ISSN 1392–1320 MATERIALS SCIENCE (MEDŽIAGOTYRA). Vol. 19, No. 1. 2013

Influence of Laundering on the Quality of Sewn Cotton and Bamboo Woven Fabrics

Jurgita KOŽENIAUSKIENĖ [*], Virginija DAUKANTIENĖ

Department of Clothing and Polymer Products Technology, Kaunas University of Technology, Studentų str. 56, LT-51424 Kaunas, Lithuania

crossref http://dx.doi.org/10.5755/j01.ms.19.1.3831

Received 02 July 2011; accepted 01 December 2011

In the presented study the effect of laundering on the quality of sewn cotton and bamboo plain woven fabrics was investigated considering both the textile parameters and the type of chemical treatment. Quality parameters of sewn cotton and bamboo woven fabrics such as: fabric strength, seam strength and seam slippage at the moment of 4 mm seam opening were evaluated before and after washing with "Tide" washing powder without softeners or with softeners: "Surcare" and "Pflege Weicspuler". There was also determined surface density, warp and weft densities as well as thicknesses under the pressures 0.625 kPa and 3.125 kPa, and calculated the comparative thickness that was considered as softness or porosity of fabrics.

Notwithstanding that both the investigated fabrics were cellulosic their behavior after laundering was different. Under the tested conditions, unwashed and laundered with or without chemical softeners cotton fabric didn't demonstrate seam slippage. The seam slippage resistance of laundered without or with softener specimens of bamboo fabric was increased in respect to control fabric. The larger changes in seam efficiency and seam strength because of laundering were determined for bamboo woven fabric then for cotton fabric. They could be influenced by the higher changes in bamboo fabric's structure. The highest difference between the structure parameters of both fabrics was determined for comparative thickness. It was significantly increased for cotton fabric and decreased for bamboo fabric after chemical softening comparing to untreated fabrics.

Keywords: woven fabric, structure, cotton, bamboo, laundering, chemical softener, seam slippage.

1. INTRODUCTION

Textile laundering is the most commonly applied care process during exploitation process of casual clothing. During laundering textile materials are treated in water solvent containing chemical washing products, household rinse cycle fabric softeners and etc. It is known that the laundering conditions such as temperature, the number of laundering cycles, the concentration of chemical washing or softening products influence the changes in textile hand, hydro properties, surface friction characteristics, bending rigidity and other properties [1 – 7]. The highest changes occur in the properties and appearance of clothing textile materials manufactured from natural or man made cellulosic yarns of cotton, linen, viscose, acetate and other fibers [8]. Laundering of cotton fabrics can effect the changes in their shape properties and shrinkage [6].

During laundering the industrial finishing with softeners applied for improving some textile performances including soft handle, smoothness, elasticity, antistatic, antibacterial and soil release properties could be partially removed from textile materials [6, 9]. So, after the main laundering the washed clothing is rinsed with household liquid cationic or anionic softeners. Household fabric softeners maintain the handle and freshness even after several washings [7]. The changes in textile materials properties influence also the quality of sewn assemblies in textile products. The quality of woven fabrics sewn into the garments is affected by different factors such as seam efficiency, seam slippage and others [8]. These properties of seams are highly dependent on the stitching parameters, the properties of sewing threads and on the structure characteristics of woven fabrics [8, 10]. It is known that the friction between yarns in woven fabrics that is dependent on fiber content has the significant influence on seam slippage. As there were discussed in the earlier research works [1, 3, 5 – 9, 11], the softness of textile materials increases after their treatment with chemical rinse cycle softeners enhancing their hand properties. These changes in textile surface properties are considered positively in respect to the wear comfort that is evaluated subjectively by consumer. But contrary to this, the other quality factor such as seam slippage that is strongly affected by friction characteristics those could be increased after laundering with chemical softeners.

Therefore, the aim of this investigation was to estimate the influence of laundering on the quality of sewn cotton and bamboo fabrics considering both the textile parameters and type of chemical treatment.

2. MATERIALS AND METHODS

The study is focused on 100 % cotton A01 and 100 % bamboo A02 plain fabrics (Table 1).

The thickness measurements δ_1 and δ_2 before and after chemical treatment wee taken on a disc type instrument under the pressures of 0.625 kPa and 3.125 kPa. The number of measurements was 5. The relative measurement error did not exceed 3.0 %. Comparative thickness $\Delta\delta$ was calculated according to the following equation

[*] Corresponding author. Tel.: +370-672-50345; fax.: +370-37-353989. E-mail address: *jurgita.valiukenaite@stud.ktu.lt* (J. Koženiauskienė)

$$\Delta\delta = \frac{\delta_1 - \delta_2}{\delta_1} \cdot 100\text{, \%.} \quad (1)$$

Fabrics surface density was measured according to standard LST ISO 3801:1998 [2], warp/weft density – according to standard LST EN 1049-2:1998 [13].

Table 1. The characteristics of investigated woven fabrics

Parameter	Fabric code	
	A01	A02
Thickness δ_1, mm,	0.36 ±0.01	0.66 ±0.02
Thickness δ_2, mm	0.33 ±0.01	0.53 ±0.01
Comparative thickness $\Delta\delta$, %	8.3	19.7
Surface density m_q, g/m^2	144.4 ±0.4	218.4 ±1.2
Warp density P_{warp}, cm^{-1}	21	26
Weft density P_{weft}, cm^{-1}	26	26

Warp and weft oriented 1050 mm × 450 mm fabrics samples were laundered using front loading washing machine from "Whirpool" applying the following conditions: 95 °C cotton wash cycle and "Tide" washing powder (142 ml ≈ 100 g). A tumble dryer was not used because it could cause shrinkage that results the higher change in structure. Only line drying was used instead. One of three laundered samples was line dried for 24 h at 20 °C ±2 °C temperature. Both the second and the third samples were soaked for 20 min in the laboratory bath poured with water containing chemical softener "Surcare" and "Pflege Weichspuler", respectively (Table 2). The concentration of both rinsing solvents was 18 ml of softener in 10 liter of water. After that process the samples were line dried for 24 h at 20 °C ±2 °C temperature.

The quality of sewn control C, washed W, washed and softened with softener "Surcare" Sr, washed and softened with softener "Pflege Weichspuler" PW fabrics was evaluated analyzing seam slippage F_{ss}, seam strength determined by maximum force to seam rupture F_s, seam efficiency E_s as well as considering both the fabrics parameters (tensile force F_{cr} and elongation ε_c, thickness, surface density and both warp and weft densities) and type of chemical treatment.

Breaking forces F_{cr} of investigated fabrics were determined according to LST EN ISO 13934-1 [14]. The number of measurements was 5-15, relative measurement error varied from 3.6 % to 12.0 %. The specimens were sewn using 120 ticket number polyester sewing threads, single needle (No. 90/14) lockstitch sewing machine with 5 stitches in 1 cm density. Both the investigated fabrics were tested for seam slippage according to LST EN ISO 13936-1 standard applying the fixed seam opening $d = 4$ mm method [15]. The number of measurements was 5 – 15, relative measurement error varied from 5.6 % to 11.3 %. The maximum force to seam rupture seam strength was estimated according to ISO 13935-1 [16]. The number of measurements error was 7 – 15, relative measurement error varied from 2.4 % to 8.1 %. 100 mm gauge-length fabrics' specimens were extended using CRE-type tension machine Tinius Olsen H10K-T UTM at 50 mm/min extension rate. Seam efficiency E_s was calculated according the following equation

$$E_s = \frac{F_s}{F_{cr}} \cdot 100\text{, \% ,} \quad (2)$$

where F_{cr} is the fabric breaking force (N), F_s is the maximum force to seam rupture (N).

3. RESULTS AND DISCUSSION

3.1. The influence of chemical treatment on textile materials structure and tensile properties

The obtained results had shown that after chemical treatment both the thicknesses δ_1 and δ_2 of A01 cotton fabric increase in about 27 % after its washing. After A01 cotton fabric softening with both the investigated softeners Sr and PW, δ_1 thickness increased in 6.7 %, additionally (Fig. 1). The thickness δ_2 of cotton fabric that was measured under the higher pressure was decreased in 7 % after fabric's chemical softening with both the applied softeners in respect to washed specimen.

The chemical treatment of A02 bamboo fabric leads the higher changes in its thicknesses then of A01 cotton fabric. The thicknesses δ_1 and δ_2 were increased in about 50 % after specimen softening with softener Sr, except δ_1 thickness that was additionally increased in 20 % after applying chemical softener PW (Fig. 1).

The results of comparative thickness calculation had shown that the washing influences a very low (4.8 %) increase of this parameter of A01 cotton fabric in respect to control C specimen (Fig. 2).

The difference between the fabric thicknesses measured under different pressures increases in 165 % after A01 fabric softening contrary to A02 bamboo fabric.

Table 2. Characteristics of used washing chemical materials

Product name	Tide	Surcare	Pflege Weichspuler
Code	T	Sr	PW
Washing product	Washing powder	Rinse cycle household fabric softener	Rinse cycle household fabric softener
Producer	Procter & Gamble	McBride Company	Werner & Mertz GmbH
Country	Czech	Great Britain	Germany
Chemical content	5 % – 15 % anionic surface activator (PAM), oxygen bleacher; < 5 % cationic PAM, nonionic PAM, phosphates, phosphonates, polycarboxylates, zeolites; optical bleachers, pherments, aromatic materials, hexyl cinnamal.	5 % – 15 % cationic PAM, chloromethylisothiazolinone, methylisothiazolinone, octylisothiazolinone, lodopropynyl butylcarbamate.	5 % – 15 % vegetable cationic PAM; aromatic materials: linalool, eugenol, alfa-izometil ionon, hexyl cinnamal, butylphenyl methylpropional and etc.; and very small amount of cosmetic dyers.

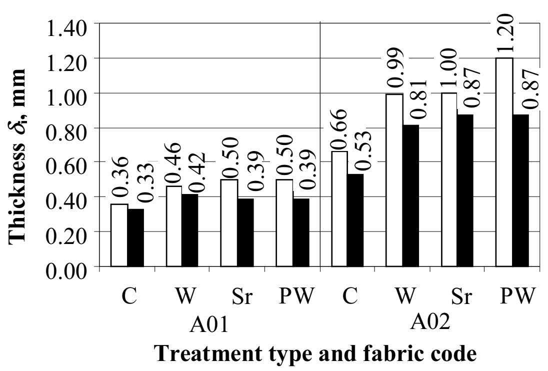

Fig. 1. Thicknesses of A01 cotton and A02 bamboo fabrics (C – control; W – washed; Sr – washed and softened with softener "Surcare"; PW – washed and softened with softener "Pflege Weichspuler"; □ – δ_1 thickness; ■ – δ_2 thickness)

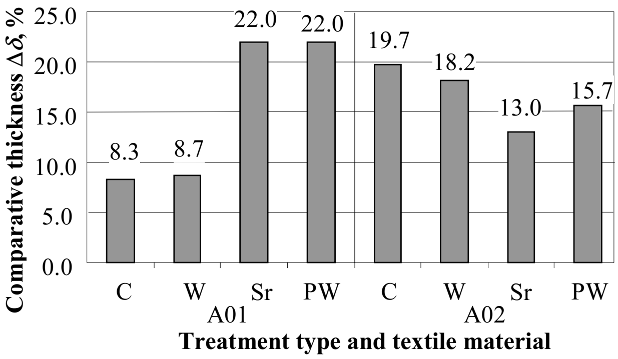

Fig. 2. Comparative thickness of A01 cotton and A02 bamboo fabrics

From Figure 2 it can be seen that after every stage of A02 bamboo fabric's chemical treatment this parameter decreases in 7.6 % – 34 %. The comparative thickness of fabrics can be considered as their softness or porosity.

So, it could be stated that every type of chemical treatment increases the porosity of A01 cotton fabric and decreases the one of A02 bamboo fabric as well as leads the different uniformity of softener deposition. If compared the investigated textile materials between themselves (Fig. 2) it can be seen that the comparative thicknesses $\Delta\delta$ of unwashed A01 fabric was lower in 137.3 % if compared to A02 fabric. In the earlier research works [17] there were determined that the uniformity of softener deposition on the fabric mainly depends on the structure, i. e. porosity that directly depends on knitting type or weave type. As the both investigated fabrics were plain weaved, so that factor of weave type was eliminated. The fabrics' having the lowest porosity has the most uniform deposition among each group of the same kind of fabric [17].

The changes in A01 and A02 fabric thicknesses (Fig. 1), in surface density (Fig. 3) as well as in warp and weft densities (Fig. 4) in respect to control C fabric were determined after washing then after rinsing with chemical softeners. These parameters for A02 bamboo fabric were increased more then for A01 cotton fabric.

Surface density of both investigated fabrics increases after chemical treatment. The changes in surface density of A01 cotton fabric is not very high (about 7 % – 8 %), but they were significant for A02 bamboo fabric and equal to 20.6 % after fabric's washing and about 26 % after softening in respect to control C specimen (Fig. 3).

The warp density of A01 fabric after washing increased in 9.5 % in respect to control C fabric after its washing and after softening it remained unchanged (Fig. 4). But the weft density of A01 fabric remains unchanged even after its washing. The changes in warp and weft densities of A02 bamboo fabric were the higher then the ones of A01 fabric and were increased in 19.2 % and 15.4 %, respectively. After softening the warp density of A02 fabric remain unchanged in respect to the one of washed fabric contrary to weft density that was slightly decreased in about 3 % (Sr) and 7 % (PW). As is apparent, A01 fabric weft direction is more stable than warp. While A02 yarn density is different in the warp and weft direction. This difference is influenced by different chemical composition and its response to the fiber. It is believable that A02 bamboo fabric adsorbed the higher amount of chemical softener as its surface density was increased after the softening (Fig. 3).

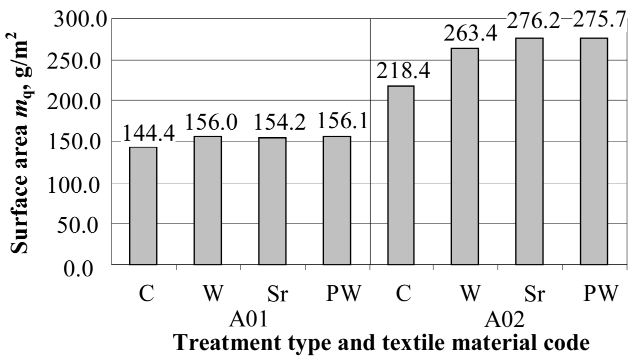

Fig. 3. Surface density of A01 cotton and A02 bamboo fabrics (Marking as in Fig. 2)

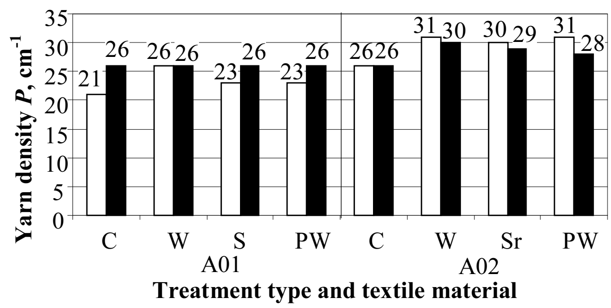

Fig. 4. Densities of A01 cotton and A02 bamboo fabrics

Analyzing the typical tension curves (Fig. 5) it is seen that the breaking force of both the investigated fabrics is the higher in warp direction then in weft direction for all cases of chemical treatment, but A02 bamboo fabric was stronger then A01 cotton fabric. The bamboo fiber belongs to cellulose I crystalline structure as flax or cotton and the cross section of the single bamboo fiber is round with small lumen [18]. The natural bamboo fiber is considered as a kind of fiber with high strength and low extension [19]. It has good water absorption properties [5, 18, 20], thus it successfully absorbs the water with softener.

After washing and softening process the breaking force of A01 cotton fabric in warp direction

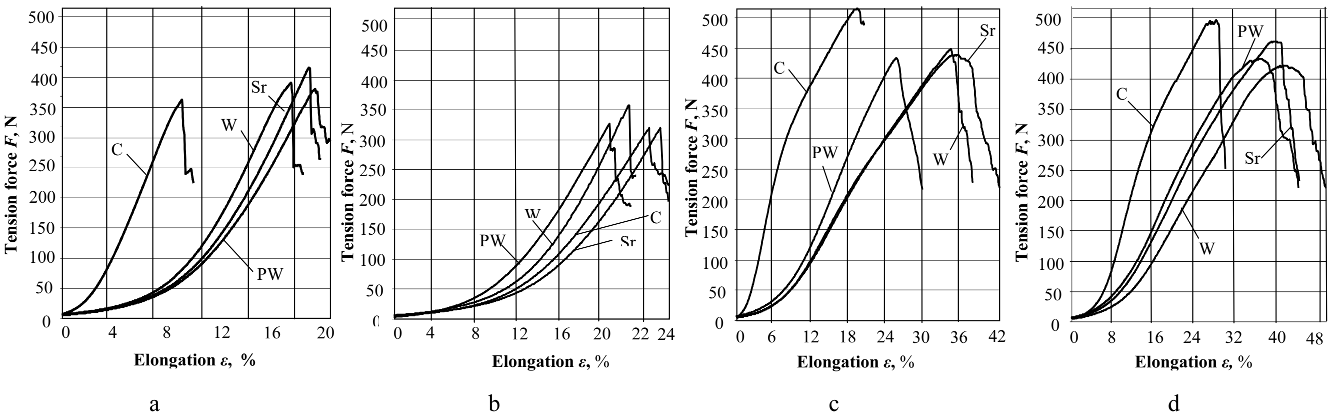

Fig. 5. Typical tension curves of woven fabrics: a – A01 cotton fabric in warp direction, b – A01 cotton fabric in weft direction, c – A02 bamboo fabric in warp direction, d – A02 bamboo fabric in weft direction

(F_{cr} = 358.5 N) and weft direction (F_{cr} = 323.1 N) increased from 8 % to 15.6 % and from 3 % to 10.0 %, respectively, (Fig. 5, a, b). Contrary to A01 cotton fabric, the strength of A02 bamboo fabric (F_{cr} = 534.0 N) decreased after chemical softening in warp direction (from 16.0 % to 17.5 % and in weft direction (F_{cr} = 531.0 N) – from 12.5 % to 19.8 % (Fig. 5, c, d).

The elongation of fabric at break was the higher for A02 bamboo fabric than for A01 cotton fabric in both warp and weft directions (Fig. 5) as well as the higher in weft direction of the both investigated fabrics compare to that in warp direction.

The deformation of treated fabrics increased in respect to control specimen (Fig. 5, a, c, d), except the case of weft oriented A01 fabric specimens (Fig. 5, b). It is known, that the physical arrangement of the usual cationic softener molecules on the fiber surface form close-packed monolayer or multilayer [17]. The long aliphatic chains of cationic softener molecule are oriented towards outside of the fiber and act as boundary lubricants between yarns and fibers [21], and results on influence the higher deformability of fabrics.

3.2. The influence of laundering on the mechanical parameters of sewn woven fabrics

During tension of sewn A01 cotton and A02 bamboo woven fabrics two different cases of seam behaviour was determined notwithstanding that both the investigated fabrics were of the same weave type as well as both were made from plant cellulosic fibers. Considering the seam slippage the fiber content and weave type are very important factors influencing that property [10]. Performing the test of seam slippage at 4 mm seam opening, there were determined that A01 cotton fabric was absolutely resistant to yarn slippage near stitching line. 4 mm seam opening in A02 bamboo fabric was formed at the force F_{ss} = 158.4 N in warp oriented specimens and at F_{ss} = 218.2 N in weft oriented specimens (Fig. 6).

The weft oriented specimens of A02 bamboo fabric were more resistant to seam slippage then warp oriented specimens. Seam slippage resistance of A02 bamboo fabric‘s increases because of chemical treatment in warp oriented specimens – from 31.1 % to 41.9 % and in weft oriented specimens – from 22.6 % to 27.5 %. Earlier it was determined [5] that the chemical softening evidently increases the smoothness of both the investigated materials, especially of bamboo material. There were also considered that washing and softening of A02 bamboo fabric increases the extracting force P_{max} through a nozzle that characterizes textile hand. It means that after treatment A02 bamboo fabric became stiffer [5] and shows the higher slippage resistance than control fabric C (Fig. 6).

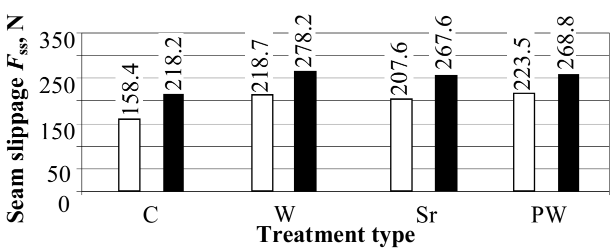

Fig. 6. Seam slippage resistance force F_{ss} at 4 mm seam opening of A02 bamboo fabric (Marking as in Fig. 2)

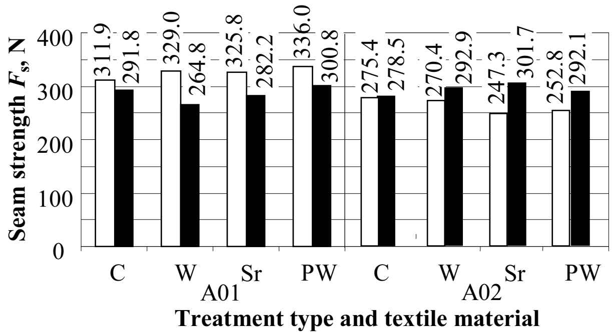

Fig. 7. Seam strength F_s of cotton A01 and bamboo A02 fabrics (Marking as in Fig. 2)

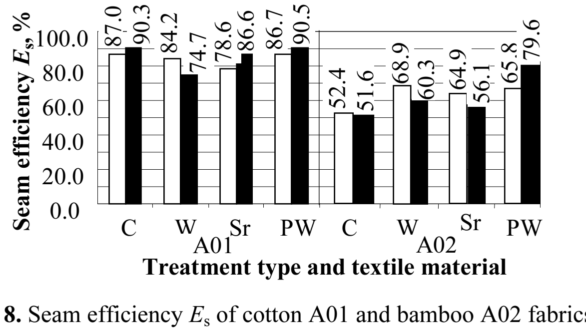

Fig. 8. Seam efficiency E_s of cotton A01 and bamboo A02 fabrics (Marking as in Fig. 2)

The strength of seams in A02 bamboo warp oriented specimens in dependence on the treatment type is the lower in 11.7 % – 24.8 % then those for A01 cotton fabric, and the higher differences were found between the softened of both A01 and A02 warp oriented specimens (Fig. 7).

The seam strength of weft oriented control fabrics A01 and A02 was very similar but after the washing or washing with softening the seam strength of weft oriented seams became the higher for A02 bamboo fabric, except treatment case PW.

Analyzing the seam efficiency test results presented in Figure 8, it can be seen that the seam efficiency of A01 cotton fabric was decreased or remained unchanged after fabric chemical treatment. That was contrary to A02 bamboo fabric the seams of what which became more efficient after washing or washing with chemical softening.

4. CONCLUSIONS

1. The obtained results had shown that the chemical softening additionally changes the fabrics' thicknesses, surface density m_q of both cotton and bamboo fabrics if compared them with the ones of washed fabrics. But these differences are the lower if compare with the differences in structure parameters of control and washed fabrics.
2. Increase of thickness more significant for cotton fabric was found. Whole bamboo fabric thickness after chemical treatment decreases.
3. The elongation at break of investigated fabrics increases almost in all cases of applied chemical treatment.
4. During uniaxial tension the seams of cotton fabric were ruptured without slippage of yarns near a stitching line while in bamboo fabric the seams slipped in the initial part of tension process.
5. The seam slippage resistance of bamboo fabric of warp oriented specimens was the lower than for weft oriented specimens. Treatment with softeners increased the seam slippage resistance of bamboo fabric.
6. The seams of cotton fabric in warp oriented specimens were the stronger then of bamboo fabric, but in weft oriented specimens their strength was similar, except the seams treated with chemical softeners as they influenced the decrease of seam strength in respect to control specimens.
7. The seam efficiency of bamboo fabric was higher for cotton fabric and it depends on the type of chemical treatment.

REFERENCES

1. **Juodsnukytė, D., Daukantienė, V., Abraitienė, A., Gutauskas, M. V.** Influence of Washing and Liquid Softeners on the Change of Knitted Fabrics Hand *Tekstil* 54 (3) 2005: pp. 99 – 103.
2. **Avinc, O., Wilding, M., Gong, H., Farrington, D.** Effects of Softeners and Laundering on the Handle of Knitted PLA Filament Fabrics *Fibers and Polymers* 11 (6) 2010: pp. 924 – 931.
3. **Daukantienė, V., Bernotienė, B., Gutauskas, M. V.** Textile Hand: The Influence of Multiplex Washing and Chemical Liquid Softeners *Fibres and Textiles in Eastern Europe* 13 (3) 2005: pp. 63 – 66.
4. **Truncytė, D., Daukantienė, V., Gutauskas, M. V.** The Influence of Washing on Fabric Wearing Properties *Tekstil* 56 (8) 2007: pp. 493 – 498.
5. **Koženiauskienė, J., Daukantienė, V.** Modification of Textile Materials' Surface Properties Using Chemical Softener *Materials Science* (*Medžiagotyra*) 17 (1) 2011: pp. 52 – 55.
6. **Luan, X. L., Ding, X. M., Xu, P. H., et al.** Effect of Softener on Textile Performances During Laundering *Proceedings of the Fiber Society 2009 May 27 – 29, Donghua University, Shanghai* Vols I and II 2009: pp. 1507 – 1510.
7. **Horrocks, A. R., Allen, J., Ojinnaka, S., Price, D.** Influence of Laundering on Durable Flame Retarded Cotton Fabrics. Part 1. Effect of Oxidant Concentration and Detergent Type *Journal of Fire Sciences* 10 (4) 1992: pp. 335 – 351.
8. **Yucel, O.** Seam Efficiency and Slippage in Linen Fabrics *Tekstil* 54 (10) 2005: pp. 497 – 503.
9. **Obendorf, S. K., Dixit, V., Woo, D. J.** Microscopy Study of Distribution of Laundry Fabric Softener on Cotton Fabric *Journal of Surfactants and Detergents* 12 (3) 2009: pp. 225 – 230. http://dx.doi.org/10.1007/s11743-009-1115-9
10. **Malčiauskienė, E., Milašius, A., Laureckienė, G., Milašius, R.** Influence of Weave into Slippage of Yarns in Woven Fabric *Materials Science* (*Medžiagotyra*) 17 (1) 2011: pp. 47 – 51.
11. **Agarwal, G., Koehl, K., Perwuelz, A., Lee, K. S.** Interaction of Textile Parameters, Wash-ageing and Fabric Softener with Mechanical Properties of Knitted Fabrics and Correlation with Textile-hand *Fibers and Polymers* 12 (5) 2011: pp. 670 – 678.
12. LST ISO 3801:1998. Textiles. Woven fabrics. Determination of Mass per Unit Length and Mass per Unit Area.
13. LST EN 1049-2:1998. Textiles. Woven fabrics. Construction. Methods of analysis. Part 2: Determination of Number of Threads per Unit Length.
14. LST EN ISO 13934-1:2000. Textiles. Tensile Properties of fabrics. Part 1: Determination of Maximum Force and Elongation at Maximum Force Using the Strip Method.
15. LST EN ISO 13936-1:2004. Textiles. Determination of the Slippage Resistance of Yarns at a Seam in Woven Fabrics. Part 1: Fixed Seam Opening Method.
16. ISO 13935-1:1999. Textiles. Seam Tensile Properties of Fabrics and made-up Textile articles. Part 1: Determination of Maximum Force to Seam Rupture Using the Strip Method.
17. **Agarwal, G., Koehl, L., Perwuelz, A.** The Influence of Constructional Properties of Knitted Fabrics on Cationic Softener Pick up and Deposition Uniformity *Textile Research Journal* 80 (14) 2010: pp. 1432 – 1441.
18. **Wang, Y. P., Wang, G., Cheng, H. T., Tian, G. L., Liu, Z., Xiao, Q. F., Zhou, X. Q., Han, X. J., Gao, X. S.** Structures of Bamboo Fiber for Textiles *Textile Research Journal* 80 (4) 2010: pp. 334 – 343. http://dx.doi.org/10.1177/0040517509337633
19. **Tao, L. Z., Jiang, Y. X.** The Study on the Basic Structure and the Mechanical Properties of Natural Bamboo Fiber *Advanced Materials Research* 175 – 176 2011: pp. 303 – 307.
20. **Gun, A. D., Unal, C., Unal, B. T.** Dimensional and Physical Properties of Plain Knitted Fabrics Made from 50/50 Bamboo/cotton Blended Yarns *Fibers and Polymers* 9 (5) 2008: pp. 588 – 592.
21. **Linfield, W. M., et al.** Fabric Treatment with Cationic Softeners *Journal of the American Oil Chemists' Society* 35 (11) 1958: p. 590.

Presented at the 20th International Baltic Conference "Materials Engineering 2011"
(*Kaunas, Lithuania, October 27–28, 2011*)