ISSN 1392–1320 MATERIALS SCIENCE (MEDŽIAGOTYRA). Vol. 18, No. 2. 2012

Investigation of the Strength of Textile Bonded Seams

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crossref http://dx.doi.org/10.5755/j01.ms.18.2.1922

Received 04 October 2010; accepted 25 May 2011

The strength of the textile bonded seams was analyzed. Two or more fabric layers joining are based on use of base layers structural properties and thermoplastic properties of adhesive film used for bonding. Five commercial produced fabrics of different structure (woven, knitted, laminate) and fiber content (polyester, cotton, flax) were used in this experiment. Thermoplastic polyurethane film was transferred from the base of silicone to fabric using 160 °C temperature and 10 seconds pressing duration. Fabric layers were bonded using 180 °C temperature and 30 seconds pressing duration. The strength of textile bonded seams was investigated using four different bond types, in order to determine method suitable for the analyzes of bonded seams of knitted fabrics and method suitable to analyze woven fabrics.

Keywords: thermoplastic film, bonded seam, peeling.

INTRODUCTION

New design possibilities have opened up as a result of Sewfree's ability to permanently bond an almost unlimited range of materials. Different technologies of pasting and welding are used for thermoplastic bonding of textile layers. It allows the elimination of sewing for many applications, including seams, hems, zippers, pockets and patches. By using adhesive films designers may perfect the technology of garments and improve their construction. Sewfree bonds bring both aesthetic and economic benefits. Bonded garment technology allows for a seamless look and feel, moreover, bonded seam can be waterproof [1]. As a rule bonded garments weigh less than sewn ones.

Adhesives are widely used in textile industry for bonding layers of materials or fibres together [2–4], application of protective layers of coated fabrics [5–7], carpet backing [8, 9], application of decorative finishes [10].

Bonded seams are developed by BEMIS company for the textile industry [11]. The thermoplastic materials can be incorporated into the fabric or there is a wide range of films, tapes, nets and even coated threads that can be incorporated between the layers of non-thermoplastic materials. However, ultrasonic [12, 13] and radio frequency welding can also be used for fabric bond.

Quality of the joined layers depends on their bonding parameters such as temperature, pressure intensity and pressing duration [14]. In order to obtain particular bond, correct parameters must be chosen. The melting point of thermoplastic film needs to be not too high, because it affects the dimensional stability, color and handle of the fabric. Again, too low temperature can be the reason of the bond failure [15]. Some thermoplastic materials used for textile layers bonding have additional layer of silicone paper. Therefore the two stage bonding has to be used [16].

The particular demands that a fabric bond must satisfy make the replacement of conventional thread stitching very difficult: adequate bond strength, resistance to washing and cleaning, no staining or discoloration, no spoiling of texture, maintain breathability, rapid setting [17].

The bond strength between substrate and adhesive depends on their chemical nature. If the substrate has an irregular surface, then the adhesive may enter the irregularities prior to hardening. This simple idea gives the mechanical adhesion theory, which contributes to adhesives bonds with porous materials such as textile. The chemical adhesion theory invokes the formation of covalent, ionic or hydrogen bonds [18]. It is also worth mentioning that bonding strength depends on fabrics treatment, too [16].

The previous our experiments have shown that during delamination of bonded seams the fabrics' structure in most cases changes as seams deform due to the external forces [16]. Especially large specimens' deformation was observed during knitted fabrics bonded seams delamination. In order to determine influence of fabrics deformation on strength of adhesive joints, the several types of different specimens with bonded seams were investigated in this work. The main purpose of this work was to choose suitable bonded seam type and method for its delamination which allow to investigate fabrics with wide range of their structural elasticity.

EXPERIMENTAL

Five commercial fabrics of different structure and fiber content were used in this experiment. Table 1 provides basic information about the tested materials [19, 20].

The textile specimens were cut in lengthwise direction. Four different bonded seams were investigated (Fig. 1).

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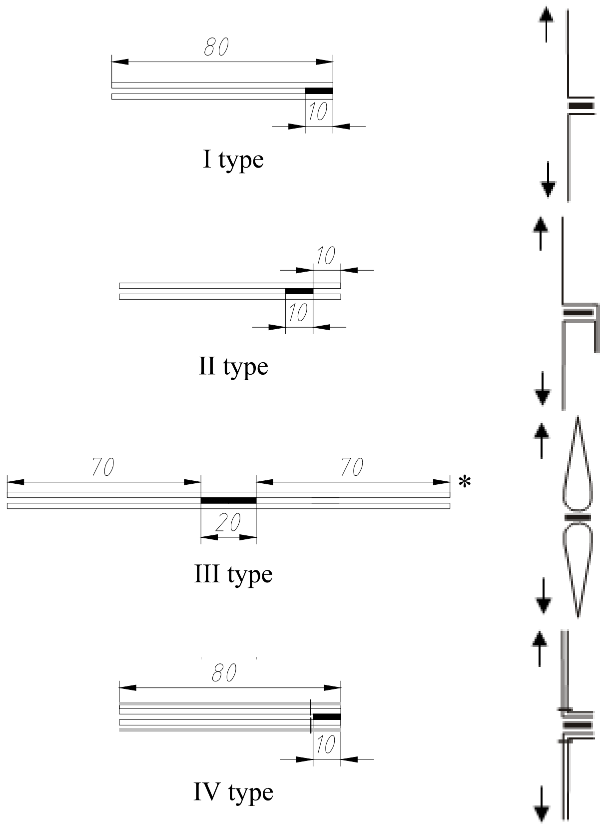
Table 1. The characteristics of investigated fabrics

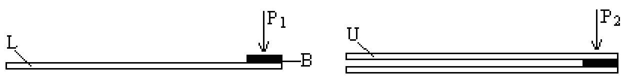
Fabric	Fiber content	Density, dm^{-1}		Surface density, g/m^2	Thickness, at p = 0.19 MPa, mm [21]
		Weft /Course	Warp/Wale		
K (woven)	Polyester	600	380	205	0.73
C (knitted)	Polyester	240	200	250	0.83
D* (laminate)	Polyester (woven) Polyester (knitted)	700 170	380 170	253	0.79
L (knitted)	Cotton	160	120	210	0.92
N (knitted)	Cotton	180	160	105	0.61

Note: * – three layer laminate: polyurethane film between knitted and woven layers.



a b

Fig. 1. Schemes of bonded seams (a) and their fixing in tension machine (b)



a b

Fig. 2. Principle scheme of fabric specimen layers (L and U) bond using adhesive film (B)

The specimens were prepared when thermoplastic tape:

1) coincides with the edges of textile tapes,
2) draw 10 mm from the edge of the textile tapes,
3) draw 70 mm from the edge of the textile tapes,
4) coincides with the edges of both textile tapes which were reinforced with additional glued and sewed layers.

The dimensions of specimens were: (80 × 25) mm for the first and the fourth seams, (90 × 25) mm for the second seam and (160 × 25) mm for the third seam. Two textile tapes were bonded together using BEMIS thermoplastic polyurethane film with silicone base. The dimensions of thermoplastic film specimens were: (10 × 25) mm for the first, the second and the fourth seams, (20 × 25) mm for the third seam. The thickness of film layer was 0.09 µm.

Due to the usage of silicon paper the specimen's bonding was performed with Stirovap press in two stages using different bonding conditions.

1 stage. Thermoplastic film was transferred onto right specimen's side at temperature 160 °C for 10 seconds pressing duration (Fig. 2, a). The silicon paper was peeled after 5 minutes.

2 stage. The second fabric layer was bonded with first layer using 30 seconds pressing duration at temperature of 180 °C (Fig. 2, b).

During both bonding stages the same pressure of 0.037 N/mm^2 was used.

The bonding conditions were chosen according to the properties of thermoplastic films and tested fabrics. The softening point of thermoplastic film is comparably low – only 72 °C, and heat resistance of tested fabrics from polyester and cotton fibres reaches 200 °C and more.

The pressing duration of thermoplastic films and specimens was chosen considering the economic aspects. Before the tests all specimens were kept at standard conditions of 65 % RH and temperature of 20 °C.

Textile bonded seams were investigated using characteristics as average peel strength F (N/mm), seam deformation degree during delamination a (%) and peel length l (mm) (Figs. 3, 4). Due to the geometrical parameters of the third seam, F and l values were divided by two.

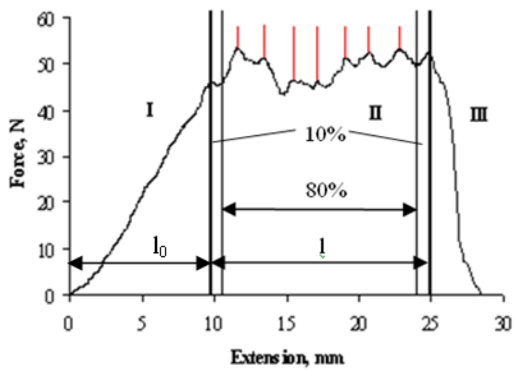
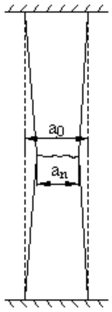


Fig. 3. Diagram of textile bonded seam strength during delamination: I – strain zone, II – peeling zone, III – end of peeling

The "Tinius Olsen H10KT" tension machine was used for seams delamination [22]. 100 mm distance between upper and bottom grips was chosen. The speed of the upper grip was kept at 100 mm/min. Experimental data of peel was received from values variation of strength. The diagram of textile bonded seam strength was divided into three zones. In zone I specimen only strains, in zone II delamination process takes place and specimen's layers begin to peel. The peel length was determined from this zone. In zone III specimen's delamination comes to the end. For these reasons only zone II data is used for bonding strength determination. In order to receive average result of bonding strength Fav maximum peaks of diagram zone II were measured, using 80 % of the central part [23]. In average 20 peaks were determined in the curve of bond strength (Fig. 3).

The length of zone I (l_0) characterizes the degree of fabric's extensibility before seam delamination.



$$a = \frac{a_0 - a_n}{a_0} \cdot 100\%$$

a b

Fig. 4. Principle scheme of bonded seam specimen deformation during delamination (a) equation to calculate degree of seam deformation during delamination: a_0 – initial width of specimen (25 mm), a_n – specimens width during delamination, mm (b)

Four specimens for each bond type were tested. The coefficient of variation of test results ranged from 1.0 % to 14.5 %.

In order to determine the infiltration of thermoplastic film into upper (U) and lower (L) layers of specimen, the scanning electron microscope (SEM), FEI Quanta 200 FEG (KTU) was used. The view of investigated textile edges surface was zoomed by the factors of ×500 using the accelerating voltage of 10 kV.

RESULTS AND DISCUSSIONS

Investigation results have shown that due to zone I length l_0 tested fabrics seams may be divided into three groups. The highest extensibility l_0 was in the case of first and second type of bonded seams and it reached till 15 mm. The medium extensibility was determined for third bonded seam and it reached till 10 mm. In this case non bonded textile tapes were 35 mm long from the bonded part. As for the fourth bonded seam it is reinforced with additional glued and sewed layers (Fig. 1). In this case zone I is shortest and reached only 5 mm. The result of II zone length indicated that though the bonded seams width in all cases is 10 mm the distance of their delamination is different. It was determined that length of peel zone II range from 15 mm to 35 mm for first and second bonded seams, from 6 mm to 25 mm for the third seam and from 5 mm to 20 mm for the fourth seam. The different lengths of zone II point out to the various degree of bonded seams deformation during specimens' extension. Short III zone is typical for all bonded seams (2 mm) (Fig. 3).

The minimal peel strength for bonded apparel fabrics recommended by company BEMIS is 0.63 kg/cm [10]. As seen in Fig. 5 the values of the bonded seams strength F for tested in this work fabrics ranged from 0.42 N/mm to 4.76 N/mm. The highest values of bonding strength are obtained in case of the laminate D. The biggest values F scattering depending on bonded seam structure and delamination conditions was determined for knitted fabric C (45 %) and the lowest in case of laminate D – 22 %.

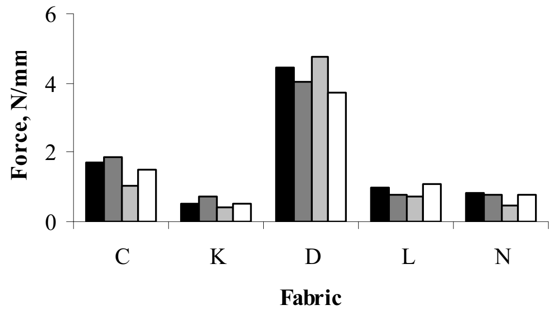


Fig. 5. Peel strength of textile bonded seams: ■ – the first seam, ■ – the second seam, C, ■ – the third seam, □ – the fourth seam

It is known that the surface texture has a significant effect on the fabrics adhesion. The smooth surface guaranty in most cases better adhesive bond than an uneven surface [23]. The bonding strength of textile fabrics depends on the contact area between adhesive (thermoplastic film) and substrate (fabric) too. Textile is made of threads, wherefore its surface is irregular and contact area with thermoplastic film may depend on fabric structural characteristic such as density and thread thickness. Because of uneven bond, the strength of bond decreases and peels uneven. Surface irregularity increase number of peaks and differences between maximum and minimum values of peaks. (Fig. 3).The cross views of bonded specimens are presented in Figs. 6 and 7.

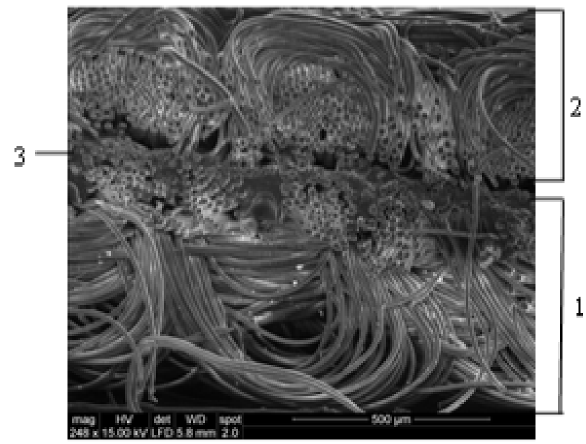


Fig. 6. The SEM of knitted fabric C bonded seam: 1 – L specimens layer, 2 – U specimens layer, 3 – thermoplastic film

Analysis of bonded seam strength diagram showed different intensity of strength range during delamination. This range was estimated by variation coefficient of strength highest peaks (Fig. 8). As it can be seen the values of the variation coefficient ranged from 2.5 % to 12 %. The highest coefficient of variation is obtained in the case of the first seam of fabric K and is equal to 12 %, because the values of the maximum peaks enlarge during peeling. The lowest coefficient of variation is obtained in the case of the third seam of laminate D and is equal to 1.8 %. With reference to variation coefficient values it can be stated that adhesion bond is more even for laminate D and knitted fabric L and less even for knitted fabric C, K and N.

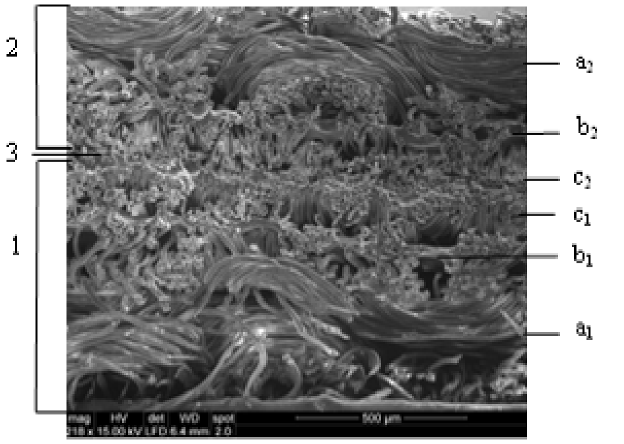


Fig. 7. The SEM of laminate D bonded seam: 1 – L specimens layer: a_1 – knitted layer, b_1 – polyurethane film, c_1 – woven layer; 2 – U specimens layer: a_2 – knitted layer, b_2 – polyurethane film, c_2 – woven layer; 3 – thermoplastic film

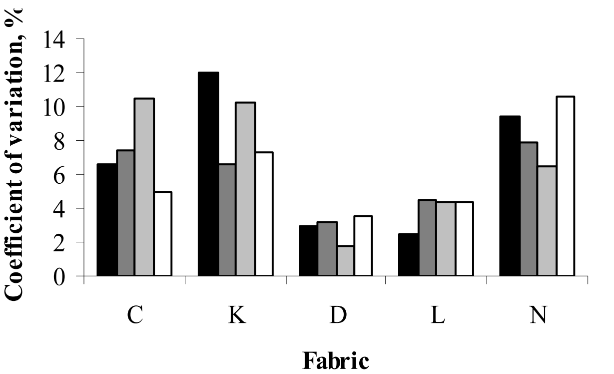


Fig. 8. Strenght peak variation of textile bonded seams: – the first, – the second, C, – the third, – the fourth

Bonding strength depends not only on thermoplastic film and fabric adhesion. The structural mobility of fabric during delamination is important too. During fabric's extension, increases not only specimen's length but also decreases it's cross measurements. According to [24] the transversal fabrics deformation may reach till 80 % and depends and on the extension force direction and fabric's structural characteristics. Regarding to it, the measurements of specimen width with bonded seam without it were made and deformation degree of seams during delamination was calculated (Fig. 4). In case of woven fabric K the width did not changed, because its extensibility is low: l_0 range from 2.0 mm to 3.6 mm. The biggest differences are estimated in case of knitted fabric N. The main reason for these results is high fabric extensibility: l_0 range from 7.4 mm to 15.0 mm (Fig. 9, d).

In case of the third seam width of the specimens decrease: 20 % for knitted fabrics C and L, 12 % for the knitted fabric N. There was no change in width of specimens of the laminate D and weaved fabric K. In case of the second seam width of the specimen decreased: 12 % for knitted fabric C, 20 % for knitted fabric L, 16 % for the knitted fabric N. Again, there was no change in width of specimens of the laminate D and weaved fabric K. In case of the first seam width of the specimen decreased: 12 % for knitted fabric C, 16 % for the knitted fabric L, 24 % for the knitted fabric N, 28 % for the laminate D. There was no change in width of specimens of weaved fabric K. In case of specimen without seam, specimens' width decreased more than two times (Fig. 8).

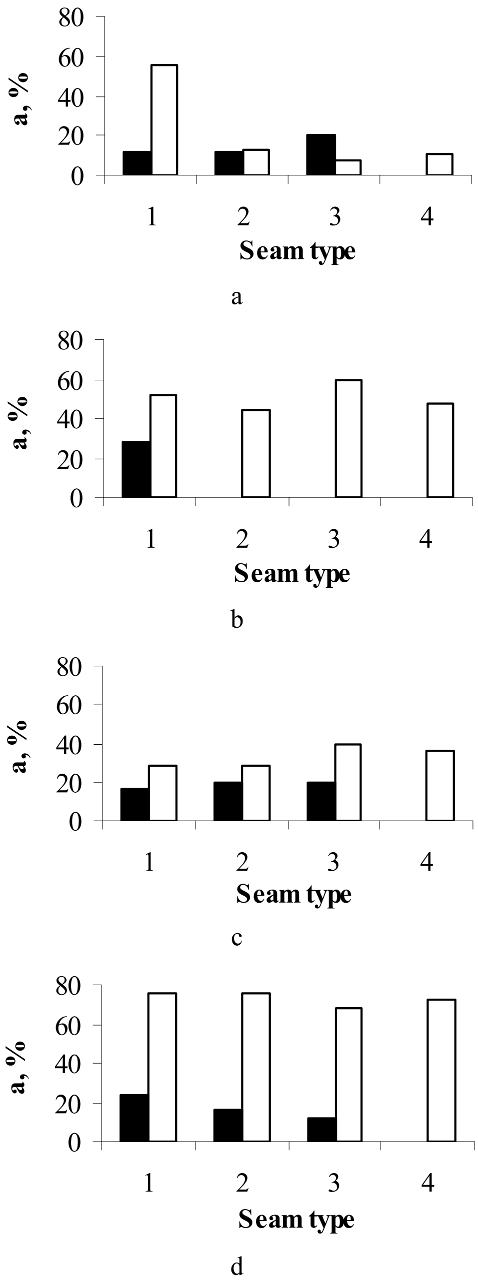


Fig. 9. Width change of textile spesimen with bonded seams (black) and without it (white): knitted fabric C (a), laminate D (b), knitted fabric L (c), knitted fabric N (d)

During delamination of the fourth bonded seam specimens' width did not changed. But this seam is not suitable to investigate knitted fabrics, because when the strength force is more then 30 N, the additional layers came unglued and fabrics began to extend again (Fig. 10).

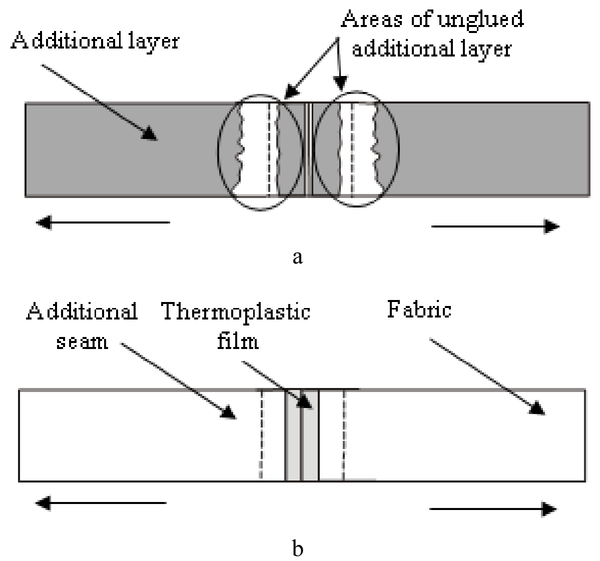


Fig. 10. Delamination scheme of the fourth seam: front side (a), back side (b)

CONCLUSIONS

1. Bonding strength of textile depends on bearing surface, therefore it is necessary take in account of fabric surface characteristics.
2. It was determined, that during the delamination of 10 mm width bonded seam, because of fabric structure deformation, its peeling length *l* enlarges from 11.2 mm to 35.5 mm. Bigger values of *l* are typical for knitted fabrics and lesser – for laminate and woven fabric.
3. It was determined, that transverse deformation degree of bonded seam during delamination range from 0 % to 76 %.
4. The most suitable specimen for bond strength analysis of woven, knitted fabrics and laminate is specimen with bonded seam of 20 mm width situated at 70 mm from the both edges of the textile tapes, because width of seams vary least.

REFEERENCES

1. **Jeong, W. Y., Kook, S. A.** Mechanical Properties of Breathable Waterproof Fabrics *Fibers and Polymers* 5 (4) 2004: pp. 316 – 320.
2. **Bhat, G. S., Jangala, P. K., Spruiell, J. E.** Thermal Bonding of Polypropylene Nonwovens: Effect of Bonding Variables on the Structure and Properties of the Fabrics *Journal of Applied Polymer Science* 92 (6) 2004: pp. 3593 – 3600.
3. **Gorchakova, V. M., Batalenkova, V. A., Izmailov, B. A.** Autoadhesive Bonding of Modified Polyester Fibres *Fibre Chemistry* 35 (1) 2003: pp. 39 – 40.
4. **Yang, C., Gao, P., Xu, B.** Investigations of a Controllable Nanoscale Coating on Natural Fiber System: Effects of Charge and Bonding on the Mechanical Properties of Textiles *Journal of Material Science* 44 (2) 2008: pp. 469 – 476.
5. **Sen, A. K.** Coated Textile – Principles and Applications, CRS Press Taylor and Francis Group, 2001, 225 p.
6. **Darwisha, N. A., El-Wakila, A. A., Abou-Kandil, A. I.** Effect of Bonding Systems and Antioxidants on the Adhesion between EPDM Rubber and Polyester Fabric *International Journal of Adhesion and Adhesives* 29 (7) 2009: pp. 745 – 749.
7. **Comyn, J.** Surface Treatment And Analysis For Adhesive Bonding *International Journal of Adhesion and Adhesives* 10 (3) 1990: pp. 161 – 165. http://dx.doi.org/10.1016/0143-7496(90)90099-J
8. **Hepburn, C., Aziz, Y. B.** The Bonding Of Polyaramid Fibres To Rubber *International Journal of Adhesion and Adhesives* 5 (3) 1985: pp. 153 – 159. http://dx.doi.org/10.1016/0143-7496(85)90058-2
9. **Packham, D. E.** Handbook of Adhesion. Second edition. Willey & Sons Ltd, 2005: 638 p.
10. BEMIS Adhesive Films, Coatings, Specialty Films and Seam Tape http://www.bemisworldwide.com/ (accessed 08 May 2010). http://dx.doi.org/10.1002/0470014229
11. **Wulfhorst, B., Gries, T., Veit, D.** Textile Technology. Hanser Gardner Publications Inc., 2006: 320 p.
12. **Vujasinovic, E., Jankovic, Z., Dragcevic, Z., Petrunic, I., Rogale, D.** Investigation of the Strength of Ultrasonically Welded Sails *International Journal of Clothing Science and Technology* 19 (3 – 4) 2007: pp. 204 – 214.
13. **Pocius, A. V.** Adhesion and Adhesives Technology. 2002: 319 p.
14. **Packham, D. E.** Handbook of Adhesion. Second edition. Willey & Sons Ltd, 2005: 638 p. http://dx.doi.org/10.1002/0470014229
15. **Jakubcioniene, Z., Masteikaite, V.** Investigation of Textile Bonded Seams *Materials Science* (*Medžiagotyra*) 16 (1) 2010: pp. 76 – 79.
16. **Gierenz, G., Karmann, W.** Adhesives and Adhesive Tapes. Wiley VCH Verlag GMbh, 2001: 113 p.
17. **Cognard, P.** Adhesives and Sealants. General Knowledge, Application Techniques, New Curing Techniques. Volume 2. 2006: pp. 2, 41 – 42.
18. LST ISO 3801: 1998. Textiles. Woven Fabrics. Determination of Mass per Unit Length and Mass per Unit Area, 12 p.
19. 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), 11 p.
20. Fabric Assurance by Simple Testing, SCIRO Division of Wool Technology, FAST Instruction Manual, Australia, 1997: 6p.
21. LST EN ISO 13934-1:1999. Textiles – Tensile Properties of Fabrics – Part 1: Determination of Maximum Force and Elongation at Maximum Force Using the Strip Method.
22. LST EN ISO 6133:1998(E). Rubber and Plastic – Analysis of Multipeak Trace Obtained in Determinations of Tear Strength and Adhesion Strength.
23. **Simmons, T. R., Runyan, D., Liu, K. K. Y., Paroli, R. M., Delgado, A. H., Irwin, J. D**. Effects of Welding Parameters on Seam Strength of Thermoplastic Polyolefin (TPO) Roofing Membranes *Proceeding of the North American Conference on Roofing Technology* pp.56 – 68.
24. **Klevaityte, R., Masteikaite, V.** Anistropy of Woven Fabric Deformation after Stretching *Fibres and Textiles in Eastern Europe* 16 (4) 2008: pp. 52 – 56.

Presented at the International Conference
"Baltic Polymer Symposium'2010"
(*Palanga, Lithuania, September 8–11, 2010*)