ISSN 1392–1320 MATERIALS SCIENCE (MEDŽIAGOTYRA). Vol. 20, No. 1. 2014

Influence of Industrial Washing and Cyclic Fatigue on Slippage of Linen Fabric Threads along the Seam

Irina KORUNČAK, Milda JUCIENĖ [*], Vaida DOBILAITĖ, Eglė Ina MACKEVIČIENĖ

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

http://dx.doi.org/10.5755/j01.ms.20.1.2486

Received 21 September 2012; accepted 13 February 2013

All seams of garments shall withstand the established force effect in the longitudinal and transverse directions. Resistance to thread slippage along the seam is a major property of fabrics that is regulated by strict guidelines. In many research works, lining fabrics are chosen as the object of research as thread slippage is the most typical of them. What concerns the reports exploring slippage of linen fabric threads along the seam, just very few papers are available. Studies dealing with the influence made by industrial washing and cyclic load on the defect under investigation, thereby taking into account operational properties of garments are not readily available at all. The objective of the paper is to define the influence of industrial washing and cyclic tensile on slippage of linen fabric threads along the seam. For the research, five 100 % linen fabrics of plain weave have been selected. Control test specimens, unwashed and processed with different washing methods, have been analysed. Cyclic tensile of the test specimens has been carried out by a tensile machine “Tinius Olsen” at tensile force $P = 20$ N, tensile speed of 12.55 mm/s, number of cycles of 100. The carried-out testing has demonstrated that industrial washing decreased resistance of linen fabrics to thread slippage along the seam in the most cases. Analysis of the results obtained has shown that cyclic tensile led to particularly significant increase in the seam gap.

Keywords: seam slippage, linen fabrics, industrial softening, cyclic loading.

1. INTRODUCTION

In production of garments, thready assemblings are generally used. All seams shall withstand the established effect of certain forces both in the longitudinal and transverse directions. In the garments sewn from slippery fabrics with unusual composition, a defect, i. e. slippage of fabric threads along the seam may be observed. Resistance to thread slippage along the seam is a major property of fabrics that is regulated by strict guidelines. The aforementioned defect may both impair the garment appearance and weaken the seam. After multiple washing and wear, the seam may break up completely. Frequently, thread slippage along the seam is observed when the seam in the process of wear is affected by greater tensile forces in the transverse direction.

The carried-out analysis of scientific literature has demonstrated that lining fabrics, fine dress fabrics are chosen as the object of research in most cases focusing on investigation of fabric thread slippage along the seam [1 – 2]. More detailed studies with respect to the aforementioned defect in fabrics of cellulose fibre, i. e. in linen and cotton fabrics, are not readily available [3 – 4].

Recently, in order to highlight decorative seams and pleats, obtain lighter colour effects and improve drape of the garment, linen articles undergo additional finishing, industrial washing usually. Inappropriately selected treatment modes, however, may impair both the garment appearance and operational properties. Analysis of the influence made by washing processes and laundry chemicals on resistance of fabrics to thread slippage has shown that fabrics are affected by the aforesaid factors differently, whereas change in slippage is related to fibre composition and fabric structure [5].

Investigations have demonstrated that fabric structure and physical properties are affected by various modes of industrial washing and softening differently [4]. A negative effect of softening or washing on operational properties of the garment is often observed only in the process of wear. In order to clarify variation of fabric resistance to thread slippage in the process of wear, tests simulating the process of wear have been carried out. To carry out the aforesaid tests, test specimens were subject to multiple washing, drying and mechanical fatigue in some cases or just underwent cyclic tensile in other cases [6 – 7]. Analysis of the influence made by cyclic tensile on fabric resistance to thread slippage along the seam has shown that the first 100 cycles are the most important ones, i.e. after the first 100 fatigue cycles, the tensile force required to obtain a certain seam gapping value [8] decreases continually. The carried-out research has also illustrated that fabric resistance to weft thread slippage decreases after cyclic tensile together with decrease in density of the same thread system and with increase in fabric extensibility [6, 9]. In addition, physical properties of fabrics have been established to make greater influence on fabric resistance to thread slippage compared to stitch length, and this tendency becomes more obvious after cyclic tensile [9]. Researches of wear process [10] investigated the influence of deformation mode on seam slippage in woven fabrics using the new seam slippage test method. This method was also suitable to evaluate the influence of the position of seam allowances, the weave type, the fabric direction and the specimen elongation on the on seam slippage.

[*]Corresponding author. Tel.: +370-37-300212; fax.: +370-37-353989.
E-mail address: *milda.juciene@ktu.lt* (M. Jucienė)

Besides, thread slippage along the seam has been established to depend on fabric structure, thread properties, stitch type and length, performances of sewing threads [11 – 13]. Tests with the furniture upholstery have revealed that slippage of present upholstery threads along the seam is closely related to density of weft threads (density of warp threads was the same in all fabrics). The results obtained have demonstrated that fabric resistance to thread slippage grows with increase in density of weft threads. The direction of the piece assembling seam in respect of weft threads has also been established to have great influence on thread slippage along the seam. The results have illustrated that an increasing angle between weft threads and the seam direction leads to greater resistance to thread slippage.

The carried-out analysis of scientific literature has revealed that what concerns the reports exploring slippage of linen fabric threads along the seam, just very few papers are available. Complex studies dealing with the influence made by industrial washing and cyclic load on the defect under investigation, thereby taking into account operational properties of garments are not readily available at all.

The objective of the paper is to define the influence made by industrial washing and cyclic tensile on slippage of linen fabric threads along the seam.

2. EXPERIMENTAL

For research, five 100 % linen fabrics of plain weave have been selected. The main structure performances of fabrics are listed in Table 1.

Table 1. Properties of analyzed fabrics

Fabric code		C1	C2	C3	C4	C5
Weave		Plain				
Raw material, %		100 % linen				
Surface density, g/m^2		219	130	149	161	250
Thickness, mm		0.52	0.33	0.38	0.51	0.64
Thread density, cm^{-1}	warp	15	22	19	22	17
	weft	11	19	15	18	15
Linear density, tex	warp	74	26	44	42	64
	weft	77	29	45	40	85

In the fabrics under investigation, surface density of control tests and tests after washing processes has been established in compliance with the requirements of LST ISO 3801:1998 [14], whereas a variation coefficient has not exceeded 5 %. Thickness of the test specimens has been established in compliance with the requirements of LST EN ISO 5084:2000 [14], a variation coefficient has ranged from 1.9 % to 5.6 %. Density of warp and weft threads has been established in compliance with the method provided in LST EN 1049-2:1998 [16].

Tests with respect to fabric thread slippage in the fabric have been carried out in compliance with LST EN ISO 13936-2:2004 [17]. For each testing, by 6 test specimens were cut out from the fabrics under investigation, in the directions of warp and weft, with dimensions of 200 mm × 100 mm. Each test specimen was folded halfway, with the face inward, and sewed at a distance of 20 mm from the folded edge. For sewing, one-needle universal sewing machine “Juki DDL-5550N” was used applying stitch type 301 and density of 5 stitches per cm. For sewing, 100 % PES core spun sewing threads linear density 40 tex, sewing needle “Schmetz” Nm 90 were used. The folded edge of the test specimen was cut leaving the 12 mm wide seam overlap.

For investigation, control test specimens, unwashed and processed with different industrial washing methods applied for finishing of linen garments, were employed (Table 2). Finishing was carried out for sewn test specimens.

Table 2. Description of the industrial washing methods applied

Industrial washing code	Description
I	Test specimens were washed in an industrial washing machine in the solution of 40 °C for 20 min. To water, the following liquid chemicals were added: liquid cationic softener (6 – 7 ml/l), softener “Merkor” (6 – 7 ml/l) and 10 % vinegar. Test specimens were dried in a dryer, at the temperature of 60 °C
II	Test specimens were washed in the solution of 40 °C for 20 min with addition of enzyme washing agent (nature: acid) designed to remove pile and ends of fibres from the fabric surface (0.2 % of the fabric mass) and 10 % vinegar (6 – 7 ml/l). Test specimens were rinsed twice by 5 min each time in cold water containing no chemicals. Rinsed test specimens were wrung softly and softened in the solution of 40 °C for 20 min. To water, the following liquid chemicals were added: liquid cationic softener, softener “Merkor” and 10 % vinegar. Test specimens were dried in a dryer, at the temperature of 60 °C
III	Test specimens were washed twice with washing powder containing enzymes (5 g/l) in the solution of 40 °C for 15 min each time. After first and second washing, test specimens were rinsed twice each time in cold water containing no chemicals for 5 min. Test specimens rinsed after second washing were wrung softly. Then, similarly to the first and second situations, test specimens were softened and dried in a dryer

Cyclic tensile test was carried out applying the method of established load. For cyclic tensile of test specimens, tensile machine “Tinius Olsen” was employed. According to the Kawabata Evaluation System used for the fabrics [18], tensile force P of 20 N was applied. Referring to the investigations carried out by other authors [8], test specimens were subject to 100 fatigue cycles. Tensile speed (12.55 mm/s) was selected according to a human dynamic movement.

Test specimens with respect to fabric thread slippage in the fabric were shot by digital camera “Canon Ixus 60”, the lens axis whereof is in the one centreline with the place of stitching. Seam gap was measured applying “Corel Draw Software Package” with accuracy of 0.1 mm. Variation coefficient ranged from 3.8 % to 9.9 %.

3. RESULTS AND DISCUSSION

Referring to the standard with respect to establishing fabric thread slippage in the fabric [15], tensile force in test specimens depends on surface density. Therefore, change in surface density of fabrics after the processes of industrial washing has been established first of all (Table 3). The obtained results have demonstrated that the greatest change was observed in surface density of fabric C3 during treatment of tests specimens by industrial washing method I, i. e. from 149 g/m^2 to 162 g/m^2. Industrial washing method II has made the greatest influence on change in surface density of fabrics C3 and C4. During application of industrial washing method III, surface density of fabrics C4 and C5 has increased 11 % and 13 % respectively. The results have shown that change in surface density (up to 3 %) of fabric C2 was the lowest during industrial washing in all three cases.

Table 3. Influence of industrial washing on surface density, g/m^2

Fabric code	Surface density, g/m^2			
	Control test specimens	Industrial washing code		
		I	II	III
C1	219	228	222	236
C2	130	134	131	129
C3	149	162	156	155
C4	161	160	172	178
C5	250	259	252	283

According to the carried-out analysis of research results, linen fabrics after the process of industrial washing show the tendency of decreasing seam gap d in the direction of warp with increase of warp and weft thread density P (Fig. 1). The lowest dependence ($R = 0.53$) between the values of weft thread density and seam gap has been observed in the control test specimens (Fig. 1, b), whereas the greatest dependence ($R = 0.86$) has been demonstrated by the test specimens subject to industrial washing method III (Fig. 1, a).

Analysis of the obtained results has revealed that the lowest resistance to warp thread slippage was demonstrated by fabric C5. The gap observed between warp threads was 2.6 mm. Besides, warp threads of the aforesaid fabric have shown the lowest resistance to slippage even after cyclic tensile, i. e. the seam gap in control test specimens amounted to 3.7 mm. Fabric C5 has the greatest surface density among all the fabrics under investigation, however, it features low thread density in the directions of warp and weft compared to other fabrics. Before the process of industrial washing, the greatest resistance to warp thread slippage has been observed in test specimens of fabric C3. In this situation, the seam gap amounted to 0.8 mm (Fig. 2, a), and to 1.3 mm after cyclic tensile (Fig. 2, b). Evaluation of the obtained results has revealed that the lowest gap between weft threads in control test specimens was also observed in fabric C3 and amounted to 0.7 mm. After cyclic tension in this direction, however, the gap has increased as much as ~357 % and amounted to 3.2 mm. The aforesaid change in the seam gap is the greatest one among all the test specimens under investigation.

Therefore, the carried-out analysis of results has demonstrated that cyclic tensile made no essential influence on the seam gap between warp threads in most control test specimens. Slightly different results have been shown by investigation of the seam gap between weft threads. In the present situation, the seam gap after cyclic tensile has increased on the average from 50 % to 357 %. Such tendencies in this direction could be explained by lower density of weft threads. Similar results were obtained by others authors [6], namely slippage increase with decrease density of weft threads.

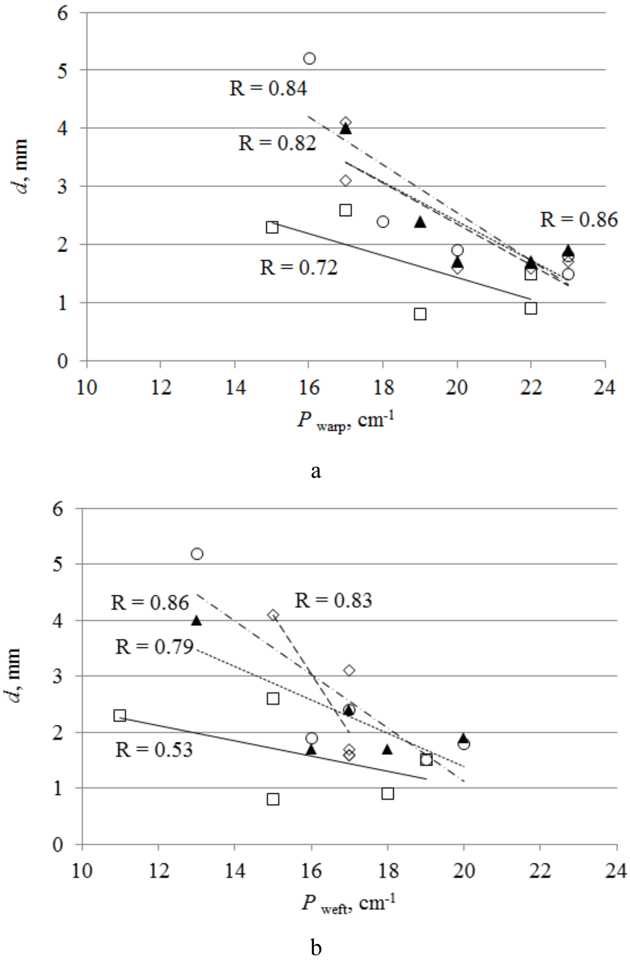
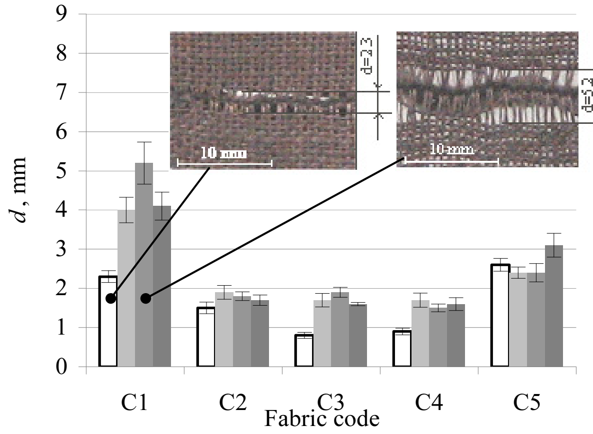


Fig. 1. Dependence of seam warp thread gap d on density of warp threads P_{warp} (a) and weft threads P_{weft} (b) when □ – control test specimens; ▲ – industrial washing method I; ○ – industrial washing method II; ◇ – industrial washing method III

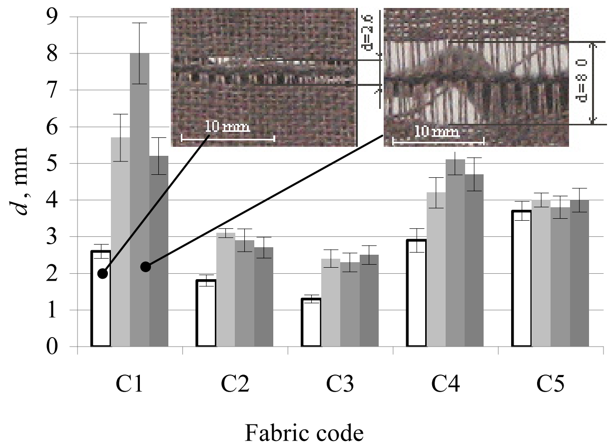
After industrial washing of test specimens, the aforesaid finishing in most cases has been established to impair resistance of analysed fabric threads to slippage, i. e. the seam gap has increased from 20 % to 100 % in most situations. According to the carried-out analysis of results, any industrial washing should be not recommended to fabric C1. The seam gap between warp threads (Fig. 2, a) has increased almost twice (from 2.3 mm to (4 ÷ 5.2) mm) and is the greatest among all the fabrics under investigation.

In the direction of weft in the aforementioned fabric (Fig. 3, a), the defect under investigation has also been the greatest. In this example, the seam gap between weft threads of fabric C1 has increased more than three times (from 0.8 mm to 2.7 mm) after washing. Fabric C5 shall also be mentioned as industrial washing has made no significant influence on slippage of threads along the seam, even reducing the present assembling defect in most cases,

i. e. the gap of the seam has decreased from 6 % to 28 %. However, a significant defect with respect to the seam gap was observed in fabric C5 even before industrial washing, therefore, the aforesaid decrease is not sufficient to obtain a high-quality seam.



a

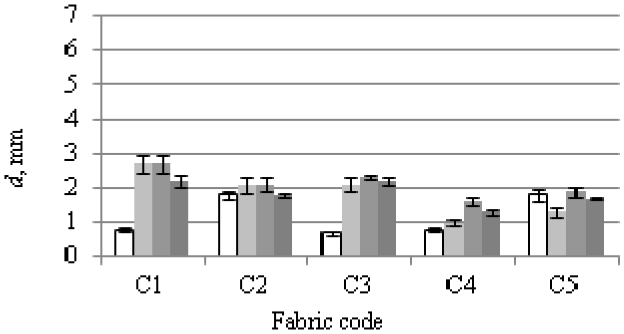


b

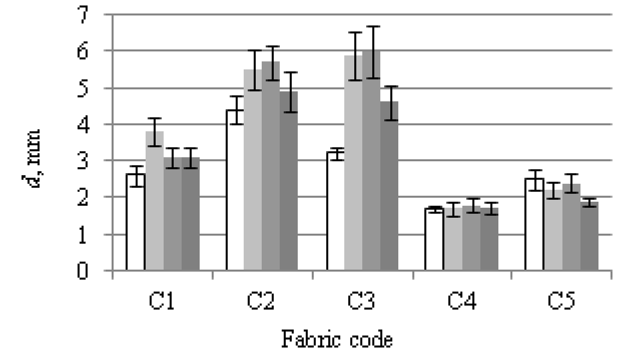
Fig. 2. Seam gap *d*, mm between warp threads prior (a) and post (b) cyclic tensile when ☐ – control test specimens; ☐ – industrial washing method I; ☐ – industrial washing method II; ☐ – industrial washing method III

As analysis of the obtained results and assessment of errors show, all the applied methods of industrial washing have been established to make similar influence on resistance of fabrics to thread slippage and no significant differences have been observed.

Complex assessment of the influence made by industrial washing and cyclic tensile on the seam gap has illustrated that resistance of the fabrics under investigation to slippage of threads was lower in washed test specimens compared to one in control test specimens. Among all the variants analysed, the greatest seam gap, i. e. of 8 mm, after cyclic tensile has been demonstrated by the test specimens of fabric C1 treated by industrial washing method II. After cyclic tensile, the seam gap between warp threads has increased more than twice in test specimens of linen fabric C4. Slightly lower values have been observed for fabric C5; in this case, the seam gap between warp threads has increased from 30 % to 67 % (Fig. 2, b). The greatest seam gaps between weft threads have been demonstrated by fabrics C2 and C3. In the aforementioned two situations, the seam gap has increased from 110 % to 180 % (Fig. 3, b). Hence, research results have shown that most cases after cyclic tensile demonstrated significant increase in the seam gap.



a



b

Fig. 3. Seam gap *d*, mm between weft threads prior (a) and post (b) cyclic tensile when ☐ – control test specimens; ☐ – industrial washing method I; ☐ – industrial washing method II; ☐ – industrial washing method III

The carried-out analysis has illustrated that for complex investigation of the influence made by industrial washing and cyclic tensile on the seam gap value of linen fabrics taking into account operational performances of garments, industrial washing method III is recommended due to the reason that it leads to the lowest change in the seam gap value after cyclic tensile in the most cases under research. Generalisation of the obtained results allows stating that industrial washing should not be applied to fabric C1. For fabrics C2 and C3, splitting in the direction of weft is not recommended due to the reason that the greatest thread slippage along the seam may be observed in this direction in the process of wear. Examination of the obtained results has also revealed that higher quality and greater durability is characteristic of garments from fabrics C4 and C5 when assembling of pieces is made in the direction of weft.

The analysis of the results obtained by other authors' shows, that it is important to investigate the influence of exploitation on seam slippage [6, 7, 10]. The researches have shown, that in most cases, the influence of exploitation on the warp threads slippage is less than the weft threads slippage. It is necessary to keep in mind these facts in the product development and exploitation processes. Hence, analysis of finishing and operational factors as well as evaluation of the influence thereof on the defect under investigation is very important in order to assess thread slippage along the seam.

4. CONCLUSIONS

The research has demonstrated that industrial washing decreased resistance of linen fabrics to thread slippage along the seam in most cases. Variation value was very different ranging from 6 % to 238 %. In the fabrics under investigation, thread resistance to slippage has decreased even more after cyclic tensile of test specimens. Compared to the test specimens having experienced no fatigue, variation value has ranged from 12 % to 357 %.

The carried-out investigation has demonstrated that the greatest slippage of warp threads along the seam, prior and post cyclic tensile, was observed in the fabrics with the lowest density of warp and weft threads. In the direction of weft, a similar tendency has not been established.

REFERENCES

1. **Kalaoglu, F., Binnaz Meric, B.** Investigation of the Performance of Linings *International Journal of Clothing Science and Technology* 17 (3/4) 2005: pp. 171 – 178. http://dx.doi.org/10.1108/09556220510590867
2. **Bačkauskaitė, D., Daukantienė, V.** Investigation of Wear Behaviour of Sewn Assemblies of Viskose Linings *Materials Science* (*Medžiagotyra*) 17 (2) 2011: pp. 155 – 159.
3. **Yucel, O.** Seam Efficiency and Slippage in Linen Fabrics *Tekstil* 54 (10) 2005: pp. 497 – 503.
4. **Behera, B. K., Chand, S., Singh, T. G., Rathee, P.** Sewability of Denim *International Journal of Clothing Science and Technology* 9 (2) 1997: pp.128 – 140. http://dx.doi.org/10.1108/09556229710168261
5. **Bačkauskaitė, D., Daukantienė, V.** The Change of Seams' Slippage during their Exploitation *Baltic Polymer Symposium* 2007: pp. 161 – 165.
6. **Gürarda, A., Meriç, B.** Slippage and Grining Behaviuor of Lockstitch Seams in Elastic Fabrics under Cyclic Loading Conditions *Tekstil ve Konfeksiyon* 1 2010: p. 65 – 69.
7. **Domingues, J. P., Manich, A. M., Sauri, R. M., Barella, A.** Assembling Textile Structures: Wear Simulation *International Journal of Clothing Science and Technology* 9 (1) 1997: pp.75 – 87. http://dx.doi.org/10.1108/09556229710157894
8. **Webster, J., Laing, R. M., Enlow, R. L.** Effects of Repeated Extension and Recovery on Selected Physical Properties of ISO-301 Stitched Seams: Part II: Theoretical Model *Textile Research Journal* 68 (12) 1998: pp. 881 – 888. http://dx.doi.org/10.1177/004051759806801202
9. **Kenan Yildirim.** Predicting Seam Opening Behavior of Woven Seat Fabrics *Textile Research Journal* 80 (5) 2010: pp. 472 – 480.
10. **Daukantienė, V., Lapinskienė, M.,** Influence of the Deformation Mode on Seam Slippage in Woven Fabrics *Fibers and Polymers* 13 (8) 2012: pp. 1086 – 1093.
11. **Pasayev, N., Korkmaz, M., Baspinar, D.** Investigation of the Techniques Decreasing the Seam Slippage in Chenille Fabrics: Part 1 *Textile Research Journal* 81 (20) 2011: pp. 2075 – 2081. http://dx.doi.org/10.1177/0040517511413321
12. **Rogina-Car, B., Brnada, S., Kovačević, S.** Impact of Fabric Weave and Density on Thread Slippage in Stiched Seam *6th International Textile, Clothing & Design Conference – Magic World of Textiles* 2012: pp. 412 – 416.
13. **Group, A.** Importance of Seam Quality for the Quality of Sewn Products *Tekstil* 58 (10) 2009: pp.: 507 – 511.
14. Standard LST ISO 3801:1998. Textiles. Woven Fabrics. Determination of Mass per Unit Length and Mass per Unit Area. 1998: p 12.
15. Standard LST EN ISO 5084:2000. Textiles - Determination of Thickness of Textiles and Textile Products (ISO 5084:1996). 2000: p 5.
16. Standard LST EN 1049-2:1998. Textiles – Woven Fabrics – Construction – Methods of Analysis – Part 2: Determination of Number of Threads per Unit Length (ISO 7211-2:1984 modified). 1998: p 11.
17. Standard LST EN ISO 13936-2. Textiles – Determination of the Slippage Resistance of Yarns at a Seam in Woven Fabrics – Part 2: Fixed Load Method (ISO 13936-2:2004). 2004: p 11.
18. **Kawabata, S., Masako Niwa, Ito, K.** Recent Progress in the Application of Objective Measurement to Clothing Manufacture. Textile Objective Measurement and Automatization in Garment Manufacture. Elis Harwood Limited. 1991: pp. 81 – 105.

Presented at the National Conference "Materials Engineering 2012"
(*Kaunas, Lithuania, November 16, 2012*)