The Peculiarities of Clothing Fabrics During Exploitational Behavior

Dainora TRUNCYTĖ[1*], Matas GUTAUSKAS[1], Arūnas BALTUŠNIKAS[2]

[1]*Department of Clothing and Polymer Products Technology, Kaunas University of Technology, Studentu 56, LT-51424 Kaunas, Lithuania*
[2]*Department of Silicate Technology, Kaunas University of Technology, Radvilenu 19, LT-50254 Kaunas, Lithuania*

Received 05 December 2007; accepted 27 July 2008

The behavior of polyester (PES), polyamide (PA) and acetate (CA) fibrous fabrics in clothing exploitation conditions (washing, softening and thermo-mechanical formation) is analyzed. The estimation of the investigated materials behavior was performed according to the measurements of electrostatic charge accumulation, friction, hand and structure parameters. The strength of adhesion interaction between the specimen and glass stand and its changes due to accumulation of the electrostatic charge was controlled by a friction experiment. The variations of the intensity of X-ray diffraction peaks from the main fibrous polymer reflection planes due to the technological treatment regimes are presented. The dependencies between the textile hand parameters and concentration of chemical softener were determined.
Keywords: textile fabric, fibrous polymer structure, X-ray diffraction, friction, electrostatic charge, chemical softening.

1. INTRODUCTION

Clothes and their fabrics during exploitation are often impacted mechanically and after some time loose their initial properties and quality (colour, hand, and form). Thus clothing fabrics are often affected by friction, washing, dry cleaning and mechanical deformation. Due to the friction between two different polymeric materials, they produce adhesion interaction among each other. Electrostatic interaction between the fabric and equipment component can interfere with the manufacturing or influence the test results. The more different sliding surfaces, the stronger is the charge effect during friction. The collected charge on fibrous materials depends on many factors, such as relative humidity, the nature of materials and properties of electrical ground. The more drastic conditions of washing, cleaning and deformation are during exploitation, the quicker are the loss of the product qualitative parameters. The intensity of the worsening of some parameters can be minimized with chemical materials, but it has only temporary character [1 – 7].

Previous investigations have shown [8, 9] that the friction curves of many natural and chemical fibrous materials significantly differ from the appropriate curves of other materials. Specifically the values of friction coefficients μ_S and μ_D (static and dynamic) vary. In the case of identical pairs of polymers sliding: $\mu_S > \mu_D$, and in the case of different pairs: $\mu_S << \mu_D$ [10]. Dynamic frictional force F_D of the fabric sliding on a glass or other surface has variable character with repeated rises and falls. The variable amplitude $\Delta = F_D^{\max} / F_D^{\min}$ changes by 2 – 3 times, depending on the formation of adhesion interaction and micro-discharges between the elements of sliding pair.

The electrostatic charge sign on the fabric surface determines the conditions of its treatment or processing. It was determined that the chemical cationic softener effectively reacts with negatively charged natural fibers (e. g. cotton) and completely does not soften polyester fabrics that are positively charged [10].

The aim of this research is to determine the behavior of the textile fabrics during clothing exploitation.

2. MATERIALS AND METHODS

The subjects of investigations were three fibrous materials of different nature, such as polyester (PES), polyamide (PA) and acetate (CA) used for production of clothing fabrics (Table 1). As the investigated fabrics differ greatly in terms of fibre nature and structure, the influence of different kinds of fabrics on the obtained results is not discussed. The main objective of the research is to show general behavior tendencies of pure fibrous polymers PES, PA and CA in certain exploitation regimes.

Fabrics thermal treatment in water soak was regarded as an exploitation regime imitating washing process. Thermal deformation of the investigated fabrics imitated the formation process. Two groups of the specimens treated at different regimes were prepared and their results were compared with those of the untreated specimens (marked as C in figures). There were 10 specimens in all groups.

The first group was impacted by the thermal treatment in water soak. The samples were boiled for 10 minutes, later cooled and dried. After that the test results were analyzed. This was the imitation of the drastic washing (marked as B in figures).

The second group of samples was impacted by a punch deformation (P = const = 200 N) with heating T = 120 ±10 °C (5 h) and cooling (marked as D in figures). This was the imitation of the formation (Fig. 1). All specimens were conditioned in a standard atmosphere and relative humidity for 48 hours before each experiment.

The influence of concentration of the cationic liquid softener *Lenor* on the fabrics properties was estimated according to the changes of hand parameters [8 – 10]. The interaction between the fabric surface and the cationic

[*]Corresponding author. Tel.: +370-37-300205, fax.: +370-37-353989.
E-mail address: *Dainora.Truncyte@stud.ktu.lt* (D. Truncytė)

Table 1. Characteristics of investigated materials

Symbol of fabric	Structure	Thickness δ, mm	Area density w, g/m^2	Sign and value of electrostatic potential charge (kV) on surface
PES	Woven fabric	0.09 ±0.01	57 ±1	+0.02
PA	Knitted fabric	0.27 ±0.01	60 ±1	−0.04
CA	Knitted fabric	0.58 ±0.01	154 ±2	−0.01

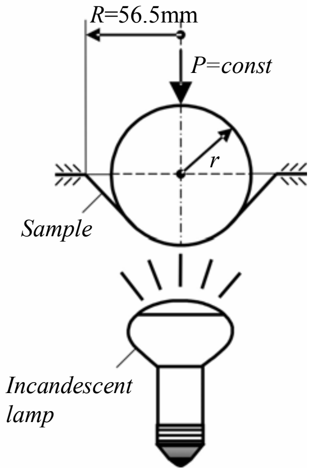

Fig. 1. The scheme of sample punch deformation: r/R = 0.53

softener depends on the electrostatic charge of fabric, thus the parameters of electric charging were controlled using the electrostatic field-meter FMX-002 (the Netherlands).

Fabric specimen while sliding on the glass stand can experience electric charge accumulation, which can initiate formation of the adhesion interaction. Within the friction test, the potential of the electric charge (positive or negative) on the specimen and stand surfaces was controlled.

The friction experiments were performed with a tensile testing machine Zwick/Z005 according to the requirement of DIN 53375, hand experiments were performed with an original device KTU-Griff-Tester [11 – 15]. Structural measurements and analysis of fabrics were made using X-ray diffraction method by DRON-6 diffractometer. 6 – 10 samples were tested in each experiment. Such number of samples has always ensured the error level within the limits of 5 %.

3. RESULTS AND DISCUSSIONS

Previous investigations have shown that the clothing fabrics significantly changed some of their mechanical properties during washing process. Especially the hand parameters got worse [16]. Within 20 washings the parameters of softness, rigidity and other rates became 2 – 3 times worse compared with untreated fabrics values [17].

In this paper the internal polymer structure was investigated using X-ray diffraction analysis [18 – 21]. The intensity of the main diffraction peaks of specimens with special treatments has distinctly changed by 10 % – 50 % (Figs. 2 – 4).

It means that polymer structure of clothing fabric during the exploitation changes and it causes ageing processes. Thermal treatment of the fabric PES showed the decrease of the intensity of main diffraction peaks, i. e. polymer amorphisation process. The same treatment of the knitted fabrics CA and PA showed the reverse process, i. e. the intensity of diffraction peaks increased or the crystallization increased due to the orientation processes of structural elements.

During the deformation of woven or knitted fabric made from polymeric yarns, the further orientation of fabric elements occurs. It can be determined according to the change intensity of the most intensive diffraction peaks.

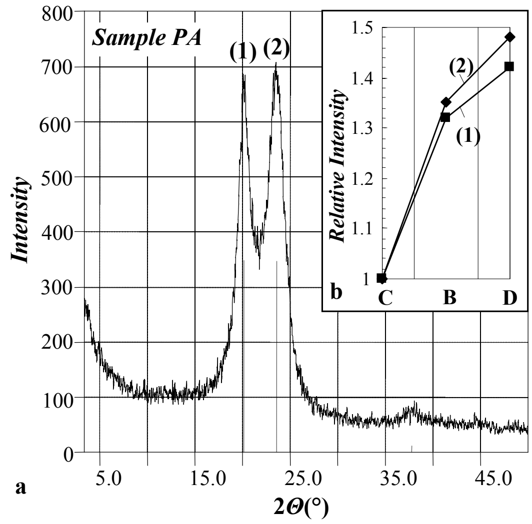

Fig. 2. X-ray diffraction pattern (a) and the variation of relative intensity of diffraction peaks (1) and (2) under the influence of exploitation treatment (b) for PA sample

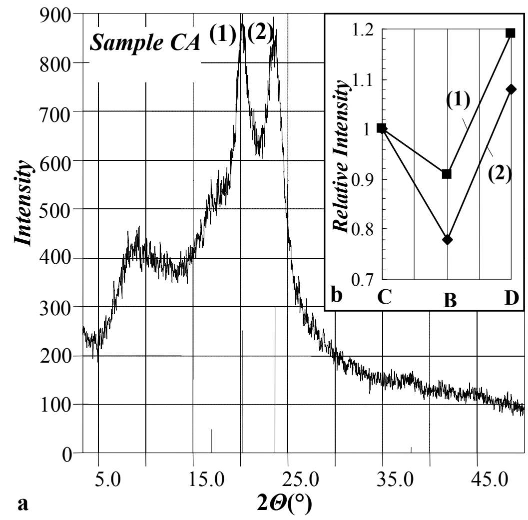

Fig. 3. X-ray diffraction pattern (a) and the variation of relative intensity of diffraction peaks (1) and (2) under the influence of exploitation treatment (b) for CA sample

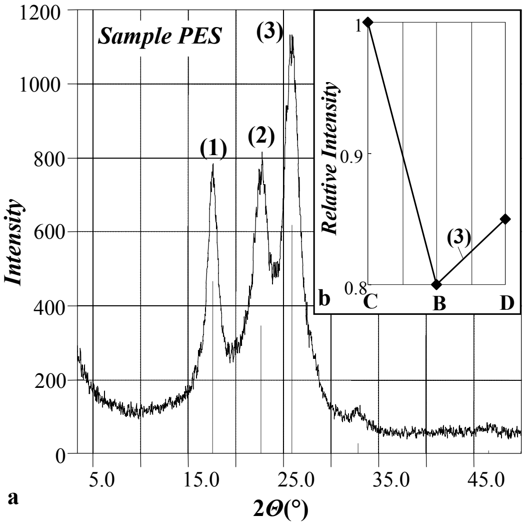

Fig. 4. X-ray diffraction pattern (a) and the variation of relative intensity of diffraction peaks (1), (2) and (3) under the influence of exploitation treatment (b) for PES sample

Three diffraction peaks (1), (2) and (3) are specific to polyester (PES), and two peaks pertain to polyamide (PA) and acetate (CA). During manufacture all these polymers were impacted by spinneret formation and appropriate orientation of structural elements. Thus it was unexpected to find any structural changes after deformation of the investigated fabrics by different exploitation regimes.

Biaxial punch deformations in case of fabrics PA and CA showed the intensity increase of diffraction peaks from both planes. It evidences the further densification of structural derivatives of internal yarns (Figs. 2, 3). During biaxial deformation every structural element (yarn) of textile fabric remains in the state of uniaxial stress. Thus the processes followed by further increase of compactness of the secondary structures in the yarn occur during punching. After the deformation, in the case of PA fabric, the intensity of diffraction peaks from both planes (1) and (2) increased by 42 % – 48 % (Fig. 2.), and in the case of CA the increase is only 8 % – 19 % (Fig. 3). The reverse situation can be seen in the case of PES fabric (Fig. 4). After punching the intensity of diffraction peaks from all three planes is decreased as compared with the untreated specimens. It should be noted, that the most distinct decrease of intensity of diffraction peaks is determined from the plane (2), and the weakest – from the plane (3).

The thermal treatment of the investigated fabrics in water, when boiling according to the intensity level of diffraction peaks from typical planes, using PES and CA is similar (Figs. 3, 4) to the level of punch deformation indices. PA fabric is in the intermediate position between the intensity level of diffraction peaks of untreated specimens and appropriate levels of punch deformation indices (Fig. 2).

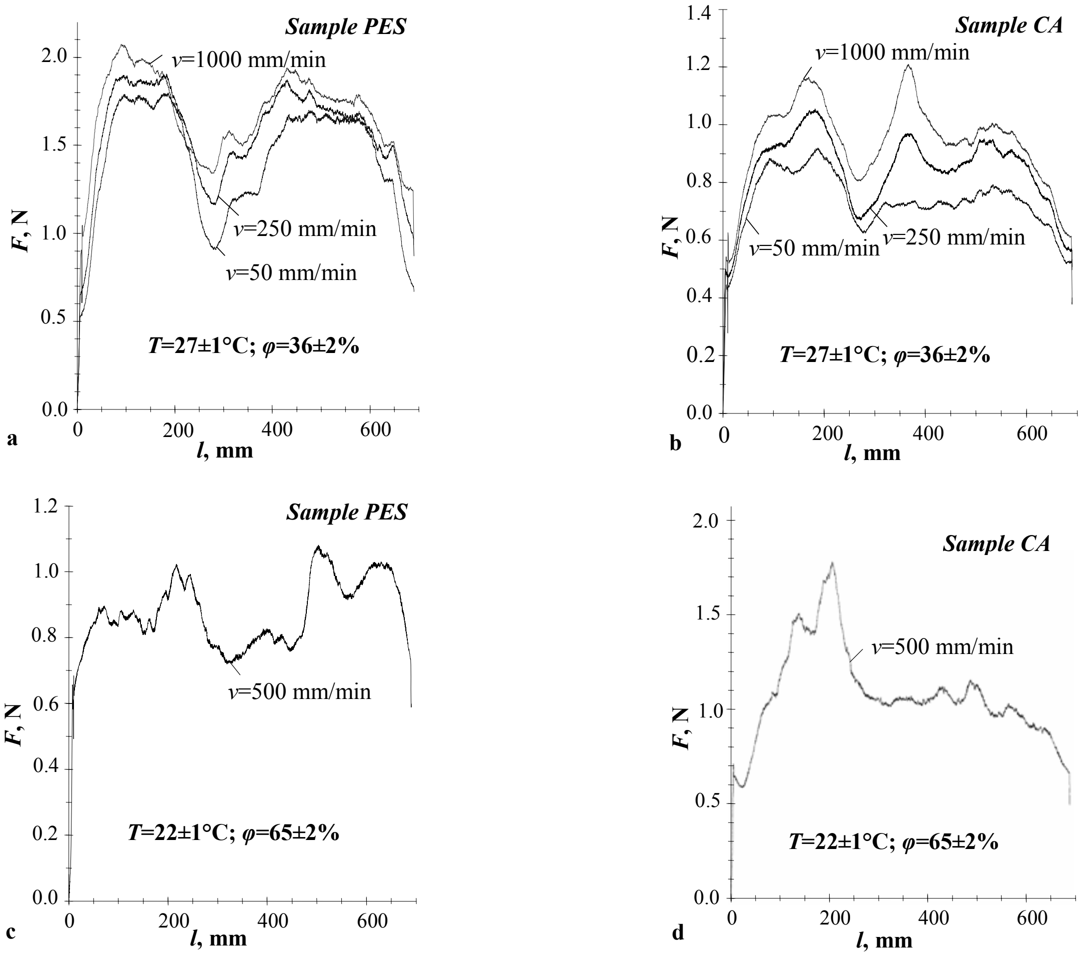

Fig. 5. Friction curves of woven polyester fabric (a, c) and knitted acetate fabric (b, d) at various sliding velocities *v* and different ambient conditions

The X-ray diffraction analysis method enabled to exhibit the kinetic variations of the secondary structures in the polymers widely used in textile industry. The analysis of friction processes showed (Fig. 5), that in constant ambient conditions ($T = 27$ °C ±1 °C, $\varphi = 36$ % ±2 %) when woven fabric PES and knitted fabric CA are sliding on the glass stand friction curves *l-F* get a "double hills" shape with deep sag at $l = 300$ mm ÷ 400 mm (Fig. 5 a, b).

This, obviously, could be explained by electrostatic charge accumulation on sliding surfaces and formation of adhesion interaction between the specimen and the stand. It was described in previous research [10] that the shape of the same sliding pair curve *l-F* was different, because the experiments were performed under the different environmental conditions: $T = 22$ °C ±1 °C, $\varphi = 65$ % ±2 % (Fig. 5 c, d). Then relative humidity had impact on the electrostatic discharge. Thus the differences between the maximum and minimum points (Δ) of curves were less.

The sliding velocity of the specimen on the stand does not change the shape of the curve *l-F*. The curve sag always remains in the same place, though the sliding velocities vary 20 times. At higher velocity only the values of dynamic frictional force F_D increase (Fig. 5 a, b).

The analysis of the friction parameters showed that maximal dynamic frictional force F_D^{max} and parameter Δ obey linear dependence $y = a + bv$ with a sliding velocity v (at $v = (50 – 1000)$ mm/min). The dynamic friction coefficient μ_D can be described by the function $y = a + b/v$.

The comparison of the investigated fabrics friction parameters showed that the static friction coefficient μ_S in all cases is 2 – 3 times less than the dynamic friction coefficient μ_D (Table 2). This shows that the electrification significantly influences the shape of curve *l-F* and its standardized parameters. All friction parameters of PES are higher than the appropriate parameters of other specimens.

Table 2. Friction parameters and the values of electrostatic charge potential of fabrics after the friction on the glass surface

Symbol of fabric	$v = 1000$ mm/min					$e = $ kV
	μ_S	F_S, N	μ_D	F_D, N	$\Delta = F_D^{max} / F_D^{min}$	
PES	0.44	0.82	0.83	1.56	1.76	−0.39
PA	0.43	0.81	0.71	1.34	1.40	−0.08
CA	0.28	0.53	0.49	0.93	2.15	−0.14

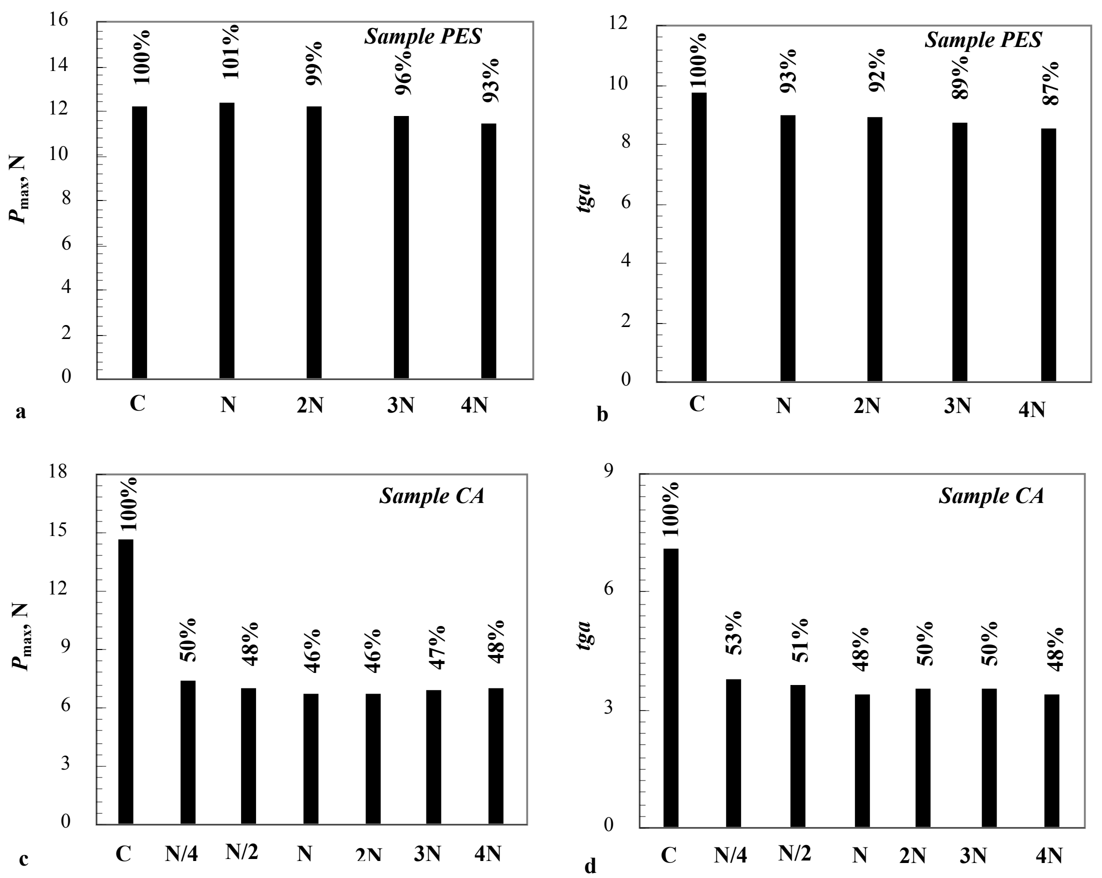

Fig. 6. The influence of concentration N of cationic liquid softener *Lenor* on hand parameters P_{max} (the maximum pulling force) and tgα (the tangent of the slope angle of the typical curve *H-P* initial part) determined for PES (a, b) and CA (c, d) fabrics (Concentration N – the amount of liquid softener recommendable by it manufacturer; C – hand parameters determined for untreated specimens)

The electrostatic charge sign of initial fabric surface highly influences some processes of textile fabric finishing. In the case of fabrics softening, cationic softener are efficient when fabric has negative charge sign and ineffective, when fabric has positive charge sign. The tests of the hand parameters of investigated fabrics with the indices (Fig. 6). Even the increase of softener soak concentration does not soften the polyester fabric (Fig. 6, a, b). Meanwhile even small doses of *Lenor* softener give good softening effect when negatively charged acetate specimens are used (Fig. 6, c, d).

4. CONCLUSIONS

The investigation showed that during washing and thermo-mechanical treatment of clothing fabrics by various exploitation regimes the measurable structural changes occur in their yarns. The intensity of some diffraction peaks of X-ray changes by 48 %. The intensity of the fabric made of PES yarns decreases, and increases for knitted fabrics made of PA and CA yarns.

When the fabrics slide on the glass stand the electrostatic charge accumulates on its surface that initiates the formation of pulsating adhesion interaction between the sliding pair elements. The value of dynamic frictional force during the sliding process greatly depends on the environment humidity and sometimes changes up to 1.5 – 2 times.

REFERENCES

1. **Taylor, D. M., Secker, P. E.** Industrial Electrostatics: Fundamentals and Measurements. Somerset, England, 1994: 272 p.
2. **Gieftier, M. L.** Electro-static Phenomenon during the Processing of Chemical Fibres. Liegkombytizdat, Moscow, 1989: 272 p. (in Russian).
3. **Lüttgens, G., Glor, M.** Electrostatische Aufladungen Begreifen und Sicher Beherrschen. *Expert-Verlag ISBN 3-8169-2506-5* 1988: 230 p. (in Germany).
4. **Ficker, T.** Electrification of Human Body by Walking *Journal of Electrostatics ISSN 0304-3886* 64 (1) 2006: pp. 10 – 16.
5. **Pellumb Berberi, G.** Effect of Processing on Electrical Resistivity of Textile Fibers *Journal of Electrostatics ISSN 0304-3886* 51 – 52 2001: pp. 538 – 544.
6. **Shinohara, I., Yamamoto, F., Anzai, H., Endo, S.** Chemical Structure and Electrostatic Properties of Polymers *Journal of Electrostatics ISSN 0304-3886* 2 (2) 1976: pp. 99 – 110.
7. **Asanovic, K. A., Mihajlidi, T. A., Milosavljevic, S. V., Cerovic, D. D, Dojcilovic, J. R.** Investigation of the Electrical Behavior of Some Textile Materials *Journal of Electrostatics ISSN 0304-3886* 65 (3) 2007: pp. 162 – 167.
8. **Truncytė, D., Gutauskas, M.** The Influence of the Technological Treatment Regime on the Mechanical Properties of Textile Fabrics *Materials Science* (*Medžiagotyra*) *ISSN 1392-1320* 12 (4) 2006: pp. 350 – 354.
9. **Truncytė, D., Gutauskas, M.** The Change of Handle Properties of Knitted Fabrics Influenced by Washing Process *Materials Science* (*Medžiagotyra*) *ISSN 1392-1320* 12 (2) 2006: pp. 158 – 161.
10. **Truncytė, D., Daukantienė, V., Gutauskas, M.** Triboelectricity and it's Influence on the Mechanical Parameters of Clothing Fabrics *Magic World of Textiles: 3rd International Textile Clothing & Design Conference: book of proceedings ISBN 953-7105-12-1*, Zagreb, Croatia, 2006: pp. 751 – 755.
11. **Strazdienė, E., Papreckienė, L., Gutauskas, M.** New Method for the Objective Evaluation of Technical Textile Behaviour *6th Dresden Textile Conference 2002, Biofunktionelle Materialien, FIZ Technik Literaturdatenbank,* http://www.fiz-technik.de
12. **Strazdienė, E., Daukantienė, V., Gutauskas, M.** Bagging of Thin Polymer Materials: Geometry, Resistance and Application *Materials Science* (*Medžiagotyra*) *ISSN 1392-1320* 9 (3) 2003: pp. 262 – 265.
13. **Daukantienė, V., Bernotienė, B., Gutauskas, M.** Kontrola opipa tekstila karištenjem uredaja KTU-Griff-Tester *Tekstil ISSN 0492-5882* 53 (7) 2004: pp. 356 – 360 (in Croatian).
14. **Daukantienė, V., Bernotienė, B., Gutauskas, M.** New Aspects of Polymer Sheet Punch Deformation *Journal of Applied Polymer Science ISSN 1097-4628* 102 (3) 2006: pp. 358 – 361.
15. **Strazdienė, E., Gutauskas, M.** The Peculiarities of New Textile Hand Evaluation Method *Fibers and Polymers ISSN 1229-9197* 7 (4) 2006: pp. 414 – 419.
16. **Juodsnukytė, D., Daukantienė, V., Abraitienė, A., Gutauskas, M.** Influence of Washing and Liquid Softeners on the Change of Knitted Fabrics Hand *Tekstil ISSN 0492-5882* 54 (3) 2005: pp. 99 – 103 (in Croatian).
17. **Daukantienė, V., Bernotienė, B., Gutauskas, M.** Textile Hand: the Influence of Multiplex Washing and Chemical Luquid Softeners *Fibres and Textiles in Eastern Europe ISSN 1230-3666* 13 (3) 2005: pp. 63 – 66.
18. **Dornyi, B., Csiszar, E., Somlai, C., Sajo, I.** Effect of Liquid Ammonia on the Fine Structure of Linen Fabrics *Textile Research Journal* 76 (8) 2006: pp. 629 – 636.
19. **Daukantienė, V., Gutauskas, M.** The Peculiarities of Structural Changes of Polyethylene films after Uni/bi-axial Deformation Process *Materials Science* (*Medžiagotyra*) *ISSN 1392-1320* 1 (8) 1999: pp. 39 – 41.
20. **Brinkienė, K., Kėželis, R., Baltušnikas, A., Mėčius, V.** Thermal Treatment Influence on Microstructure of Plasma Sprayed Zirconia Thin Films *Materials Science* (*Medžiagotyra*) *ISSN 1392-1320* 9 (4) 2003: pp. 387 – 390.
21. **Ivanauskas, R., Janickis, V.** The Modification the Polyamide Films by Layers of Copper Selenide *Proceedings of Baltic Polymer Symposium 2007 Vilnius University, Kaunas University of Technology, ISBN 978-9955-33-150-6* 2007: pp. 24 – 29.