both in transverse and machine directions. Seam strength properties of fabric specimens were tested on Lloyd LRX Plus according to TS 1619-1 EN ISO 13935-1 standard. In order to assemble the samples, one sewing thread (ticket number 120) made of 100% PES was used for the upper and lower thread at the lockstitch sewing machine and the stitch density adjusted as 3 stitches per cm, which was kept constant. 301 stitch type was used for the fabrics and the code number of needle was selected as 90/14.

RESULTS AND DISCUSSIONS

In order to determine the statistical significance of the effects of weft/warp density and yarn count on fabric properties independent samples T-Tests were applied, whereas ANOVA tests were applied to investigate the effect of material type on the lining fabric properties. Student-Newman-Keuls Test and Tamhane's T2 post hoc tests were conducted, according to the Levene Homogeneity test results. To deduce whether the parameters were significant or not, p values were examined (tables 3, 4 and 5) according to α = 0.05 significance level. The test results of studied lining fabrics are given in table 2.

Surface properties

Surface properties of fabrics are very important in terms of both psychological and physical effects on the human being's appreciation of that fabric [3].

Surface roughness is an important physical feature for lining fabrics to estimate surface properties and frictional behavior. Lining fabrics help tight clothes to slip over the skin, as the clothes are being worn. Therefore, smoother lining surfaces provide compliance with the intended use [4]. Surface roughness of studied fabrics was measured by FricTorq instrument and the kinetic friction coefficient, μ_{kin}, value, which is obtained from the instrument, was used for the comparison of surface roughness. Friction coefficient is not an inherent characteristic of a material or surface, but results from the contact between two surfaces [5, 6]. This method consists of characterizing the coefficient of friction between two flat surfaces, namely textile fabrics, based on torque evaluation [6].

According to the kinetic friction coefficient results (fig. 1), it can be stated that, as the yarns per unit area increases, surface roughness decreases. It is related with the distance between yarns which decreases in denser fabrics.

Table 2

TEST RESULTS OF LINING FABRICS										
Fabric parameters / Searched parameters	Number of test samples	Weft density, picks/cm		Warp density, ends/cm		Material type			Yarn count, tex_{weft}/tex_{warp}	
		28	*38*	*38*	*76*	*100% PES*	*50% PES/ 50% CA*	*100% CA*	*5 tex/ 3.5 tex*	*8 tex/ 5.8 tex*
Kinetic friction coefficient, μ	3	0.293	0.271	0.244	0.239	0.251	0.247	0.240	0.284	0.257
Air permeability, l/m^2/s	10	192.00	96.17	657.80	63.80	86.34	89.12	95.31	675.50	401.90
Thickness, mm	10	0.23	0.24	0.19	0.22	0.18	0.19	0.18	0.16	0.21
Breaking force - warp wise, N	5	590.49	761.23	579.91	1 335.53	924.14	849.12	259.10	533.74	1 406.27
Breaking force - weft wise, N	5	509.75	586.37	390.17	429.22	801.73	207.96	147.88	184.69	487.29
Weft seam strength, N	5	22.38	23.53	23.93	58.42	47.52	13.17	9.75	15.74	28.18
Warp seam strength, N	5	25.99	26.28	17.90	38.21	52.77	14.08	9.90	11.26	28.86
Tear resistance - transverse direction, N	5	25.35	28.63	17.93	38.22	52.79	10.64	994	11.27	28.87
Tear resistance - machine direction, N	5	22.06	21.86	23.96	51.64	47.53	10.12	9.74	15.73	28.20

Table 3

P VALUES OF INDEPENDENT SAMPLES *T*- TEST						
Measured parameters	Weft density, picks/cm		Warp density, ends/cm		Yarn count, tex_{weft}/tex_{warp}	
	28	*38*	*38*	*38*	*(5/3.5)*	*(5/3.5)*
Kinetic friction coefficient, μ	0.004*		0.012*		0.027*	
Air permeability, l/m$^2\cdot$ s	0.000*		0.000*		0.000*	
Thickness, mm	0.006*		0.001*		0.000*	
Breaking force - warp wise, N	0.000*		0.000*		0.000*	
Breaking force - weft wise, N	0.002*		0.039*		0.000*	
Weft seam strength, N	0.046		0.000*		0.000*	
Warp seam strength, N	0.045		0.000*		0.000*	
Tear resistance - transverse direction, N	0.757		0.000*		0.001*	
Tear resistance - machine direction, N	0.001*		0.001*		0.000*	

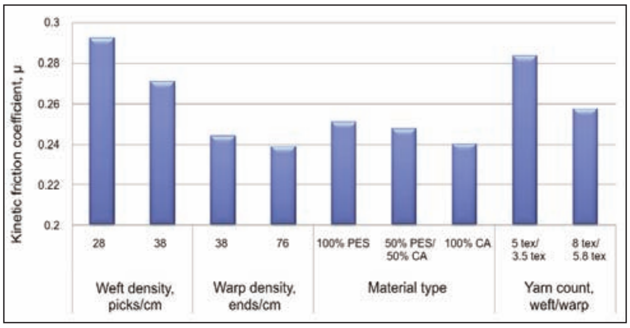

Fig. 1. Kinetic friction coefficients of lining fabrics

The same situation was observed in the case of yarn counts. Thinner the yarn, higher the kinetic friction coefficient is. It means higher surface roughness will make wearing difficult.

Material type has also an important effect on surface roughness. Surface of 100% CA fabric was found smoother than the surface of 100% PES fabric. Therefore, it can be stated that, fabrics including acetate fibers supply easy wearing and better tactile feeling.

Air permeability

Air permeability is an important factor in fabric comfort, since it plays a role in transporting moisture vapor from the skin to the outside atmosphere. The assumption is that, vapor travels mainly through fabric spaces by diffusion in air from one side of the fabric to the other [7]. Lining fabrics are used in next to skin applications. Thus, it is thought that, air permeability becomes a more significant comfort factor.

Air permeability values of the studied lining fabrics are given in figure 2. According to the experimental

Table 4

POST HOC TEST RESULTS (RESULTS OF TAMHANE'S T_2 TEST FOR AIR PERMEABILITY)		
Group *I*	**Group *J***	***P***
100% PES	50% PES-50% CA	0.632
	100% CA	0.643
50% PES/50% CA	100% PES	0.632
	100% CA	0.665
100% CA	100% PES	0.643
	50% PES-50% CA	0.665

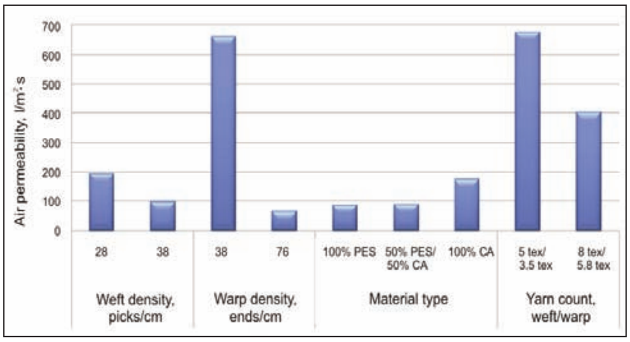

Fig. 2. Air permeability of lining fabrics

results and statistical analysis, it can be denoted that, air permeability values are lower for the fabrics, which are denser and including thicker yarns. This result can be explained by fabric porosity. The porosity decreases with the increasing number of yarns per unit length and yarn count (tex). As the air permeability values of the lining fabrics including different materials were analyzed, the effect of material type on air permeability was found statistically insignificant (table 4). This result can be associated with the fabric porosities, which are similar for the 100% PES, 50% PES – 50% CA and 100% CA fabrics.

As a result, fabrics contain thinner yarns and less dense structure transmit vapor through the fabric better and provide more comfortable feeling.

Fabric thickness

Thickness is the distance between one surface of a material and its opposite [8]. Fabric thickness is important, since it affects permeability and insulation characteristics of the fabrics [9].

The thickness values of the lining fabrics can be seen in figure 3. As it can be seen from the figure, the thickness of the fabric increases, with the increasing number of yarns per unit area and yarn count.

Fabric thickness is affected by the crimp of the yarns [9], which is also related with the number of picks and ends in unit area. Therefore, the thickness values of the fabrics increase, when the fabric density is higher. In the same way, as the yarn count increases, the diameter of the yarns increases too. Therefore, the thickness of the fabrics will be higher. However, the effect of material type on fabric thickness was found insignificant.

Since fabric thickness has a significant role on fabrics tactile properties [10], it can be signified that, thinner fabrics will be more suitable to be used as lining fabrics.

Table 5

POST HOC TEST RESULTS (RESULTS OF STUDENT-NEWMAN-KEULS TEST)										
Fabric test	**Group**	***N***	**Subgroups**		**Fabric test**	**Group**	***N***	**Subgroups**		
			1	2				1	2	3
Kinetic friction coefficient	100% CA	3	0.2403	-	Seam strength - weft wise	100% CA	5	9.75	-	-
	50% PES-50% CA	3	0.2475	0.2475		50% PES-50% CA	5	-	13.17	-
	100% PES	3	-	0.2510		100% PES	5	-	-	47.52
	Significance	-	0.078	0.334		Significance		1.000	1.000	1.000
Thickness	100% CA	10	0.1820	-	Seam strength - warp wise	100% CA	5	9.90	-	-
	50% PES-50% CA	10	0.1880	-		50% PES-50% CA	5	-	14.08	-
	100% PES	10	0.1820	-		100% PES	5	-	-	52.77
	Significance	-	0.649	-		Significance		1.000	1.000	1.000
Tear resistance - transverse direction	100% CA	5	9.74	-	Breaking force - warp wise	100% CA	5	259.10	-	
	50% PES-50% CA	5	10.12	-		50% PES-50% CA	5	-	849.12	-
	100% PES	5	-	47.53		100% PES	5	-	-	924.14
	Significance	-	0.703	1.000		Significance		1.000	1.000	1.000
Tear resistance - machine direction	100% CA	5	9.94	-	Breaking force - weft wise	100% CA	5	147.88	-	
	50% PES-50% CA	5	10.64	-		50% PES-50% CA	5	-	207.96	-
	100% PES	5	-	52.79		100% PES	5	-	-	801.73
	Significance	-	0.58	1.000		Significance		1.000	1.000	1.000

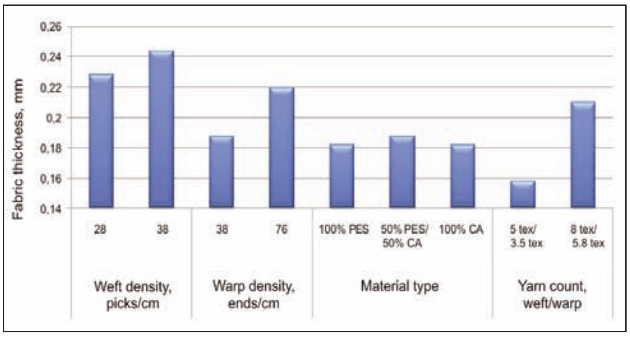

Fig. 3. Thickness of lining fabrics

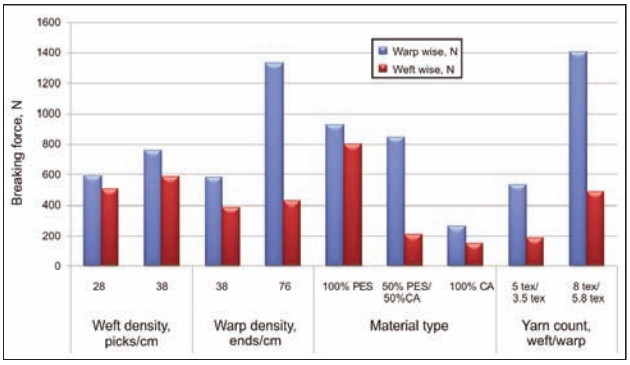

Fig. 4. Breaking force of lining fabrics

When the results were evaluated in terms of fabric thickness, it is observed that, the fabric thicknesses vary between 0.16 mm and 0.24 mm. Therefore, it is thought that, studied lining fabrics are in accordance with the expectations by means of fabric thickness.

Breaking force

Durability is an important parameter for lining fabrics. They should have a wear-life as long as garment fabric [11]. Therefore, linings which have higher tensile strength are expected to fulfill such requirements more.

Breaking force values of the lining fabrics are given in figure 4. According to figure 4, it is observed that, in both warp and weft directions, fabric density and yarn count have positive effects on it. It could also be noted that the fabric including polyester fibers have higher breaking force value, as compared to the fabric including acetate fibers, due to the tenacity difference of acetate and polyester fibers.

In addition, the changes in the warp density exerted a tremendous influence on the warp wise strength of the fabric. The warp wise breaking force of the fabrics was found higher than the weft wise, as expected.

Tearing force

Tearing force is an important feature for lining fabrics. As it can be seen in figure 5, tearing force values of the fabrics mostly show a similar tendency with the tensile strength results, which are given in figure 4.

Tearing force is associated with the fiber strength. Higher the tenacity of the fibers, higher the tearing force is. Therefore, the tearing force of the fabrics containing polyester fibers was found higher than the fabrics containing acetate fibers. Also, yarn count has a significant influence on tearing force, which is higher for thicker yarns. Tearing force transverse direction values of the fabrics increase with the increasing fabric density. However, the effect of weft density on tearing force machine direction was found insignificant.

Seam strength

Seam is one of the essential factors for garment quality [12]. Failure at a seam makes a garment unusable even though the fabric may be in good condition [10]. The characteristics of a properly constructed seam

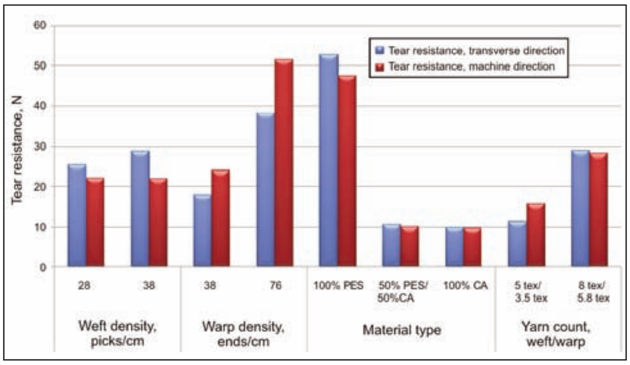

Fig. 5. Tearing force of lining fabrics

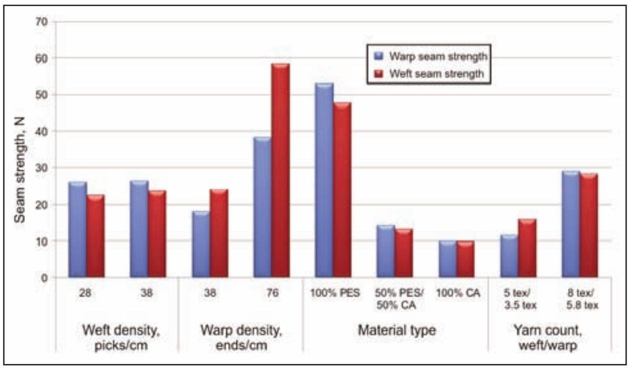

Fig. 6. Seam strength of lining fabrics

are strength, elasticity, durability, stability and appearance, which depend on the type of seam, the stitches per unit length of the seam, the thread tension and the seam efficiency [12].

Seam strength values of the studied lining fabrics are given in figure 6. According to the experimental results and statistical analysis, there is a significant effect of weft/warp density, yarn count and material type on seam strength both in warp and weft directions.

Since the sewing parameters are constant, seam strength is associated with the fabric structure and fabric strength parameters. According to the results it can be stated that, the seam strength test results show similarities with the breaking force test results.

Yarn count, fabric density and material type can be changed according to the application area of the lining materials. However, in the scope of these results, it can be stated that, in order to get better mechanical properties; denser structures and thicker weft and warp yarns should be chosen in the fabric construction. Usage of polyester fibers will also provide an advantage in terms of tensile properties.

CONCLUSIONS

In this study, 9 different commonly used lining fabrics, that have different physical properties, were supplied and the effects of fabric density, yarn count and material type on the properties of lining fabrics were examined.

Lining fabrics help tight clothes to slip over the skin, as the clothes are being worn. Therefore, it is expected from lining fabrics to have lower kinetic friction coefficient values. According to the kinetic friction coefficient results, the lining fabrics which are denser and include thicker yarns have smoother surfaces. It was also found that the roughness of 100% CA fabric is lower than 100% PES fabric. Consequently, the acetate lining fabrics which are smoother provide compliance with the intended use.

Increasing density and yarn count in lining fabric structure, causes an increase in the thickness values of lining fabrics. Higher thickness is not favored for tactile properties, thus fabrics comprise yarns having lower linear density and less dense structure will give a better handle.

It was indicated that increment of the number of yarns per unit area, and usage of yarns, which have higher linear density increase the fabric strength, as it was expected. Meanwhile, the fabric produced from acetate fibers has lower tensile strength values than the fabrics including polyester fibers.

Since, the sewing parameters were kept constant for all fabrics, the seam strength results were found parallel to the tensile strength results, which confirmed the expectations.

As the fabric density increases, the seam strength of the fabrics also increases in both directions. 100% PES fabric has the highest and 100% CA fabric has the lowest seam strength values. It was also found that the seam strength values of the fabrics that are made of yarns having higher linear density are higher than the fabrics consist of finer yarns.

In general, the tear resistance of the fabrics increase with the increasing yarn density and yarn count. Polyester fabrics are more resistive to tearing than the acetate fabrics.

It can also be denoted that, air permeability values are lower for the fabrics, which have denser structure and thicker yarns, due to the lower porosity of these fabrics.

The investigated physical and technical properties of linings in this study will be helpful to choose the most appropriate lining material for the consumers and industrial producers, which may change according to priorities and the application areas.

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BIBLIOGRAPHY

[1] Kalaoğlu, F., Meriç, B. *Investigation of the performance of linings.* In: International Journal of Clothing Science and Technology, 2005, vol. 17, issue 3/4, p. 171

[2] Kawabata, H., Obara, K., Komiyama, H., Narumi, T. *The effects of skirt lining properties on comfort and movement*. In: International Journal of Consumer Studies, 2001, vol. 25, issue 4, p. 271

[3] Hu, J. *Structure and Mechanics of Woven Fabrics*. Cambridge: Woodhead Publishing Ltd., 2004

[4] Kurumer, G. *Konfeksiyon Üretimi ve Teknolojisi*. Printer Ofset Matbaacılık, İzmir, 2007

[5] Nosek, S. *Problems of friction in textile processes.* International Conference Textile Science 93, TU Liberec, Czech Republic, 1993

[6] Lima, M., Vasconcelos, R., Abreu, M. J., Cabeço Silva, M. E. *Comparative study of friction coefficient in nonwovens using Frictorq, fabric friction tester*. Proceedings of the World Textile Conference – AUTEX, Raleigh, North Carolina, USA, 2006

[7] Mavruz, S., Ogulata, R. T. *Investigation of air permeability of single jersey fabrics with different relaxation states*. In: Journal of the Textile Institute, 2011, vol. 102, issue 1, p. 57

[8] ASTM D 1777 – 96. Standard Test Method for Thickness of Textile Materials 1, 2007

[9] Adanur, S. *Handbook of weaving*. CRC Press, Taylor & Francis Group, Chapter 13: Fabric Structure, Properties and Testing, 2001, By Sulzer Textil Limited Switzerland

[10] Saville, B. P. *Physical Testing of Textiles*. Cambridge: Woodhead Publishing Ltd, 1999

[11] Bilen, U. *Hazırgiyimde Kullanılan Malzeme ve Aksesuarlar*. Karadeniz Kitap Ltd. Şti., İstanbul, 2010

[12] Gurarda, A. *Investigation of the seam performance of PET/nylon-elastane woven fabrics.* In: Textile Research Journal, 2008, vol. 78, issue 1, p. 21

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A new line balancing algorithm for manufacturing cell transformation in apparel industry

CAN ÜNAL

REZUMAT – ABSTRACT

Algoritm de echilibrare a unei noi linii pentru transformarea celulei de producție din industria confecțiilor

Producerea confecțiilor este o industrie tradițională, cu concurență globală. Astfel, fiecare producător de confecții înțelege importanța creării unor sisteme de producție mai bune, încercând să reducă timpii necesari asamblării, pentru a accelera livrarea, şi intensificând utilizarea maşinilor/forței de muncă în scopul reducerii costurilor de producție. De aceea, echilibrarea liniei de asamblare este un important factor pentru creşterea eficienței şi competitivității. În cadrul acestui studiu, s-au folosit şase algoritmi diferiți de echilibrare a liniei de producere a cămăşilor, într-o unitate de confecții cu un număr mare de operații tehnologice. În acest scop, au fost stabilite unitățile standard de timp pentru diverse operații, printr-o evaluare a timpului şi validări statistice. Mai mult, pentru a lua în calcul întârzierile, au fost efectuate studii de normare a muncii. Au fost examinați algoritmii recent elaborați, ținând cont de cerințele managerului, şi a fost creat un nou algoritm care reflectă mai bine procesul de producere a confecțiilor. Astfel, comparând noul algoritm cu algoritmii recent elaborați, pe lângă conceptul de utilizare, au fost emise noi concepte privind calitatea, direcția fluxului operațiilor şi abilitățile operatorilor.

Cuvinte-cheie: echilibrarea liniei, producție confecții, utilizare, algoritmi euristici

A new line balancing algorithm for manufacturing cell transformation in apparel industry

Apparel manufacturing is a traditional industry with global competition. Thus any apparel manufacturer realizes the importance of improved production systems tries the best to finish the assembly work soon to increase on-time delivery and to increase machine/labour utilization to reduce production cost. Assembly line balancing is therefore a critical issue for the efficiency and competitiveness. In this study, six different line balancing algorithms are applied in shirt production band of a suit manufacturer which involves great number of operations. For this purpose, standard unit times of operations are determined by time study and statistical validations. Furthermore in order to add delay allowances to calculations, work sampling study is performed. Recent algorithms are examined by considering request of manager and a new algorithm which expresses the garment manufacturing process better is created. Thus, by comparing new algorithm with recent ones, other issues except utilization such as quality, work flow direction and skills of operators are emphasized.

Key-words: line balancing, garment manufacturing, utilization, heuristic algorithms

Balancing the work load of workers is an important task of the manager of any organization. If the work load is not well balanced, one operator is very busy while other operators are idle; this situation wastes valuable human resources. In such cases, the overall efficiency as well as the morale of the organization will decrease. Sometimes, continual resentment of workers about the uneven work load may create an unhealthy organizational working climate [1].

In the apparel industry, the production process involves a set of workstations in which a specific task in a predefined sequence is processed [2]. The production process of garments is separated into four main phases: designing/clothing pattern generation, fabric cutting, sewing, and ironing/packing. The most critical phase is the sewing phase, as it generally involves a great number of operations [3]. Before production, the sewing line supervisors assign one or more sewing operators to each task based on the standard time required to complete the task, in order to achieve a balanced line [2].

The fundamental of line balancing problems is to assign the tasks to an ordered sequence of stations, such that the precedence relations are satisfied and some measurements of effectiveness are optimized (e.g. minimize the balance delay or minimize the number of work stations etc.) [4]. The aim of assembly line balance planning in sewing lines is to assign tasks to the workstations, so that the operators/machines of the workstation can perform the assigned tasks with a balanced loading [5].

The assembly line balancing problem, ALBP, is firstly introduced by Salveson (1955) who presented a linear programming solution [6]. As *ALBP* falls into *NP*-hard (nondeterministic polynomial time hard) class of combinatorial optimization problems, has been of great interest to researchers and thus numerous research efforts have been directed towards the development of computer-efficient approximation algorithms or heuristics and exact methods to solve ALB problems. Examples of detailed reviews on the topic have been provided by Ghosh and Gagnon

(1989) [7], Erel and Sarin (1998) [8], Kriengkorakot and Pianthong (2007) [9].

In literature, there are different classifications about *ALBP*. One of them makes the classification according to the type of task times and model type:

- Single Model Deterministic, *SMD* – single model assembly lines where the task times are known deterministically and an efficiency criterion is to be optimized;
- Single Model Stochastic, *SMS* – the *SMS* problem category introduces the concept of task-time variability where workers' operation times are seldom constant;
- Multi/Mixed Model Deterministic, *MMD* – the MMD problem formulation assumes deterministic task times, but introduces the concept of an assembly line producing multiple products;
- Multi/Mixed Model Stochastic, *MMS* – the MMS problem perspective differs from its *MMD* counterpart in that stochastic times are allowed [7].

Other classification type considers constraints and objectives of *ALBP*. Those problems are classified in two categories:

- *SALBP* – the simple assembly line balancing problem is a class of *NP*-hard optimization problem – effective exact and heuristic procedures are available which solve medium-sized instances in a quality sufficient for use in practice [10]:
  - Type 1 – *SALBP-1* – this problem consists of assigning tasks to work stations such that the number of stations, *m,* is minimized for a given production rate (fixed cycle time, *c*);
  - Type 2 – *SALBP-2* – this problem minimizes cycle time (maximize the production rate) for a given number of stations, *m*;
  - Type *E* – *SALBP-E* – this problem is the most general problem version maximizing the line efficiency, *E,* thereby simultaneously minimizing *c* and *m* considering their interrelationship;
  - Type *F* – *SALBP-F* – this problem is a feasibility problem which is to establish whether or not a feasible line balance exists for a given combination of *m* and *c* [9].
- *GALBP* – the general line balancing problems formulate and solve more generalized problems with different additional characteristics such as cost functions, equipment selection, paralleling, *U*-shaped line layout and mixed-model production [10];
  - *MALBP* – the mixed model assembly line balancing problem, has to assign tasks to stations considering the different task times for the different models and find a number of stations and a cycle time as well as a line balance such that a capacity – or even cost – oriented objective is optimized;
  - *MSP* – the mixed model sequencing problem, has to find a sequence of all model units to be produced such that inefficiencies (work overload, line stoppage, off-line repair etc.) are minimized;
  - *UALBP* – the *U*-line balancing problem considers the case of *U*-shaped (single product) assembly lines, where stations are arranged within a narrow *U* [9].

Although many types of assembly lines have been examined one the most labour intense and complicated assembly lines, the sewing line used by the apparel industry, has not received much attention [11]. In literature, different methods are used in order to solve line balancing problem in apparel industry but a few of them is considering the real data. Boysen et al. pointed out that there were less than 5% articles explicitly solving line balancing of real world assembly systems [12]. As a result, for practical consideration, this paper focuses on the real case of an assembly line in garment manufacturing. Considering advantages and disadvantages of the aforementioned studies and needs of garment sewing production line, in order to determine more practical and suitable line balancing algorithm, six different line balancing algorithms are applied in a suit manufacturer's shirt production band. A new algorithm is proposed regarding the expectations of production manager. The remainder of the paper is organized as follows: section 2 describes the problem in shirt production and gathering standard unit time of operations; section 3 examines line balancing algorithms used in shirt production; section 4 presents experiments and results of real case study; in section 5 are discussed the results of experimental studies.

PROBLEM DESCRIPTION

Generally, sewing line supervisors in apparel manufacturing solve the *ALB* problems on intuition and experience, and very often this cannot help to achieve a desirable line balance. To ensure the balance of the sewing line, supervisors have to arrange at least one spare operator to monitor the sewing line regularly. Based on the visual observations and records of the production process, the supervisors make decisions on the number of operators to be added or removed for a particular operation. Such manual efforts can incur inferior productivity. Because it often occurs that operators who are skilful in some machines are allocated to machines that they are unskilful. Also much operator's time is wasted during the frequent operation switching owing to the long setup time for operation switching or machine switching [11]. Thus, the production manager investigates an efficient way of shirt production process by transforming straight production line to manufacturing cells considering the aforementioned problems. Shirt production process has 63 tasks and picture of production model is given in figure 1.

As an engineering study is never done before, there is no information about production process. Firstly, a framework of the study is constructed (fig. 2). Secondly in order to explain line balancing procedure clearly and focus in efficiency, line balancing problem

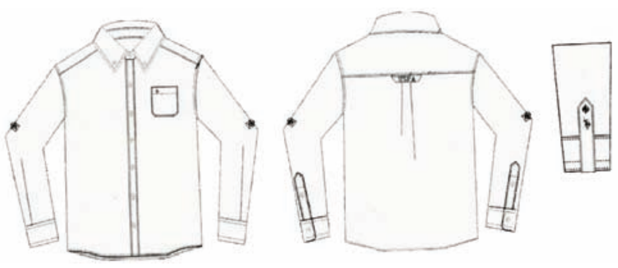

Fig. 1. Picture of shirt model

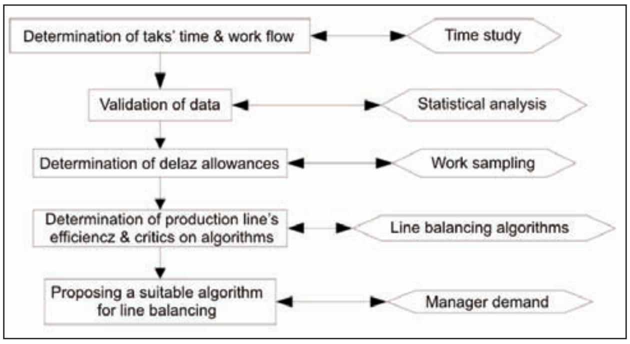

Fig. 2. The framework of line balancing study

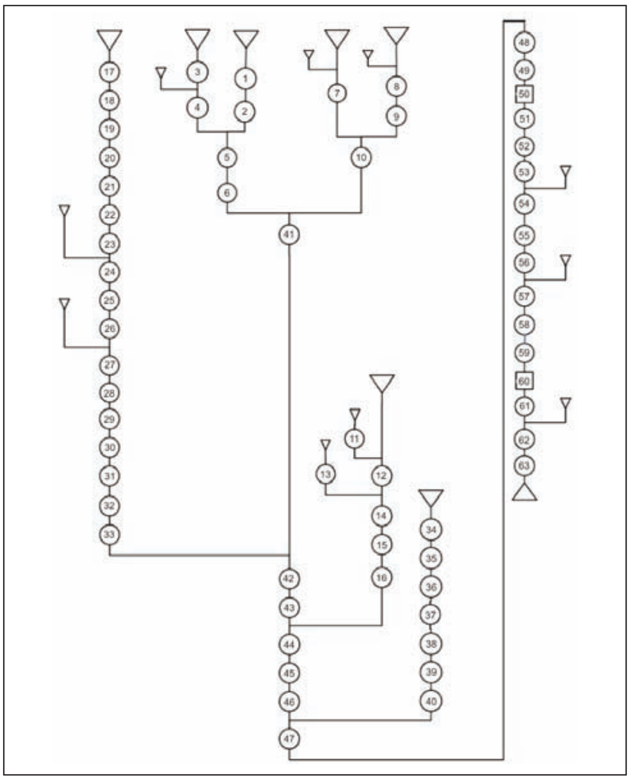

Fig. 3. The work flow of shirt production

type is determined as single model deterministic, *SMD*. Thus to get deterministic data, time study applications with statistical control are carried out by combining work sampling measurements. Then, well known heuristic algorithms are applied and criticized. And a new algorithm is proposed according to manager's demand and reviews.

Gathering required data

First of all, in order to start time study process, work flow of tasks and their predecessors are determined. Each task is numerated from *1* to *63* as seen in figure 3. Then each task is divided into elements and recorded complete description of working method. Standard time of each is task is determined by using the equation (1).

$$ST = \sum NT + \left\{ \sum \left[NT + (FA + DA) \right] \right\} \qquad (1)$$

where:
ST – standard time;
$\sum NT$ – total normal time;
FA – fatigue allowances in percent;
DA – delay allowances in percent.

Normal time, presented in equation (2), is calculated by multiplying the mean observed time*, OT*, of each element with the performance rating of the operator, *R*, expressed as a percentage where 100 percent is accepted as standard performance of a qualified operator [13].

$$NT = OT \cdot R/100 \qquad (2)$$

In order to determine the mean observed time, 15 observations are performed for each element by using a decimal unit stopwatch. Then the required number of observations is calculated for each element by equation (3) to predict the normal time within ±5% precision and 95% confidence level [14]. If required number of observation that is calculated is higher than 15, then additional observations are performed.

$$N' = \left(\frac{40\sqrt{N \sum X^2 - [\sum (X)]^2}}{\sum X} \right)^2 \qquad (3)$$

where:
X is each stopwatch reading.

Fatigue allowances are subdivided into constant and variable fatigue allowance factors which are developed through consensus agreements between management and workers across many industries by International Labour Office (ILO). These factors include standing versus sitting, abnormal positions, use of force, illumination, atmospheric conditions, required job attention, noise level, mental strain, monotony and tedious [13]. Thus each task is examined and evaluated according to aforementioned factors in order to determine appropriate *FA* value.

Delay allowances are classified as avoidable or unavoidable. Avoidable delays that the operator makes intentionally will not be considered in determining time standard. Unavoidable delays do occur from time to time, caused by the machine, the operator, or some outside forces [14]. Thus in order to calculate delay allowances work sampling method is used which requires taking a large number of random observations. In this method, no stopwatch is used, as observers merely walk through the area under study at random times and note briefly what each operator is doing. The number of delays recorded, divided by total number of observations during which

Table 1

DELAY ALLOWANCES OF SUB-CLUSTERS		
Sub-clusters	**Task no.**	**Delay allowances, %**
Shirt preparation	1 – 10	6
Sleeve tasks	11 – 16	6
Collar tasks	17 – 33	5.8
Cuff tasks	34 – 46	5.8
Ironing and packing	47 – 63	4.2

the operator is engaged in productive work, approximates the allowance required by the operator to accommodate the delays encountered [13].

Thus, in order to perform work sampling method, 63 operations are grouped in 5 sub-production clusters, after the determination of observation times and sequence by using random number table, initially 500 observations are performed for each cluster. Then motions of each cluster are observed and classified in three categories as “efficient”, “supporter” and “inefficient”. The required number of observations, *N*, is calculated by equation (4) with 95% confidence level [15] and additional observations are performed when needed. Finally, percentage of “inefficient” motions is appraised as delay allowances for all operations of sub-production clusters. In table 1, sub-clusters of shirt production (with related tasks), each delay allowances of sub-clusters are given.

$$N = \frac{4(1-p)}{S^2 p} \qquad (4)$$

where:

S is desired accuracy (taken as 5%);

p – percentage of working time, efficient category.

In the light of aforementioned calculations standard time of each task is calculated by using equation (1) and given in table 2.

Table 2

STANDARD TIME OF ALL TASKS					
TN*	***ST*****	***TN****	***ST*****	***TN****	***ST*****
1	0.34	**22**	0.11	**43**	0.44
2	0.1	**23**	0.12	**44**	0.35
3	0.07	**24**	0.05	**45**	0.27
4	0.1	**25**	0.15	**46**	0.48
5	0.04	**26**	0.07	**47**	0.42
6	0.4	**27**	0.11	**48**	0.22
7	0.26	**28**	0.18	**49**	0.07
8	0,.13	**29**	0.06	**50**	0.48
9	0.23	**30**	0.15	**51**	0.34
10	0.24	**31**	0.07	**52**	0.37
11	0.04	**32**	0.06	**53**	2.33
12	0.18	**33**	0.05	**54**	0.12
13	0.08	**34**	0.03	**55**	0.11
14	0.2	**35**	0.17	**56**	0.13
15	0.07	**36**	0.04	**57**	0.11
16	0.12	**37**	0.11	**58**	0.56
17	0.1	**38**	0.16	**59**	0.16
18	0.08	**39**	0.14	**60**	0.35
19	0.13	**40**	0.05	**61**	0.83
20	0.22	**41**	0.25	**62**	0.1
21	0.04	**42**	0.21	**63**	0.06

*TN – task no
**ST – standard time in minutes

LINE BALANCING ALGORITHMS

In order to create suitable manufacturing cells in shirt production, six different line balancing algorithms are applied to production line. As tasks of sewing department consist of sewing machines, it is possible to change the number of workstations easily. Thus, the problem considered in this study is about *SALBP-I.* Also as production manager investigates efficient way of production a *SALBP-E* algorithm is considered. SALBP-I process involves six steps:

- *Step 1* – list the tasks in descending order according to five different line balancing heuristics in table 3 [16]. Also list the corresponding immediate predecessor task(s) for each task;
- *Step 2* – start with the first station, and number the remaining stations consecutively as step 3 is applied;
- *Step 3* – beginning at the top of the task list, assign the first feasible task to the station under consideration. Once the task is assigned, all reference to it is removed from the predecessor task list. A task is feasible only if it does not have any predecessor or if all the predecessors have been

Table 3

SALBP-I HEURISTICS	
Heuristic algorithms	**Explanation**
Longest task time, *LTT*	From the available task with the largest (longest) time
Most following tasks, *MFT*	From the tasks, choose the task with the largest number of following tasks
Ranked positional weight, *RPW*	From the available tasks, choose the task for each following task is longest
Shortest task time, *STT*	From the available tasks choose the task with the shortest task time
Least number of following tasks, *LNFT*	From the available tasks, choose the task with the least number of subsequent tasks

deleted. It may be assigned only if it does not exceed the cycle time for the station. This condition can be checked by comparing the cumulative time for all jobs so far assigned to that station, including the task under consideration, with the cycle time. If the cumulative time is greater than the cycle time, the task under consideration cannot be assigned to the station. Go to the next feasible task. If not task is feasible, proceed to step 5;

- *Step 4* – delete the task that is assigned from the first column of the task list. If the list is now empty, go to step 6; otherwise, return to step 3;
- *Step 5* – create new station by increasing the station count by one. Return to step 3;
- *Step 6* – all jobs are assigned, and the present station number reflects the number of stations required. The procedure also shows the jobs assignments for each station. The largest cumulative time for the individual station is the cycle time [17].

As it is seen in algorithm, cycle time has an important role for task assignment. Generally, cycle time (5) is determined by dividing the units required per day to productive time available per day which is the maximum time allowed at each workstation [16]. In this study, cycle time is taken as maximum task time in order to decrease the tasks variety in a manufacturing cell.

$$Cycle\ time = \frac{Production\ time\ available\ per\ day}{Unit\ required\ per\ day} \qquad (5)$$

Utilization of line balancing heuristic is calculated by using the equation (6) [16].

$$Utilization = \frac{\Sigma\ task\ time}{(Actual\ number\ of\ workstations) \cdot (Larges\ assigned\ cycle\ time)} \qquad (6)$$

For *SALBP-E*, the incremental utilization heuristic, *IUH*, which simply adds tasks to a workstation in order of task precedence one at a time until utilization is 100 percentage or is observed to fall is used. This procedure is repeated at the next workstation for the remaining tasks. Figure 4 illustrates the steps in the incremental utilization heuristic. An important advantage of this heuristic is that it is capable of solving line-balancing problems regardless of the length of task times relative to the cycle time. Utilization of algorithms is calculated by equation (7) [18].

$$Utilization = \frac{Minimum\ number\ of\ workstations}{Actual\ number\ of\ workstations} \cdot 100 \qquad (7)$$

where:

$$Minimum\ number\ of\ workstations = \frac{Sum\ of\ task\ times \cdot Demand\ per\ hour\ or\ day}{Productive\ time\ per\ hour\ or\ day} = \frac{Sum\ of\ task\ times}{Cycle\ time} \qquad (8)$$

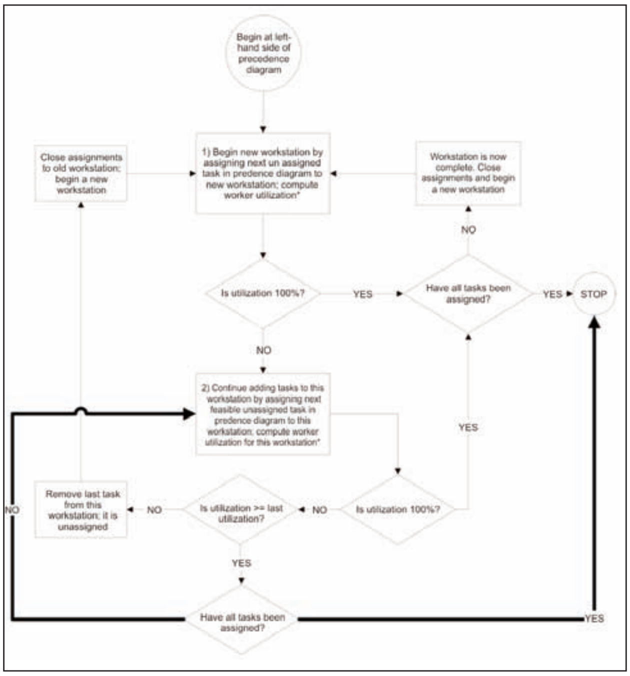

Fig. 4. Steps in the incremental utilization heuristic

EXPERIMENTS AND RESULTS

During the line balancing process of shirt production two different cycle time is used. *SALBP-I* algorithms cycle time is taken as longest tasks time which is "2.33" (task 53) considering aforementioned reasons and the rule of the cycle time cannot be smaller than maximum task time. But for *SALBP-E* algorithm cycle time is calculated as 0.28 minutes by using equation (5) considering the production time available per day (540 minutes) and daily demand (1950 units). Then, utilization results of six different line balancing procedure are calculated by using related algorithms and are given in table 4.

Table 4

UTILIZATION RESULTS OF ALGORITHMS	
Algorithms	**Utilization, %**
Longest task time, *LTT*	84.1
Most following tasks, *MFT*	98.12
Ranked positional weight, *RPW*	98.12
Shortest task time, *STT*	73.59
Least number of following tasks, LNFT	73.59
The incremental utilization heuristic, *IUH*	92.73

Even though *MFT* and *RPW* give the best results, reverse workflow and machine type combination in a manufacturing cell is not considered. Reverse workflow will cause significant quality issues especially in *SALBP-I* algorithms. Because sometimes different type of semi-products can be disordered in a manner of body size and can become dirty in long transformation paths of production. In order to explain reverse workflow better, the manufacturing cell combination

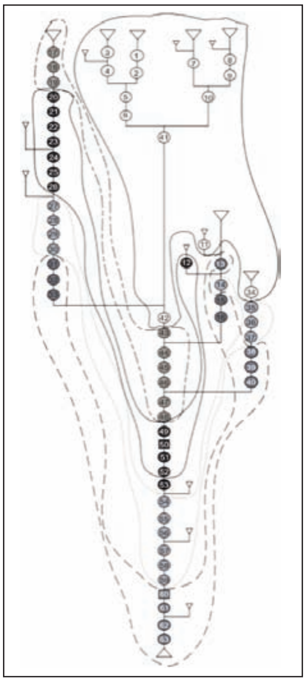

Fig. 5. Manufacturing cells of MFT algorithm

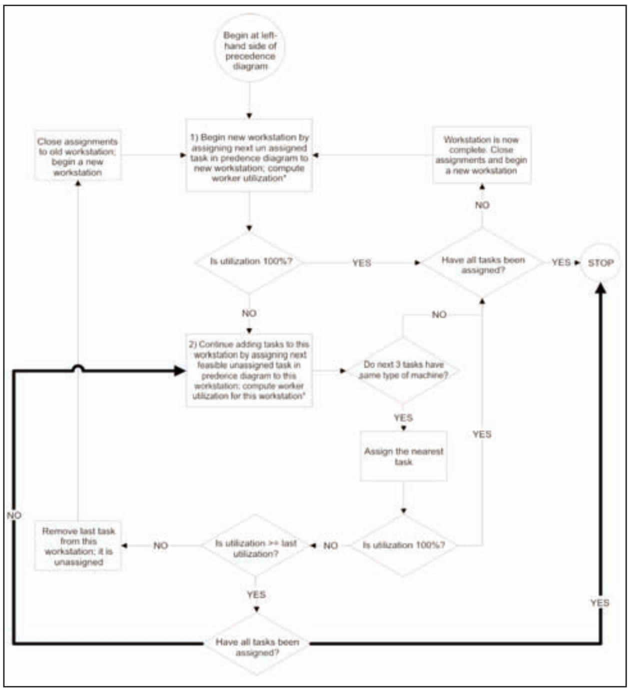

Fig. 6. Steps in NIUH

Table 5

MANUFACTURING CELLS IN *NIUH*				
Cells	**Tasks**	**Minutes**	**Minimum number of workstations,** (3)/cycle time	**Actual number of work-stations**
C_1	1, 3, 5	0.45	1.61	2
C_2	2, 4, 7	0.46	1.64	2
C_3	6	0.4	1.43	2
C_4	8, 9, 10, 12	0.78	2.79	3
C_5	11, 13	0.12	0.43	1
C_6	14, 15	0.27	0.96	1
C_7	16	0.12	0.43	1
C_8	17	0.25	0.89	1
C_9	18, 20	0.23	0.82	1
C_{10}	21	0.22	0.79	1
C_{11}	19, 22, 23	0.23	0.82	1
C_{12}	24, 25, 27	0.24	0.86	1
C_{13}	26,28	0.26	0.93	1
C_{14}	29	0.18	0.64	1
C_{15}	30, 32, 34	0.18	0.64	1
C_{16}	31, 33, 35, 36, 37, 38, 40	1.9	6.79	7
C_{17}	39	0.48	1.71	2
C_{18}	41	0.22	0.79	1
C_{19}	42, 50	0.12	0.43	1
C_{20}	43	0.48	1.71	2
C_{21}	44, 46, 47	0.18	0.64	1
C_{22}	45	0.17	0.61	1
C_{23}	48, 51, 53, 54, 55	3.05	10.89	11
C_{24}	49,52	0.51	1.82	2
C_{25}	56,57	0.24	0.86	1
C_{26}	58	0,56	2.00	2
C_{27}	59,62	0.26	0.93	1
C_{28}	60,63	0.41	1.46	2
C_{29}	61	0.83	2.96	3
Total			49.29	57

of *MFT* is given in figure 5. As seen in figure each manufacturing cell contains lots of tasks, machine and operation types and this situation causes reverse workflow and flow conflicts.

As *IUH* works regardless to cycle time, gives better and smaller manufacturing cell combination. However this algorithm (likewise others) cannot provide solution for the problem of performance differences in multi-skilled and novice or mono-skilled operators who affect the quality directly. Thus in order to cope with this problem, new algorithm gathers the same type of machines in manufacturing cells is developed by modifying *IUH* algorithm. As it is seen in figure 6, new incremental utilization heuristic, *NIUH*, checks for up to three tasks whether they use the same type of machine or not. If next tasks have same type of machine, algorithm assigns the nearest task to recent workstation (manufacturing cell), if not it creates a new workstation.

After applying *NIUH* algorithm, 86.47% utilization is obtained by using equation (8). The distribution of tasks to manufacturing cells and calculations for number of minimum workstations/cells are given in table 5.

CONCLUSIONS

Competitive environment of today's working conditions requires application of practical and flexible solutions and realization of high production efficiency as much as possible. The path of high production efficiency in apparel industry passes through engineering applications such as line balancing methods. However in apparel industry as line balancing task is done far from scientific methods by uneducated supervisors, the line balance performance cannot be guaranteed from one manager to another with different assignment preference and/or work experience Thus apparel industry requires more practical, user-friendly and easy to apply methods in order to cope with this problem.

In this study, six different heuristic algorithms are applied to balance the assembly lines at a clothing company and a new algorithm (NIUH) is purposed considering quality issues by grouping same kind of machines and adjusting fewer circulating workflow. In order to accomplish these objectives; firstly framework of the study is developed such engineering studies are never done before. Following the time study process and statistical validation of stop-watch times, determination of delay allowances are performed by using work sampling method. As s result of standard times' determination SALBP-I and SALBP-E algorithms are applied in shirt production process. By considering manager demand and quality issues IUH algorithm is modified. It's noted that NIUH algorithm gives slightly less (86,47%) utilization results, can create solution for recent problem. It should be noted that the proposed line balancing approach can be used in all types of apparel production easily. However, implementing this approach to another type of apparel production would require doing all time studies and work sampling again.

It is hoped that this study illustrating the use of line balancing in detail for all clothing companies will provide guidance for supervisors and it is recommended to the future researchers will be working on this issue to emphasize an approach where quality factor is included in all calculations.

BIBLIOGRAPHY

[1] Keytack, H. Oh. *Expert line balancing system (ELBS).* In: Computers and Industrial Engineering, 1997, vol. 33, pp. 303–306

[2] Wong, W. K., Mok, P. Y., Leung, S. Y. S. *Developing a genetic optimization approach to balance an apparel assembly line.* In: The International Journal of Advanced Manufacturing Technology, 2006, vol. 28, pp. 387–394

[3] James, C. C., Chun-Chieh, C., Ling-Huey, S. et al. *Assembly line balancing in garment industry*. In: Expert Systems with Applications, 2012, vol. 39, pp. 10 073–10 081

[4] Kriengkorakot, N., Pianthong, N. *The assembly line balancing problem: review articles*. In: KKU Enginerring Journal, 2007, vol. 34, pp. 113–140

[5] Miltenburg, J. *U-shaped production lines: a review of theory and practice.* In: International Journal of Production Economics, 2001, vol. 70, pp. 201–214

[6] Salveson, M. E. *The assembly line balancing problem.* In: The Journal of Industrial Engineering, 1955, vol. 6, pp. 18–25

[7] Ghosh, S., Gagnon, R. J. *A comprehensive literature review and analysis of the design, balancing and scheduling of assembly systems*. In: International Journal of Production Research,1989, vol. 27, pp. 637–670

[8] Erel, E., Sarin, S. C. *A survey of the assembly line balancing procedures*. In: Production Planning & Control, 1998, vol. 9, pp. 414–434

[9] Kriengkorakot, N., Pianthong, N. *The assembly line balancing problem: review articles.* In: KKU Enginerring Journal, 2007, vol. 34, pp. 113–140

[10] Scholl, A., Becker, C. *State-of-the-art exact and heuristic solution procedures for simple assembly line balancing*. In: European Journal of Operational Research, 2006, vol. 168, pp. 666–693

[11] Zeng, X., Wong, W. - K., Leung, Y. - S. *An opperator allocation optimization model for balancing control of the hybrid assembly lines using Pareto utiliy discrete differential evolution algorithm*. In: Computers & Operations Research, 2012, vol. 39, pp. 1 145–1 159

[12] Boysen, N., Fliender, M., Scholl, A. *Assembly line balancing: Which model to use when?* In: International Journal of Production Economics, 2008, vol. 111, pp. 509–528

[13] Freivalds, A. *Niebel's Methods, Standards, and Work Design.* 12th ed., Singapore: Mc Graw Hill, 2009, pp. 425, 453, 455

[14] Barnes, R. M. Motion and time study: Design and measurement of work. 6th ed., New York, John Wiley & Sons Inc., 1968, pp. 359, 398

[15] Barnes, R. M. *Work sampling*. 2nd ed., London, John Wiley & Sons Inc., 1956, pp. 29, 53

[16] Heizer, J., Render, B. *Operations management.* Pearson International Edition. Pearson Education 9th ed., USA, 2008, pp. 366–369

[17] Dileep, R. S. Production *planning and industrial scheduling.* 2nd ed., CRC Press. USA, pp. 296–313

[18] Gaither, N., Fraizer. G. *Operations management.* 9th ed., South-Western, USA, pp. 195–204

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DOCUMENTARE

Materii prime

FIBRE CU PROPRIETĂȚI DE SCHIMBARE A CULORII

Universitatea Harvard, în colaborare cu *Universitatea Exeter*, din Marea Britanie, a dezvoltat o nouă fibră, care îşi schimbă culoarea la întindere. Sursa de inspirație pentru echipele de cercetători a reprezentat-o albastrul irizant al unui fruct tropical.

"Noua fibră se bazează pe o structură naturală, a cărei performanță a fost îmbunătățită pe baza unei tehnologii inteligente" – a declarat Mathias Kolle, postdoctorand la Şcoala de Inginerie şi Ştiințe Aplicate Harvard. Efectul de schimbare a culorii s-a realizat prin crearea unei versiuni artificiale, introducând un material elastic în structura fibrei. Noua structură face ca, în momentul întinderii, aceasta să treacă printr-o gamă variată de culori. Fibra multistratificată ar putea fi folosită la obținerea unor materiale inteligente, care reacționează vizibil la căldură sau presiune.

Lumina şi culoarea

Din cele mai vechi timpuri, performanța multor organisme s-a bazat pe modul în care acestea interacționează cu lumina şi culoarea, transformându-le în adevărate modele pentru dezvoltarea de noi materiale. În cazul semințelor şi al fructelor, se presupune că strălucirea culorii a evoluat prin împrăştierea semințelor, în special de către păsări. Fructul tropical *Margaritaria Nobilis*, provenit din America de Sud, este un exemplu interesant al acestei adaptări. Fructul, de culoare albastră, foarte strălucitoare, are un conținut nutritiv scăzut, dar imită un alt fruct cu o valoare nutritivă mult mai mare. Păsările sunt păcălite de această asemănare şi mănâncă fructele, ale căror semințe le eliberează, fiind răspândite pe o arie geografică vastă.

"*Din punct de vedere ştiințific, caracteristicile acestui fruct sunt foarte interesante... Arhitectura stratului de suprafață, care poate fi transformată cu ajutorul luminii şi care a evoluat pentru a îndeplini o anumită funcție biologică, a inspirat un model tehnologic interesant şi extrem de util*" – a declarat Peter Vukusic, cercetător principal şi profesor asociat la Departamentul de Fotonică Naturală din cadrul Universității Exeter.

Profesorul Vukusic împreună cu colaboratorii săi de la Harvard au studiat originea structurală a culorilor vibrante ale semințelor. Ei au descoperit faptul că celulele din straturile superioare ale cojilor de semințe prezintă un model curbat, repetitiv, care creează culori prin interferența undelor de lumină. Acesta este un mecanism similar celui responsabil cu culorile vii ale bulelor de săpun. Studiul efectuat a reliefat faptul că mai multe straturi de celule ale cojilor de semințe au o arhitectură cilindrică cu o mare regularitate la scară nanometrică.

Echipa de cercetători a reprodus elementele de bază ale structurii fructelor, pentru a crea fibre fotonice flexibile, elastice, care-şi schimbă culoarea printr-un mecanism de rulare inovativ, perfecționat în laboratoarele Universității Harvard.

Elemente-cheie

În procesul de creare a noii structuri artificiale, complexitatea fructului s-a redus la elementele de bază ale acestuia. S-au folosit fibre foarte subțiri şi, în jurul lor, s-a înfăşurat un strat dublu de polimer. Astfel, s-au obținut contrastul indicelui de refracție, numărul corect de straturi şi secțiunea transversală cilindrică curbată, necesare producerii unor culori vii.

Tehnologia utilizată permite obținerea unei sortiment variat de materiale, în special a celor elastice, cu o gamă foarte diversă de culori, depăşind fibrele tratate termic. Proprietățile mecanice superioare ale acestor fibre, combinate cu strălucirea şi capacitatea lor de prelucrare, le conferă un grad ridicat de adaptabilitate. De exemplu, pentru a obține forme complexe, fibrele pot fi înfăşurate. Deoarece fibrele îşi schimbă culoarea la întindere, tehnologia ar putea fi extinsă în domeniul textilelor inteligente pentru sport, care îşi schimbă culoarea în zonele de tensiune musculară sau atunci când detectează un obiect aflat pe punctul de a se deforma din cauza căldurii.

Echipa de cercetare susține că procesul ar putea fi dezvoltat şi extins pentru producția la scară industrială.

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A study about garment collection preparation steps and quality control methods

OZLEM KURTOGLU NECEF ZIYNET ONDOGAN

REZUMAT – ABSTRACT

Studiu privind etapele creării unei colecții vestimentare şi metode de control al calității

În acest articol au fost analizate principalele elemente – culoarea, țesătura şi modelul – necesare în pregătirea unei colecții vestimentare, în vederea lansării sub o anumită marcă comercială. Au fost selectate cinci modele de tricouri şi au fost analizate toate detaliile privitoare la etapele de pregătire a colecției, aspectul estetic şi metodele de control tehnic al calității – de la etapa de concepție până la obiectul vestimentar final, într-o firmă de confecții de dimensiuni medii. Rezultatele obținute au arătat că, pentru a pregăti o colecție reuşită, trebuie stabilite mai întâi etapele de control pentru fiecare stil, iar controalele de calitate, tehnic şi estetic, trebuie făcute de persoane calificate. În literatura de specialitate nu există suficiente studii privind etapele de pregătire a unei colecții vestimentare. Rezultatele acestui studiu vor fi utile în industria de confecții, pentru a crea colecții de cea mai bună calitate.

Cuvinte-cheie: industria de confecții, pregătirea colecției, marcă comercială, controlul calității, metode

A study about garment collection preparation steps and quality control methods

In this paper, the mainly defined factors such as color, fabric, model of a commercial collection which was prepared for a commercial brand were examined. Five t-shirt designs existing in the collection were chosen and all the collection preparation step details, aesthetic and technical quality control methods from design to final garment were observed in a medium-size apparel company. The achieved results showed that for preparing a successful collection, first of all, the quality control steps must be determined for each style, and then both aesthetic and technical quality controls should be made by qualified people. There has not been enough study about garment collection preparation steps in the literature. The results of the study will be helpful to apparel manufacture industry for preparing better and quality collections.

Key-words: apparel manufacture, collection preparation, commercial brand, quality control, methods

A seasonal creation prepared by companies, taking into consideration the customers' needs, taste, fashion and usage are usually called a "collection". While preparing a collection, a series of research and development studies are carried out to consider the economic and social structure of target markets [1].

Three methods have been used for preparing a collection:

- Commercial collection – it is prepared within the framework of a brand and the essential purpose is to make money for the owner/distributor/licensor of the brand. They can be repeated through mass production and prepared in regular periods [2];
- Fashion collection – it is a selection of outfits and individual garments that fashion designers put together every season and that reflect predictions of upcoming trends, including color, cut, line and proportion [3];
- Collections created upon customers' requests – it is prepared in accordance with a person or a group of people's requests and orders [2].

Although the preparation steps of a collection vary according to the models, they are usually listed as follows:

– theme and target market research;
– color, fabric, graphic, accessories and auxiliary materials research;
– model creation and drawing the technical sketches;
– pattern and prototype samples preparation;
– revision of the collection models;
– collection production and quality control steps;
– quotation of collection samples [4].

As it can be seen from the above list, preparation of a collection is a process that calls for intensive effort, time and money [1]. Because of that while preparing a collection, the aesthetic and technical quality control methods must be performed in a systematic way. Quality has been suggested to be one of the most important factors in an order winning strategy for enterprises [5]. For achieving the goals and targets, quality control methods were developed. It is possible to design, develop and produce quality goods by using quality control methods [6]. Quality control methods which are used in both collection preparation steps and mass production can be divided four types:

- Test methods;
- Inspection: 100% control and sampling control;
- Process control;

- Statistical quality control [7]: input quality control, in-process quality control and output quality control.

In this study, a commercial collection preparation steps and quality control methods were examined in a medium-size apparel company.

MATERIALS AND METHODS

Materials used

The commercial brand profile. In this study, an Italian brand, founded in 2003, was examined. The models of the commercial collection were designed by this Italian brand and the manufacturing was accomplished by the company introduced below.

The company profile. The company was founded in 1991 in Izmir, Turkey. It works as a supplier for brands in collection preparation steps and mass production.

Models. Five different models and their colorways, which belong to 2010 spring summer women collection of the brand, were examined. The models were shown in figure 1. Tss001 has fuchsia, white and blue, Tss002 has white, Tls003 has white, black and green, Tls004 has brown and purple colorways.

Fabrics, accessories and auxiliary materials. The same fabric type was used for all the models, below given the technical features:

Construction: 40/1 single jersey, 92% cotton – 8% elastane, 150–160 g/m^2.

The accessories and auxiliary materials were used in collection: 100% polyester no. 120 and 95% polyester 5% lurex no. 40 sewing threads, silver and gold elastic band (8 cm width), silver velvet tape (1 cm width), black strass (2 mm diameter), size, brand, care and cartoon label, plastic bag, 30*40*30 parcels in white color. Foil print, water-based print, flock print and strass pressing were used for graphics. In order to use a common language in supply chain management of the collection, all the graphics, accessories and auxiliary materials were given code.

Methods used

Theme and target market research. The theme of the collection was "love". While choosing the theme, designers were inspired by Worth Global Style Network, Promostyl web sites and fairs such as Premier Vision. At this point, some definitions required which were given as follows:

– WGSN is the leading online trend-analysis and research service providing creative and business intelligence for the apparel, style, design and retail [8];
– Promostyl is lead to anticipate the currents in design, fashion and marketing to give the clients a strategic edge in the market place [9];
– Premiere Vision offers a large selection of fabrics as well as trimming collections of the highest quality and creativity. It is the ultimate guide to the main season trends [10].

The target market of the collection determined as women aged between 16–25 years.

Color, fabric, graphic, accessories and auxiliary materials research. Before determining the colors and materials for the collection, designers made trend analysis by reading fashion magazines, going to shopping malls, observing street fashion and also inspiring from web sites and fairs.

Clothing is a form of non-verbal communication [11] so the colors, graphics, designs etc. of the models should be impressed other people. The fabric, colors, accessories and auxiliary materials which were popular in the season specified and selected. While choosing, model designers paid attention to determine the materials which would not cause problems and produced easily at a suitable price and have affect the sales positively for mass production.

To be able to use the same language between suppliers and customers, all the colors were chosen from TP Pantone. The color trials were prepared by using these codes by laboratory. The colors used in the collection were shown in figure 2.

Model creation and drawing the technical sketches. Model designers prepared the silhouette drawings by using computer aided design programs. After deciding the models that would be in the collection, technical drawings and measurement charts were prepared by the pattern department.

Technical drawings identify the garments correctly within the framework of summarizing the model details and indicating the garment cutting with structure lines, seam decorative and technical details [12]. Therefore, all the details were shown on the technical drawings. The model designers should transfer their thoughts,

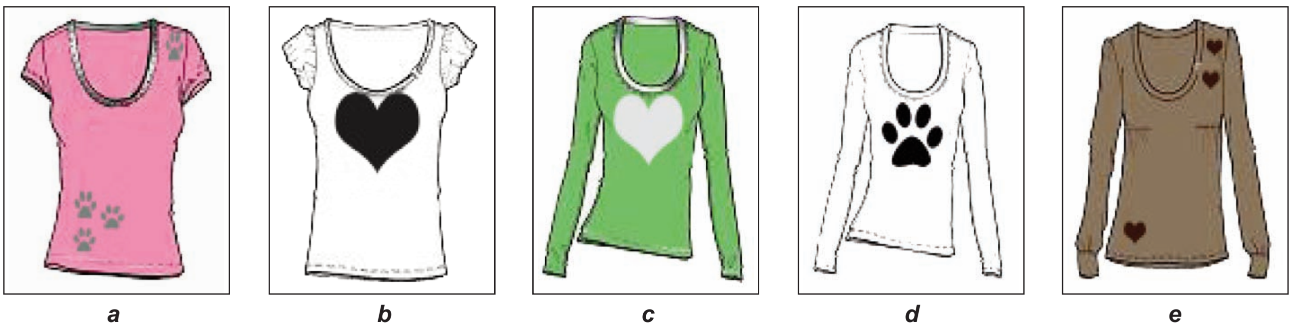

Fig. 1. Front view drawings of collection models: ***a*** – Tss001; ***b*** – Tss002; ***c*** – Tss003; ***d*** – Tss004; ***e*** – Tss005

Blue Fuchsia Green Brown Purple White Black

Fig. 2. The colors used in the collection

inspirations and details of the models to the sample and pattern department chefs in order to prevent any misunderstanding and prepare a correct collection.

Pattern and prototype samples preparation. The base size of the collection was “S”. All the patterns were prepared by using computer aided pattern preparation system and prototype samples were prepared by sample department. Some minor modifications, which did not change the appearance of the models, were made for facilitating sewing process. Prototype sample preparation’s aim was to see the stance on the human body. All the graphics were prepared simultaneously with prototype samples.

Revision of the collection models. After sending the prototype samples to the customer, following critics were received:

– It was realized that for style Tss001 and Tls003, sleeve and bottom cover stitches were not sewed with polyester-lurex sewing thread. But in the technical drawings, these stitches were shown with polyester-lurex sewing thread. Also, for these styles, while applying the elastic piping to the collar, some gatherings were occurred;
– Style Tss002, Tls004 and Tls005 prototype samples were approved by changing some measurements;
– All the graphics and their placements were approved as prototype samples.

Collection production and quality control steps. Regarding the brands requirements, 30 pieces of each model were prepared for the collection. The company ordered the fabric, accessories and auxiliary materials by considering these pieces with wastes.

Input quality control – is a preventive technique to decrease costs of products and tardiness in the system when every receiving lot is controlled. In this point, companies must have decisions for accepting or rejecting receiving lots according to randomly chosen units [13]. The collection fabrics were taken into the warehouse by using single acceptance sampling plans method. This is a method of taking a decision to accept or reject the party by examining the units taken from the party [14]. The weight of the fabric was controlled by using fabric weight balanced. The other visual quality controls except color were skipped. Accessories and auxiliary materials were accepted to the warehouse by using single acceptance sampling plan method. All the technical and aesthetic quality controls such as color, width, shape, size and font character (for labels) were checked. In addition, the velvet ribbon were sewed to the white fabric and washed at 30°C in home type washing machine to control the the color fastness to washing.

In-process quality control – means the control of garment parts before they are assembled into a complete product. This method reduces the major problems and decreases the labor costs of the repairs. The fabric, accessories and auxiliary materials were transferred to the sample department after acceptation. For each model, production files which included all the models definitions, technical drawings, fabric types, graphics, measurement charts, sewing and packing details were prepared. The first stage was cutting the fabrics into the necessary pattern shapes by straight knife. When cutting is completed, the front piece of the model Tss002 and Tls004 were sent to the supplier for printing and strass pressing. Production process chart was prepared and all the sewing steps for each model were identified. Attaching sleeve, puckering stitches and attaching neck piping operations were selected as critical processes and these operations were 100% controlled. Regarding the in-process quality controls, the quality control staff detected and prevented some problems such as measurement, stains and printing defects. However, the most significant problem for model Tss001 and Tls003 was the bottom cover stitches that had not been sewed with polyester-lurex sewing thread and changed into flatlock stitch.

Output quality control – is the final quality control. When aiming at zero defects, reliable results were obtained by using 100% sampling quality control method. On the other hand, 100% sampling method has a high cost [15]. All the finished collection samples were controlled by using 100% sampling quality control method. The defects such as sewing, color, printing, measurement were determined. The first quality garments were pressed, packed and delivered.

Quotation of collection samples. The costs of each model were calculated by considering fabric, labor, accessories and auxiliary materials expanse.

RESULTS AND DISCUSSIONS

As defined in the methodology, while producing the collection some minor and major quality problems were occurred that given below:

Collection production and quality control steps

Input quality control

All the fabrics were accepted to the warehouse without making 100% visual quality control because of this, many defects such as stains and oil spots were

determined on the fabrics. Fabrics are the most significant input and affect the quality and cost directly so that these defects caused waste of time and costs. Especially, while preparing a collection, apparel factories must make 100% visual quality control to the fabrics before accepting into the company. If the visual quality controls had occurred systematically, costs and the number of second quality garments would have been reduced.
Also all the technical tests, such as color fastness to washing, spirality after washing and dimensional change in washing were skipped. These testes are very important especially for the final customer. During the customer usage, when the garment has been washed and shrunk, the prestige of the company would have been affected negatively.

In-process quality control

In this step, the most significant problem was the sleeve and bottom cover stitches for models Tss001 and Tls003. In prototype sample preparation step, polyester-lurex sewing thread was not used and this was criticized by the customer. During the production, the sewing operators tried to use polyester-lurex sewing thread, but the lurex gathered on the needle eye and the thread was broken. 4 different sewing threads of different brands were tried to solve this problem, but could not be succeeded. When polyester-lurex sewing thread was used for flatlock stitch, there was not any problem because it passed through the looper. Therefore the chief of sample department explained this problem to the designers and cover stitch changed into flatlock stitch. During this period, too much time was lost. If this problem had been realized while preparing prototype samples, the production of the collection would not be consume too much time. While in-process controls, seam puckering was obtained and prevented.

Output quality control

This collection was presented in fairs and franchisee meetings, so that all the garments must be faultless. They were controlled by using 100% sampling quality control method.
Fabric defects had the highest rate because of skipping 100% visual quality control. Measurement defects and seam puckering followed as second.

Quotation of collection samples

The cost of a garment can vary significantly depending on manufacturers, suppliers [16] and amount. Because the amount of material to be used for the collection is small, its costs are more expensive than mass production.
The costs of the collection samples were calculated, however, for the mass production, these prices must be revised according to amount. The costs of collection samples were given in table 1.

Table 1

THE COSTS OF COLLECTION SAMPLES

Model name	Tss 001	Tss 002	Tls 003	Tls 004	Tls 005
Unit prices	10.58 €	11.93 €	14.73 €	10.80 €	15.30 €

CONCLUSIONS

Nowadays, besides great fashion designers, apparel manufacturer factories in developed countries are preparing their own collections for marketing. Previously, subcontracting production look beneficial, but apparel manufacturer factories realized that it will be slowly damage the industry in a long period. The apparel industry will recognize the importance of collection preparing and search the most effective ways to use competitive factors such as speed, quality, costs.
In this study, the mainly defined factors such as color, fabric, model of a commercial collection which is prepared within a framework of a brand were examined. Five T-shirt designs existing in the collection were chosen and all the preparation steps, aesthetic and technical quality control methods from design to final garment were observed in a medium-size apparel company. Regarding the collection preparation steps, the company experienced some minor and major quality problems which caused waste of time and cost. However, the shipment of collection was done on time. Quality control operations are concerns of all departments in the factory. All of the staff was responsible for the quality in each steps of apparel manufacture.
Consequently, the importance of effective quality control activities occurred in every step. For preparing a successful collection, first of all, the quality control steps must be determined for each style, and then both aesthetic and technical quality controls should be made by qualified people. The correct collection will be helpful to the apparel manufacture industry for increasing the orders.
There has not been enough study about garment collection preparation steps in the literature. The results of the paper will be helpful to apparel manufacture industry for preparing better and quality collections.

BIBLIOGRAPHY

[1] Ondogan, Z. *A detailed study calculating the cost of preparing a collection*. In: Journal of Fashion Marketing and Management, 2001, vol. 5 , issue 2, pp. 145–153

[2] Ondogan, Z. *Konfeksiyon sanayinde koleksiyon hazırlamanin onemi ve asamaları.* In: Tekstil ve Konfeksiyon, 1994, vol. 4, issue 3, pp. 244–252

[3] Kurtoglu, O. *Analyzing the suitable production and quality control systems for the stages of collection preparation.* M. Sc. Thesis, Ege University, Textile Engineering Department, 2009

[4] Wang, H. C. *Economic off-line quality control strategy with two types of inspection errors*. In: European Journal of Operational Research, 2007, vol. 179, pp. 132–147

[5] Perincek, D. S., Duran, D., Kirtay, E. *Dunyada Kalite Kontrol ve Toplam Kalite Kontrol Uygulamaları*. Bolum I. In: Tekstil ve Konfeksiyon, 2008, vol. 18, issue 3, pp. 83–88

[6] Kirtay, E. *Kalite Kontrol*. Bornova, Izmir, 1984

[7] Johnson, K. K. P., Schofield, N. A., Yurchisin, J. *Appearance and dress as a source of information: a qualitative approach to data collection.* In: Clothing and Textiles Research Journal, 2002, vol. 20, issue 3, pp. 125–137

[8] Szkutnicka, B. *Technical Drawing for Fashion*. Central Saint Martins. College of Art & Design – The University of the Arts London, 2011

[9] Aydemir, E., Olgun, O. M. *An application of single and double acceptance sampling plans for a manufacturing system*. In: Journal of Engineering Science and Design, 2010, vol. 1, issue 2, pp. 65–71

[10] Atılgan, T. *Acceptable quality levels in the textile sector and their effect on the level of competition*. In: Fibres & Textiles in Eastern Europe, 2007, vol. 15, issue 1, pp. 16–23

[11] Juran, J. M., Gryna, M. F. *Juran's Quality Control Handbook*, 1988, chapter 18.25

[12] Gam, J. H., Cao, H., Farr, C., Heine, L. *C2CAD: a sustainable apparel design and production model.* In: International Journal of Clothing Science and Technology, 2009, vol. 21, issue 4, pp. 166–178

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DOCUMENTARE

Noi tehnologii

TEHNOLOGII DE TRATARE A TEXTILELOR CU ENZIME ŞI LASER

Universitatea De Montfort în colaborare cu ***Universitatea Loughborough***, ambele din Marea Britanie, au derulat un proiect de cercetare, în cadrul căruia se investighează diverse tehnologii de tratare a materialelor textile cu ajutorul enzimelor şi a laserului sau cu o combinaţie a acestora. Scopul cercetării îl constituie explorarea aplicaţiilor şi a potenţialului laserilor şi enzimelor în industria textilă, ca instrumente creative de design.

În cadrul proiectului va fi dezvoltată o tehnologie de tratare cu enzime pentru a crea efecte de culoare şi de proiectare tridimensională. Tehnicile utilizate şi efectele obţinute vor fi perfecţionate cu ajutorul laserului şi al tratamentelor pre- şi postenzimatice, prin concentrarea asupra unor fibre specifice.

În tehnicile tradiţionale de vopsire, albire, imprimare şi finisare, folosirea substanţelor chimice este o practică obişnuită. Însă, în majoritatea proceselor sunt folosite cantităţi mari de apă şi energie şi rezultă cantităţi mari de efluenţi.

Cercetarea are potenţialul de a genera efecte de amploare asupra sustenabilităţii sectorului de textile şi confecţii. Utilizarea tehnologiilor cu enzime şi laser oferă perspectiva reducerii atât a cantităţii de substanţe chimice şi de apă, cât şi a energiei consumate şi a efluenţilor rezultaţi.

Proiectul a fost finanţat cu peste 200 000 £ din partea Consiliului Cercetării Artelor şi Ştiinţelor Umaniste, iar Speedo, Camira Fabrics şi Teresa Green Design sprijină proiectul prin aprovizionarea cu materiale textile, conceperea prototipurilor şi evaluarea conceptului. Cercetarea va fi finalizată în anul 2015.

__Smart__textiles and nanotechnology, martie 2013, p. 9

The correspondence between workforce skills and company needs

DOINA I. POPESCU

REZUMAT – ABSTRACT

Corelația dintre aptitudinile forței de muncă şi nevoile firmei

Articolul prezintă o analiză a aspectelor legate de nivelul de calificare a personalului, realizată printr-un studiu ce urmăreşte evidențierea modalităților de asigurare a unui personal calificat în cadrul firmelor din industria de confecții îmbrăcăminte din România. De asemenea, sunt descrise inițiativele la nivel european privind asigurarea unui raport optim între aptitudinile forței de muncă şi nevoile firmelor aparținătoare industriei de confecții îmbrăcăminte, precum şi particularitățile sistemului educațional din România, pentru acest sector de activitate. Lucrarea subliniază necesitatea creşterii interdependenței dintre aptitudinile forței de muncă şi nevoile firmelor, în noul context socio-economic.

Cuvinte-cheie: nivel de calificare, competențe, abilități, motivație, industria de confecții îmbrăcăminte, sistem de învățământ

The correspondence between workforce skills and company needs

The paper presents an analysis of the issues related to the level of personnel qualification, analysis that has been carried out through a study that aims to highlight the means to provide with qualified personnel the companies in the clothing industry in Romania. The paper also presents the European initiatives towards correlating the workforce skills with the needs of the companies in the clothing industry, and the features of the educational system in Romania for this branch. The paper highlights the need to increase the correlation between workforce skills and the needs of the companies of this industry, in the new social and economic context.

Key-words: level of qualification, skills, abilities, motivation, clothing industry, educational system

Workforce mobility is a real fact of our times, among both managers and that of workers. Pressures caused by the global economic crisis and the extensive changes taking place at branch level, it obliges large, but also small companies to downsize with direct effect on employment and the qualifications required.

Flexibility can affect humans, but stability can further affect them by reducing the economic activity. According to French specialists Robert Boyer and Michel Freyssenet, job security was associated with higher productivity (but not with product innovations) in industrialized countries in the 70s, but starting with the 80s this link disappeared. In this context, many countries have weakened regulations with the purpose to ensure a greater flexibility, but also to ensure a better match between workforce skills and the needs of companies [1].

This is also the case for Romania that adopted by Law 40/2011 a new Labor Code to ensure a greater flexibility of the labor market and to improve the quality of employment, through the need of development, by the employer, of the criteria for professional activity evaluation. The evaluation criteria are included in the personnel evaluation form, which is an appendix of the job description. The evaluation criteria relate to professional competence, professional activity, the characterization of activities at work and specific skills. Each criteria is divided into sub-criteria, to each being assigned a certain score. The employment contract ends (is signed) after prior verification of the professional skills of the person seeking employment. Many new companies that are in a rapid growth, base their human resources policy on providing interesting, challenging, and not safe jobs.

Mobility is both a cause and an effect of mismatch between people and jobs. In many parts of the world, shortages and surplus of labor coexist. Workforce training has a specific professional structure and job vacancies have another.

According to OECD studies, Europeans are worried about the lack of skilled workers. There are embarrassing indications of the fact that the misfit between people and jobs is the result of a failure in the field to better train and retrain employees.

Rosabeth Moss Kanter, in the book “On the Frontiers of Management”, considers that the issue of mismatch requires new policies on human resources, which would put the lifelong learning in center. Communities and nations best protect their economies by investing in people. But if companies do not offer positions to increase the value of learning, discrepancies will continue.

New policies must reflect the new forms of security, at the same time including the increasingly present realities of flexibility, mobility and change. If security is not automatically brought by being hired, then it must be made by the ability to be employed. The security of the ability to be employed lies in the knowledge that it takes more and more power to meet the challenges of tomorrow, in the fact that today's work includes learning and experience in order to enhance future opportunities – either as an employee in a current company, or as an employee at another company or business. Kanter also believes that as industry standards appear, standards should be created to help people to be willing to learn, to be able to adapt to different situations, and that nations that have the largest global trade share, instead of relying on discussions within GATT (General Agreement on Trade and Tariffs) to manage their economies, should begin discussions to get to a General Agreement on People Policies – GAPP [2].

METHODOLOGY

The study begins by presenting the need to adopt a new work agenda for human resources, imposed by the new socio-economic context. European initiatives have been reviewed to ensure correspondence between the workforce skills and the needs of companies within an innovative industrial sector, namely the clothing industry. Given that the clothing industry in Romania is a branch with an old tradition, ranking third place in Romania's exports, and fourth place in the EU clothing exports and concentrating the largest number of SMEs in the industry we felt it was a representative industry to identify the level of assurance of qualified personnel (directly productive workers) and the correspondence between workforce skills and needs of these companies. To this end, a study was conducted using a questionnaire investigation based on a number of 183 companies from the industry. Also the impact of motivation on increasing the job attractiveness specific to the clothing sector was analyzed. Future directions were developed to increase the correlation between workforce skills and the needs of Romanian clothing companies.

European initiatives towards ensuring correspondence between workforce skills and the needs of companies from an innovative industrial sector

Enormous social and economic changes in Europe in recent years have had a significant impact on the business environment for companies, especially SMEs. As a result, more attention was paid to creating more and better jobs in the EU, in accordance with the EU 2020 Strategy, mainly through the three flagship initiative "An industrial policy in the globalization era", "A new agenda for jobs" and "New skills for new jobs".
Given that the light industry centers the most significant number of SMEs in the EU, namely a significant number of employees, it caused a concern across European organizations regarding the providing of this industry with skilled workforce, which materialized in a first sector initiative.
So, on 6th December 2011, in Brussels, was launched the first European Sector Council on Education Training & Employment in the Textile Clothing and Leather Sectors. This is the first sector initiative fully in line with the Europe 2020 Strategy, to bridge the skills gaps and to create more and better jobs in the Textile Clothing and Leather industries throughout the EU. Jean-François Lebrun, Head of Office of Employment and Social Affairs from the European Commission considers that this initiative is a solution to one of the most pressing needs of the labor market, namely, that of qualified staff in an innovative industrial sector.
European Council on Education Training & Employment for Textile Clothing Leather (EU TCL Skills Council) is an initiative of the European social partners: TCL (The European Federation of Textiles Clothing Leather and Footwear), EURATEX (The European Apparel and Textile Confederation), and COTANCE (The European Confederation of Leather and Tanning), with the financial support of the European Commission – Directorate General for Employment and Social Affairs. The network created by the social partners covers over 27 countries and involves over 400 entities.
The EU TCL Skills Council aims at improving the quality of the European labor force of the light industry, and, also aims to assist enterprises to be better prepared in meeting changing competitive demand.
Designed to support the networking and the activities of the EU TCL Skills Council, a web portal was also launched to allow exchanges between key players and to provide with a regularly updated collection of pedagogical materials – courses, lesson plans, activities and audiovisual resources that cover both information on the Textile Clothing and Leather Industries and strategies for adapting to/ and improving the current Labor Market. Visitors can also find web tools (as a TCL wiki tool, web based training seminars, conferences, web interviews, job searches and offers, news and events, forums of discussion, EU directories etc.) [3].
The clothing industry is one of the innovative industries. Both technological innovation and economic innovation are essential to the clothing industry, especially since the apparel market has undergone great changes in the recent years.
For Romania, the EU is the main marketplace for the apparel products. From 2009 until 2011, about 90% of Romania's total exports were to the EU countries, so any changes on this market were also felt in the garment trade and in the domestic clothing industry.
The clothing industry in Romania is an industry well represented in all the development regions of the country, concentrating the largest number of SMEs in Romania.

The Romanian educational system for the clothing industry

Although, in Romania, the educational system for the clothing industry is very well organized, in the companies belonging to this industry there is a real need for technical personnel, particularly directly productive skilled workers.

Thus, in Romania there are five universities with specialized faculties in the areas of textiles, leather, industrial management, fashion design (in Iasi – North-East region, Sibiu – Central region, Arad – Western Region, Oradea – North-West and Bucharest – Bucharest – Ilfov region), R & D institutes (in Bucharest – Ilfov region and in North-East region), colleges and vocational schools that provide technical training in textiles, fashion design, training centers for craftsmen and technicians (all regions). Equipping most of these schools is very good, both at university and at pre-university level.

Additionally, one of the most cherished and traditional Romanian schools network is the UCECOM schools (National Association of Co-operative Institutions) which prepares craftsmen in fashion since 1951, at pre-university level and at university level since 1992. During these they provide training at university level through ARTIFEX University of Bucharest (Bucharest – Ilfov region) in economics, and at undergraduate level through Spiru Haret Foundation, with 12 high schools in all developing regions of the country, namely in Bucharest (Bucharest – Ilfov region), in Arad and Timisoara (Western region), in Baia Mare and Cluj (North-West region), in Braila and Constanta (South-East region), in Breaza and Ploiesti (South region), in Odorheiul Secuiesc (Central Region), in Craiova (South-West region) and in Iasi (North-East region) [4]. Starting with 2010, UCECOM was forced to review its educational offer, because UCECOM schools had no students, amid severe and progressive reduction of applications. In addition, since 2003, the few students who enrolled in colleges that prepared for apparel professions are usually students with the smallest grades, namely those who have not managed to get qualification for another place/school where he/she wanted. In light of this, the school is investing in a future qualification of young people who do not want to practice this profession. After high school, most graduates enroll in colleges (about 90%), in most cases with profile other than textiles, while those who finish just a few years of high school prefer to seek work in another sectors. Moreover, in all technical colleges from the textiles field, since 2003, there has been a diversification in the size and expense of the educational offer in the detriment of specializations required by manufacturing companies and for which there are possibilities of entering the workforce market.

In regard to the management improvement of knowledge specific to the fashion sector, besides the master programs of the faculties of the five universities mentioned, since February of 2012, the partnership between CODECS and L'Institut Supérieur Spécialisé de la Mode in Paris (MOD'SPÉ Paris) led to the establishment of Art Academy Fashion Business School. This institution offers internationally certified courses in the field. Art Academy courses are structured in two phases: Fundamentals of Fashion (first level) and Fashion Marketing and Design (second level). Each course takes place over one academic year and ends with one week of study and practice in Paris. The curriculum includes subjects such as Consumer Behavior, Sourcing of Fashion Products, International Trade, E-marketing and E-Business Strategies, Fashion/Brand Communication, Financial Management, Production Management, Quality Control Management, Current Trends, Merchandising and Visual Merchandising etc. The cost of a course is 6 200 euro. At enrollment are received high school or college graduates, and the selection is based on an essay. Also, anyone who is interested in a particular course within Art Academy can apply only to that course without having to follow the entire program of the school. Attending a weekend course costs 290 euro, and those who enroll in three courses receive bonus free participation in a fourth course.

Also, one of the companies which are actively involved in supporting the specialized education is Lectra, the world leader in integrated technology solutions for industries using soft materials. Lectra Company signed a partnership agreement, in early 2010, with “Gheorghe Asachi" Technical University of Iasi (the North-East region). Thus, the university awarded Lectra right to use the software without paying licensing rights. All workstations are equipped with the latest technology of the Lectra. The Faculty of Textiles, Leather and Industrial Management within "Gheorghe Asachi" Technical University of Iasi are using the design programs Kaledo® and Modaris®, the market leading software for building patterns. Students also learn to work on the market standard Diamino® to achieve effective placement. Each year, over 70 students are trained on Lectra solutions [5].

Study regarding the examination of preparation and training level of staff and the correspondence between its abilities and the needs of the clothing Romanian companies

In this research we aim to bring an important contribution to both the theoretical and pragmatic aspect of the studied field. The need to examine the readiness and training of staff to achieve correspondence between workforce skills and the needs of companies is justified by the fact that even on reduction of jobs by closing firms or reduction of production capacities, employers claims the lack of skilled personnel on the labor market in Romania, especially among directly productive workers.

Also, regional employment agencies have permanent ads for recruiting qualified directly productive workers in the textiles field, most of them not finding employees. To get valid information regarding the level of training required and staff training and the correspondence between workforce skills and the needs of companies we have undertaken an investigation of opinion among them. The survey was based on a questionnaire given to managers of the analyzed companies. The present research aims at four main objectives:

Objective 1 – Identifying the features of production and based on it the level of training and training methods used in the clothing companies in Romania;

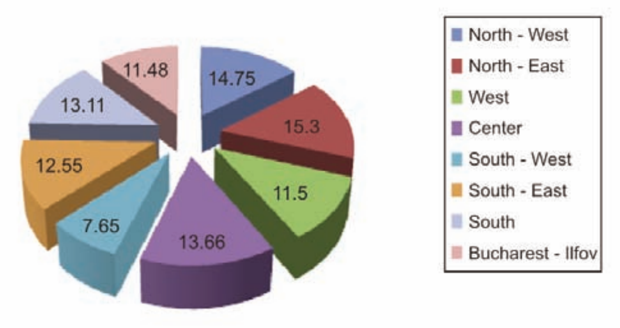

Fig. 1. Graphic of distribution of the sample by development regions

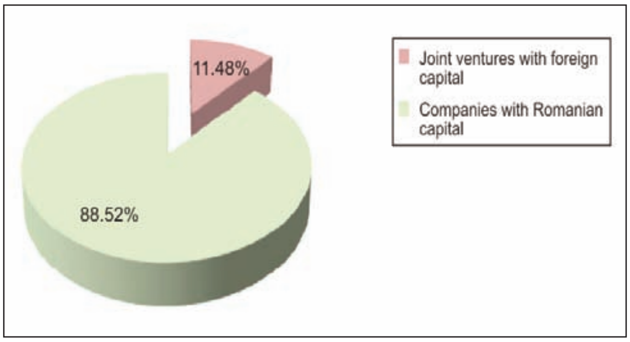

Fig. 2. Structure of the sample by capital type

Objective 2 – Identifying problems with which the analyzed companies face regarding the workforce (forms of recruitment and training of qualified directly productive workers, motivation);

Objective 3 – Identifying the current state of correspondence between workforce skills and the needs of companies;

Objective 4 – Substantiation of the future directions of growth of the degree of correspondence between workforce skills and needs of the clothing Romanian companies.

The questions were structured into three sections:

I. General information about the analyzed companies. This section contains general identification questions, address, development region to which the company belongs to, establishment of its size by number of employees, by way of capital, by goods destination.

II. Information about the extent to which human resources are tailored both in number and quality to the business needs, level of education, staff training, and motivation. The set of questions used in this section serves the direct purpose of research, the questions being aimed at identifying the respondents' opinion on the level of training of their employees, recruitment and training methods used, the correlation between the level of education and training of staff (directly productive workers) and form processing, correlation with the destination of the goods, with firm size, with the development region to which it belongs. Questions in this section also aim the identification of the motivation system used in the analyzed companies.

III. Future directions of growth of the degree of correspondence between workforce skills and the needs of the clothing Romanian companies, namely insurance of qualified personnel. This section is very important because it presents the main ways of ensuring the future of clothing Romanian companies with skilled personnel.

The research was designed, conducted and analyzed by the author:

I. The sample of surveyed companies. The questionnaire-based study was conducted on a number of 183 clothing companies for women and men in all the development regions of Romania and covers the year 2011. Details on the territorial structure of the sample of the investigated companies are presented in table 1. The graphical representation of the geographical distribution of companies by development regions is given in figure 1. By way of capital, of the 183 companies, 21 are joint ventures with foreign capital, and 162 are companies with Romanian capital (fig. 2). Structure of the companies by number of employees is presented in table 2. It is noted that the share of micro firms in the analyzed sample is 52.64%, 30.40% small companies, medium companies 14.77%, and large companies of 2.19% (fig. 3). After the product destination, of the 183 companies, 110 export, the other 73 address to the internal market with their own brands. Of the 110 exporting firms, 67 firms export their entire production in lohn system, 43 firms export full-product and they support their mostly full-product exports by processing in lohn system (fig. 4).

Table 1

DISTRIBUTION OF THE SAMPLE BY DEVELOPMENT REGIONS

No. item	Development region	No. analyzed companies	Percentage, %
1	North-West	27	14.75
2	North-East	28	15.30
3	West	21	11.50
4	Centre	25	13.66
5	South-West	14	7.65
6	South-East	23	12.55
7	South	24	13.11
8	Bucharest and Ilfov	21	11.48
Total		183	100

II. Regarding the level of education and training of employees in the analyzed companies most managers identified the lack of qualified personnel or directly productive skilled workers as a real problem with which they are facing today and will continue to face in the future. Only 34 managers consider that the lack of qualified personnel is a problem that will be solved in time by labor market regulations.

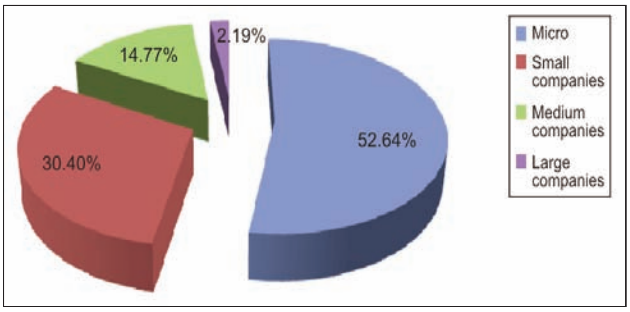

Fig. 3. Structure of the companies by the number of employees

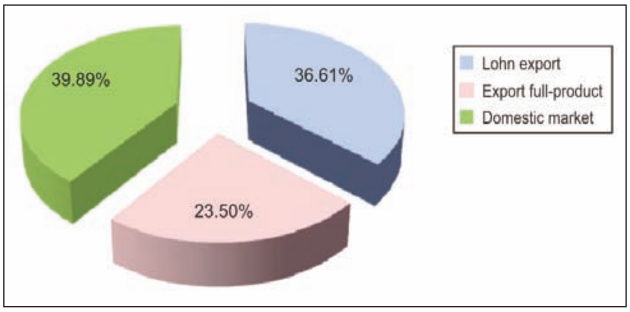

Fig. 4. Product destination

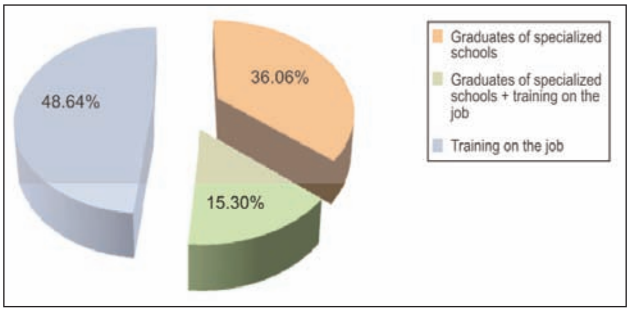

Fig. 5. Level of the professional training of directly productive workers

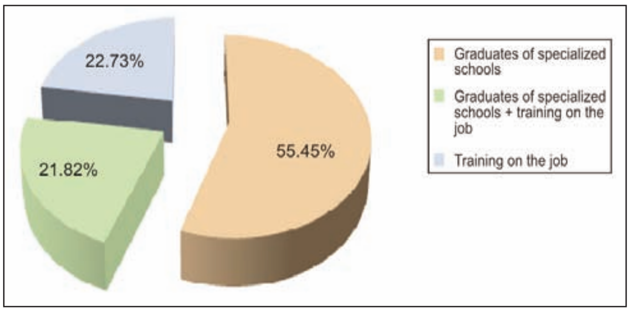

Fig. 6. Level of the professional training of directly productive workers in exporting firms

Table 2

STRUCTURE OF THE COMPANIES BY NUMBER OF EMPLOYEES

Total	Large (over 250 employees)	Medium (50 – 249 employees)	Small (10 – 49 employees)	Micro (1 – 9 employees)
183	4	27	56	96

Of the 183 analyzed companies, 66 companies have skilled workers, graduates of specialized high schools, 28 companies have skilled workers and specialized high school graduates as well as employees that they qualify at the workplace and 89 companies who qualify their employees at work (training on the job). The high percentage (48.64%) of workers who are qualified at the workplace is observed, with the associated costs, namely the precious time spent training at the expense of production and in many cases there is no guarantee that they will not leave the organization too fast. The share of firms that have hired graduates of specialized high schools is 36.06%, and the firms that have high skilled specialist and graduates as well as employees that they qualify at work (training on the job) is 15.30% (fig. 5).
From the 110 exporting companies (full-product export and lohn system) from the sample, 61 companies have skilled workers, specialized high-school graduates, 24 companies have graduates of specialized schools and training on the job, while 25 companies have training on the job for their employees (fig. 6). Of the 73 firms that address the internal market, five companies have skilled workers, graduates of specialized schools, four companies have skilled workers, graduates of specialized schools + employees that they train on the job, and 64 companies train their employees on the job (fig. 7).
It is noted that in the case of exporting companies the share of specialized high school graduate workers is very high, compared to companies that address the internal market. In contrast, the share of workers who are given training on the job is higher for firms that address the internal market.
The correlative analysis (table 3) of the level of professional preparation and training of directly productive workers with the size of the analyzed firms reveals the following: a high skill level of the directly productive workers in large firms and medium firms (percentage of specialized high school graduates is 75% and 70.37%, while the small and micro firms share is 37.5% and 23.96%).
The correlative analysis of the level of professional preparation and training of directly productive workers in exporting firms (full-product export and lohn system) with the development region which shows a high skill level in development regions such as Bucharest – Ilfov (73.34%), North-West (72.22%), followed by the Central region (64.29%).

Table 3

CORRELATIVE ANALYSIS OF THE PROFESSIONAL PREPARATION AND TRAINING OF DIRECTLY PRODUCTIVE WORKERS WITH THE SIZE OF THE COMPANIES				
Professional preparation and training	**Large (over 250 employees)**	**Medium (50 – 249 employees)**	**Small (10 – 49 employees)**	**Micro (1 – 9 employees)**
Specialized high school graduates	3	19	21	23
Specialized high school graduates + training on the job	1	6	3	18
Training on the job	-	2	32	55
TOTAL	4	27	56	96

Table 4

CORRELATIVE ANALYSIS OF THE READINESS AND TRAINING OF DIRECTLY PRODUCTIVE WORKERS IN EXPORTING FIRMS (FULL-PRODUCT EXPORT AND CMT) WITH THE DEVELOPMENT REGION IN WHICH THEY ARE LOCATED								
Development region/ level of vocational education and training	**North-West**	**North-East**	**West**	**Center**	**South-West**	**South-East**	**South**	**Bucharest-Ilfov**
Specialized high school graduates	13	7	7	9	1	6	7	11
Specialized high school graduates and qualification at the workplace	2	4	4	2	1	5	4	2
Qualification at the workplace	3	3	2	3	4	5	3	2
TOTAL	18	14	13	14	6	16	14	15

Table 5

CORRELATIVE ANALYSIS OF THE READINESS AND TRAINING OF DIRECTLY PRODUCTIVE WORKERS IN COMPANIES THAT ADDRESS DOMESTIC MARKET BY THE DEVELOPMENT REGION IN WHICH THEY ARE LOCATED								
Development region/ level of vocational education and training	**North-West**	**North-East**	**West**	**Center**	**South-West**	**South-East**	**South**	**Bucharest-Ilfov**
Specialized high school graduates	2	-	1	1	-	-	-	1
Specialized high school graduates and qualification at the workplace	1	1	-	1	-	-	-	1
Qualification at the workplace	6	13	7	9	8	7	10	4
TOTAL	9	14	8	11	8	7	10	6

Companies in the West have specialized high school graduates accounted for 53.84%, while the firms in the North-East and the South have a share of 50%. The lowest rates are those of the companies (table 4) in the South-East (37.5%), followed from a far by the South-West region (16.67%).

Correlative analysis of the readiness and training of directly productive workers in companies that address domestic market by the development region in which they are located, shows a very low skill level, namely companies in 3 of the 8 regions (South West, Southeast and South) qualify their workers at the workplace, not having specialized high school graduates. Only firms in the North-West and Bucharest – Ilfov have specialized high school graduates accounted for 22.22% and 16.67%. The Western and Central in share of 12.5% and 9.09% (table 5).

Only 6 of the 66 companies that have specialized high school graduate workers assist in specialized secondary education by providing scholarships to students with the requirement of their employment after graduation. The six companies are exporting firms (1 large firm in the Central region, 4 medium-size companies – three in the North-East, one in the North-West and one small company in Bucharest – Ilfov).

Of the 183 companies analyzed, only 19 firms (exporting firms) sent their employees to attend Art Academy supporting its costs. It comes to two large firms and 17 medium-sized companies, 6 of the North-West, 5 each in the West and respectively Bucharest – Ilfov and 3 in the Centre.

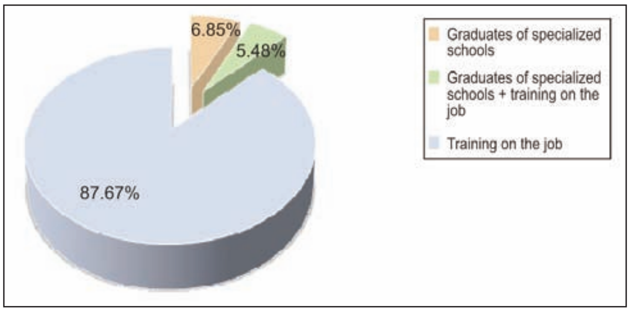

Fig. 7. Level of the professional training of directly productive workers in firms that addresses domestic market

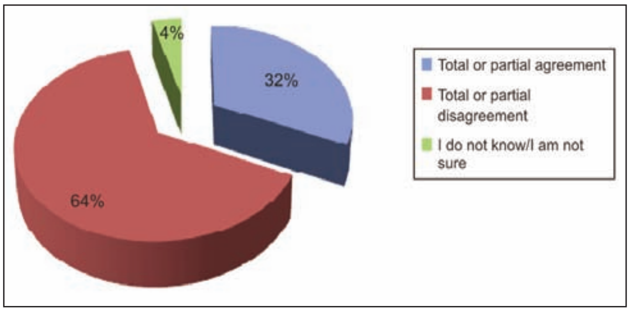

Fig. 8. Level of acceptance of the adoption of motivating salary

It is noted again that exporting firms are concerned with finding solutions and staff training, although in a very small percentage.

The gross minimum wage in the textile industry, clothing, and leather goods during 2010–2013 is 894 lei (about 200 euros), while the gross national minimum wage from 1 January 2012 is 700 lei (about 160 euros).

Questions about the motivation of directly productive worker underline the following aspects:

- motivation within analyzed firms is mostly extrinsic and is reflected in the net monthly salary of 1 000 lei (about 220 euros) and meal vouchers worth 9 lei/day (about 2 euros/day);
- exception from the wage practiced by the overwhelming majority of the analyzed firms are 15 companies located in the North-East region, where the net monthly salary practiced is 1 200 lei (about 260 euros) plus meal vouchers. The managers of such firms say they have been forced to raise the salary, significantly reducing profit to maintain employment, North-East region facing migration phenomenon in a greater degree than other regions;
- in a minor extent, on all the companies analyzed, the staff is supplied with training courses and in fairly large proportion the workers benefits from qualification at work due to lack of qualified staff.

To increase the attractiveness for jobs in the clothing industry in order to meet the demands of quality and product innovation of the industry in the current socio-economic context, managers and owners (shareholders) must realize the necessity of seeking new forms of motivation starting with the extrinsic and up to the intrinsic ones. The extent to which they have manifested their agreement that „adopting motivating salaries represents the solution for increasing the attractiveness of the clothing industry, and namely for the increase of the correspondence between employee skills and company needs” (fig. 8).

The results highlight the following:

– 32% of respondents agree with the statement above, in more or less clear terms (total or partial agreement);
– 64% disagreed with the statement made (wholly or partly disagreement);
– 4% do not express a point of view.

From the noted answers we notice that most investigated managers do not appreciate the positive role of adopting motivating salaries for the increase of the correspondence between employee skills and the needs of the company.

After analyzing the responses received regarding the granting of motivating salaries I have identified the following:

- Most of the managers which did not agree with the statement made state that in the present conditions they can not increase wages due to high costs, declining prices of their products and the lack of tax incentives offered by the state and does not consider that this would increase the attractiveness for the domain-specific jobs. In addition, all managers indicate the following aspect: labor costs incurred by companies is actually higher, they paying for the net the salary of 1 000 lei (220 euros) another 325 lei (about 70 euros), representing employee contributions owed to the State;
- The majority of these managers do not see any possibilities in the near future to increase wages and considers that in such a period, employees

Table 6

CORRELATIVE ANALYSIS OF THE AWARENESS OF THE NEED TO ADOPT MOTIVATING SALARY AND THE SIZE OF ANALYZED FIRMS

Respondent firms, of which:	**Large** 4	**Medium** 27	**Small** 56	**Micro** 96
Total agreement	1	5	11	5
Partial agreement	2	11	8	16
I do not know/ I am not sure	-	2	3	2
Partial disagreement	-	5	16	5

should understand the problems facing the organization in which they work, that which ensures the job;

- 42 managers of the 117 who did not agree with the claim made believes that young people are not interested in clothing specific professions, preferring jobs with even lower wages because they do not want to learn a profession. Four of them even accredit the idea that young people do not have passion for the job as those from previous generations, but only the passion to get money;
- Almost all 117 managers consider that young people do not know what production means because in Romania any actual labor cost was no longer given. In addition, after 1990, when Romania switched to a market economy, the textile industry, supplying raw materials for the clothing one, was virtually abolished, with dramatic effects that were propagated in the clothing industry. Moreover, Dinu C. Giurăscu believes that such destruction of own industry is probably unique in Europe, if not the world [6]. Most of these managers consider that, in this context, young people in Romania prefer to work mainly in trade;
- Almost all 117 managers consider that beside the salary in most companies are made qualifications at the workplace which also constitute into forms of motivation, employers taking on additional risk that those qualified by them will not work there.

III. Future directions to increase the correspondence between labor skills and the needs of Romanian clothing companies:

- Accessing the European funds by producers for staff training and improvement in the field of clothing;
- Initiating the collaboration with companies belonging to the four clusters in the field of in the textile-clothing industry found in Romania (ASTRICO cluster in North-East, Romanian Textile Concept Cluster in Bucharest – Ilfov, Traditions Manufacture Future Cluster in South/East and Transylvania Textiles & Fashion Cluster in the Centre) to: conduct research contracts related to occupancy and skills, the achievement of joint projects implemented by the Ministry of Labor, Family and Social Protection about counseling, employment, changing attitudes, removal of barriers, accessibility, training, inclusion, especially since the study revealed a larger financial and logistical potential especially of companies in the development regions of Centre, Bucharest – Ilfov, North-East;
- Granting of tax incentives by the government, such as tax exemption on wages of the exporters with their requirement to provide the confectioner a net wage of 1 500 lei (about 330 euros) to increase the attractiveness for the industry jobs;
- The implementation of innovative forms of motivation (Skill – Based Pay, Banking Time Off);
- Removing the routine of work and the renewal of enthusiasm for learning through job rotation;
- Providing financial incentives to producers who are involved in conducting practical training internships to students through partnership contracts with specialized high schools;
- Increasing the number of companies that provide student scholarships with a requirement that they commit at completing their studies in these companies for a preset time;
- The increase of the number of students paid tuition contracts by companies.

CONCLUSIONS

The study revealed the lack of qualified personnel in the labor market in Romania's clothing industry, especially among directly productive workers. The study identified the low attractiveness for the industry-specific jobs and, in this context, forms of insurance of the companies with skilled workforce. The study revealed a high degree of qualification in the exporting firms, companies from the Bucharest – Ilfov, North-West, followed by Centre and West regions. The lowest level of qualification was registered in the South-West region. Large and medium-sized companies are those where the level of qualification is high. The study also showed the problems that the companies are facing with, in the field, related to personnel motivation, identifying future directions of increasing correlation between workforce skills and the needs of the clothing Romanian companies.

BIBLIOGRAPHY

[1] Boyer, R., Freyssenet, M. *Les modèles productifs.* La Découverte, Paris, 2000

[2] Dobre, M., Vişan, C. *An econometric estimation of the wage determinants in the light industry*. In: Industria Textilă, 2012, vol. 63, issue 4, pp. 213-217

[3] Kanter, R. M. *Frontierele managementului*. Meteor Press, Bucureşti, 2006

[4] Giurăscu, D. *Cum arată România la 22 ani de la Revoluția din decembrie 1989.* In: Istorie şi civilizație, februarie 2012

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Nanotehnologii

PRODUSE MEDICALE MULTIFUNCȚIONALE DIN STRATURI DE NANOFIBRE

Universitatea din Washington/Seattle, S.U.A., a elaborat o nouă tehnologie de realizare a unor produse medicale multifuncționale. Aceste materiale nețesute, obținute din nanofibre, ar putea constitui viitoare alternative pentru îndeplinirea simultană a scopurilor contraceptive şi de prevenire a infectării cu virusul imunodeficienței umane (HIV).
În acest scop, echipa de cercetare a dizolvat mai întâi polimerii aprobați de Administrația Statelor Unite pentru Alimente şi Medicamente (FDA) şi apoi medicamentele antiretrovirale utilizate pentru tratarea HIV şi au obținut o soluție injectabilă cu ajutorul seringii. Atunci când fluidul intră în contact cu un câmp electric, în el se formează fibre, cu microstructură poroasă, având dimensiuni cuprinse între 100 şi câteva mii de nanometri, care se deplasează în aer şi se ataşează de o placă colectoare. Materialul rezultat în urma acestui proces este o țesătură extensibilă, care permite eliberarea controlată a unor compuşi multipli – substanțe chimice contraceptive şi antivirale.
Unul dintre materialele textile elaborate se dizolvă în câteva minute, oferind utilizatorilor o protecție imediată, iar un alt material realizat se dizolvă treptat, în câteva zile, şi constituie un mijloc eficient de contracepție şi protecție împotriva HIV.
Straturile de fibre electrofilate pot fi concepute din diferite amestecuri de fibre, care să elibereze, în anumite momente, medicamente cu acțiune de protecție mai intensă, împotriva mai multor infecții cu transmitere sexuală sau împotriva tulpinilor rezistente la medicamente.
Electrofilarea este o metodă practicată de decenii, însă doar recent a fost automatizată şi aplicată în filtrarea şi ingineria țesuturilor.
În prima etapă, aceste materiale vor fi folosite, cu precădere, în Africa, unde HIV este cel mai răspândit, dar tehnologia va putea fi aplicată şi în S.U.A. sau în alte țări, pentru a oferi un bun control al naşterilor şi pentru a preveni bolile cu transmitere sexuală.
Cercetările vor continua, pentru a evalua versatilitatea şi fezabilitatea sistemului elaborat, dar şi pentru a testa alte combinații, care eliberează medicamente antiretrovirale sau anticoncepționale hormonale.

__Smart__textiles and nanotechnology, martie 2013, p. 6

AEROGELURI DIN NANOTUBURI DE CARBON

Cercetătorii de la ***Universitatea de Ştiință şi Tehnologie***, din Hefei – China, au creat noi materiale solide poroase, din nanotuburi de carbon, care pot absorbi cantități mari de ulei sau compuşi organici, deşi sunt aproape la fel de uşoare ca aerul.
Pentru obținerea aerogelurilor, cercetătorii au selectat nanofibre din celuloză bacteriană, care pot fi produse cu uşurință la scară industrială, prin fermentare microbiană.
În acest scop, au fost tăiate bucăți mici de nanofibre din celuloză, liofilizate şi apoi pirolizate la 1 300°C, sub argon, pentru a converti celuloza în carbon grafitic. S-a constatat că, deşi densitatea a scăzut, structura rețelei a rămas intactă.
Rezultatul experimentului a fost un aerogel negru, foarte uşor şi stabil din punct de vedere mecanic. Fiind poros şi extrem de hidrofob, acesta poate absorbi solvenți organici şi uleiuri a căror masă depăşeşte de 106–312 ori propria sa greutate. Aerogelul poate extrage uleiul dintr-un amestec de ulei şi apă cu o mare eficiență şi selectivitate, apa rămânând pură. Acest lucru face din noul aerogel un produs ideal pentru curățarea scurgerilor de ulei sau aspirarea poluanților industriali.
Substanțele absorbite pot fi îndepărtate cu uşurință din gel, prin distilare sau ardere, permițând ca acest gel să fie reutilizat.
Proprietățile unice ale acestor aerogeluri – densitatea scăzută, porozitatea ridicată, suprafața specifică mare şi conductivitatea electrică ridicată – creează oportunități de utilizate a lor ca suporturi catalitice, electrozi sau supercapacitori, adsorbanți şi senzori de gaze, precum şi muşchi sintetici.
Trebuie menționat faptul că aerogelurile produse posedă o rezistență foarte ridicată la căldură şi foc, iar tratamentele cu flacără, aplicate în mod repetat, nu au provocat modificări ale formei sau structurii interne poroase 3D.
De asemenea, s-a constatat că materialul poate fi comprimat, volumul său scăzând cu aproximativ 10%, iar, ulterior, putând reveni la forma sa inițială. Odată cu creşterea gradului de comprimare, conductivitatea materialului scade într-un mod aproape liniar.

__Smart__textiles and nanotechnology, aprilie 2013, p. 14