ISSN 1392–1320 MATERIALS SCIENCE (MEDŽIAGOTYRA). Vol. 17, No. 4 2011

Textiles Objective and Sensory Evaluation in Rapid Prototyping

Eugenija STRAZDIENE *

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

crossref http://dx.doi.org/10.5755/j01.ms.17.4.778

Received 15 September 2011; accepted 04 November 2011

Most consumer purchases nowadays are driven by sensory attraction and good feeling. From this standpoint textile and fashion industries need new methods to evaluate fabric quality and to respond to consumer expectations. Recently the implementation of sensory analysis in the process of material characterization has drawn much international attention. So, the aim of the research was to find dependencies between the results of sensory analysis and objective fabric behaviour evaluation performed using KES-F and Griff-Tester devices. The later method was developed at Kaunas University of Technology and is based on fabric extraction through a rounded hole, thus describing the behaviour of textile materials and their tactile properties by one complex criterion.

Keywords: textile, objective testing, sensory evaluation.

1. INTRODUCTION

In nowadays globalization new products developed in due time are becoming essential for companies competitive ability and growth. Tendencies of mass customization and rapid prototyping effect manufacturing processes of many consumer products: clothing, haberdashery, footwear, elements of home interior, furniture, etc. [1]. 3D virtual prototyping (2D/3D and 3D/2D transformations, parametric design, etc.) became keystone of these processes. Still problems associated with 3D virtual visualization in respect to applied materials mechanical properties are not yet solved, as well as the possibilities of parametric design of complicated, e. g. human body, spatial shapes [2 – 9]. All this has a significant effect upon the results of consumer's subjective visual perception. On the other hand, the problem remains concerning objective evaluation of textile hand and its relationship with sensory, e. g. tactile, properties of applied materials [10 – 15]. Concerning the later problem significant work was done at Kaunas University of Technology, Faculty of Design and Technologies. Meantime current investigations are mainly aimed to analyse the functions of 3D CAD systems taking into account the effect of materials mechanical properties and to perfect the possibilities of 3D visualization, thus making the preconditions for the application of 3D software in mass customization and rapid prototyping processes.

2. EUROPEAN EXPERIENCE

Several projects were initiated by the European Apparel and Textile Confederation EURATEX taking into account three main development directions pointed out in European Technology Platform, the third of which is – the end of clothing and textile products mass production by shifting it to mass customization strategies. One of such projects was LEAPFROG funded in 2004 by FP6 program (www.leapfrog-eu.org) were special attention was paid for virtual prototyping of clothing and for mass customization processes application. 3D simulation was realised by draping clothing and taking into account mechanical properties of materials and their assemblies. Still final results of the project were not related to consumer's visual perception. Meantime the aim of the second E-TAILOR project (www.euratex.org/content/completed-projects) was different – virtual optimization of clothing construction and standardization of body measurement scales. The aim of HAPTEX (http://haptex.miralab.unige.ch) project, which was also funded by FP6, was to find the relationship between consumer's visual perception of virtual garment and sensory, i. e. tactile evaluation of real textile materials texture. The later problem nowadays is actual and many research works are performed to solve it [16 – 18]. In the case of HAPTEX project mechanical properties of textile materials were defined by special equipment maximal forces of which simulated real wearing loads: KES-F (Kawabata Evaluation System for Fabrics, Japan) and FAST (CSIRO, Australia). It must be noted that both sets of equipment are complex and expensive what makes them inaccessible for small and medium companies. More simple examples exist, e. g. V-Stitcher Fabric Testing Kit or OptiTex Fabric Test Utility, which are applied together with such 3D CAD systems as Modaris 3D Fit; V-Stitcher and 3D Runway Suite. In this respect the research work at Kaunas University of Technology is performed from the other standpoint, i. e. aiming to create the device and to develop the method, which could describe the behaviour of textile materials and their tactile properties by one complex criterion in a departure to KES-F and FAST equipment both of which provide up to 15 different mechanical parameters and make the characterization of textiles behaviour a complicated task. It was expected that with the help of this equipment the differences between fabrics could be distinguished more evidently and easily, especially taking into account sensory evaluation of textiles tactile feeling [27].

*Corresponding author. tel.: +370-37-300201; fax: +370-37-353989.
E-mail address: *eugenija.strazdiene@ktu.lt* (E. Strazdienė)

3. OBJECTIVE AND SENSORY EVALUATION OF TEXTILES

The project "The Development of Spatial Shells: Investigation and Evaluation of Woven Structures Formability and Quality of Construction Assembles" was financially supported by Lithuania State Science and Studies Foundation and was aimed to investigate spatial behaviour of textile materials also at low, wearing level loads [30]. Nowadays the formability of textile material is very important as textile or textile-based composite materials are widely used in clothing and soft furniture production, interior and exterior decoration, in advanced architecture projects. When the forming conditions overcome some critical limits the spatial textile shell achieves an unstable shape, i. e. wrinkles. The availability of the constructional assembles must guarantee the unwrapped design of spatial product, its stability and reliability during exploitation. So the aim of this project was to define the effect of woven structures formability for design processes and 3D visualization of spatial shells geometry [31].

Textile sensory, i. e. tactile properties evaluation is related with such fabric properties as smoothness, softness, rigidity, roughness, thickness, weight, etc [19 – 24]. Recently new tactile evaluation methods of textiles based on pulling process of a disc shaped specimen through a rounded hole were developed and more widely applied for fabrics testing [25 – 26]. For this reason test unit Griff-Tester was created at Kaunas University of Technology. It laid the basis for the project of French-Lithuanian programme of integrated activities "Gilibert" on bilateral cooperation in scientific research and experimental development "New Method for Textile Materials Tactile Properties Evaluation", which was carried out together with Université de Haute Alsace ENSITM. Usually the effect of fabric treatment in industry is evaluated subjectively. In some cases certain mechanical property variations due to finishing treatments can be tested using standard testing methods, but they are far away of representing human evaluation of tactile perception. Thus, the aim of this project was to apply Griff-Tester in real production processes. The obtained data showed that Griff-Tester provides new scientific information that can be associated with the sensory analysis results. The effects of finishing products concentrations were found to be in accordance with the manufacturer's technical specifications. The evaluation of this effect was carried out by two different methods of tactile analysis: objective evaluation with Griff-Tester and sensory evaluation [32].

The other research was aimed to investigate the behaviour of coated plain weave fabrics when their disc shaped specimens are pulled through a rounded hole of Griff-Tester [27 – 29]. The research reveals the differences of textile behaviour from the stand point of tribological properties of tested fabrics, which manifest by the variation of pulling curves *P–H* parameters and by the changes of specimens geometrical shape. The results of the investigations allow to expect that pulling of coated textile through Griff-Tester can be successfully applied to determine anisotropy level and other mechanical properties of such materials.

Pulling tests were performed by Griff-Tester (Fig. 1) mountable on the standard tensile testing machine. It consisted of two transparent plates, replaceable stand with the hole in the centre ($r = 10$ mm) and supporting plate. Spherical punch ($\rho = 5$ mm) with needle type handle was used to pull a rounded specimen ($R = 56.5$ mm) through the hole of the stand.

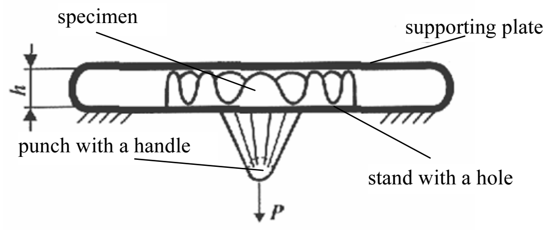


Fig. 1. Schematic view of Griff-Tester device

The investigated coated materials (Table 1) differ from traditional textiles by higher bending rigidity. Such material resistance parameters as maximum pulling force P_{max}; initial slope angle tgα and the performed work *A* were recorded on the basis of *H–P* curves (Fig. 2; Table 2). Textiles behaviour evaluation (including its mathematical approximation) was made on the basis of 4 – 5 images of deformed specimens, captured by digital camera at the intervals of $\Delta H = 10$ mm.

Table 1. Characteristics of tested materials

Material	C-21	C-111	L-20
Composition, 100 %	PA	PA	PES
Coating	PU	silicone	PTFE
Thickness δ, mm	0.11	0.15	0.50
Surface density, g/m^2	95	110	225
Elongation at break l/t$^{*)}$, %	26/29	37/34	56/42
Bending rigidity l/t$^{*)}$, μNm	6.6/3.7	55.0/75.0	49.0/23.0

$^{*)}$ Note: l – longitudinal direction, t – transverse direction.

Table 2. Mechanical parameters of pulling process versus the tested side of the specimen

Material	Tested side	P_{max}, N	tgα	*A*, Ncm
C-21	F R	21.0 ±1.3 72.3 ±5.8	6.50 8.59	9.3 15.6
C-111	F R	28.9 ±1.1 51.8 ±4.6	6.23 9.89	10.6 16.4
L-20	F R	16.6 ±2.5 14.9 ±1.8	2.48 2.78	4.10 4.50

$^{*)}$ Note: F – face side; R – reverse side.

Earlier investigations have revealed that rounded specimens of woven fabrics in pulling process obtain four-leafed shape (math. epicycloid) (Fig. 3, a) while rounded specimens of knitted materials obtain the shape of Cassini

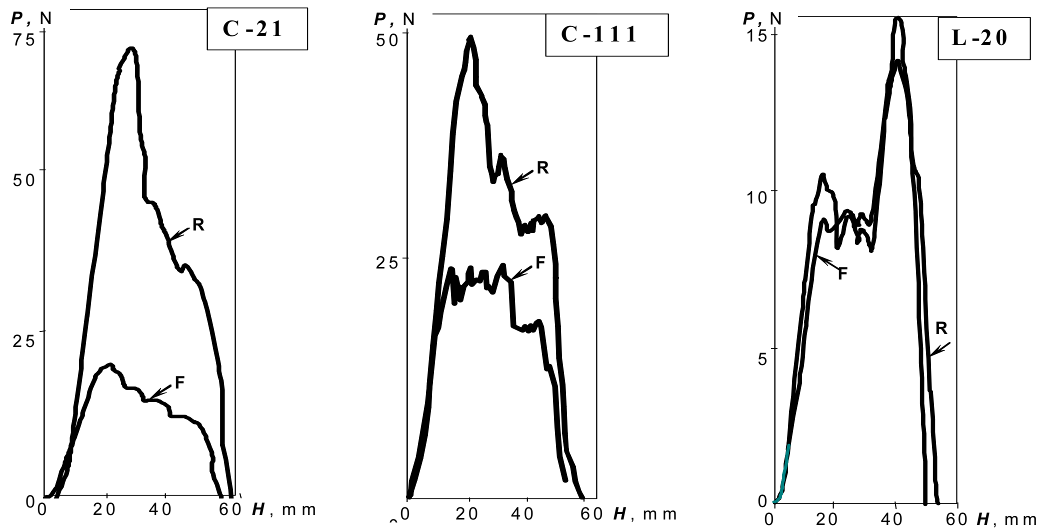
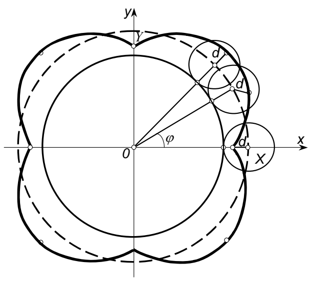
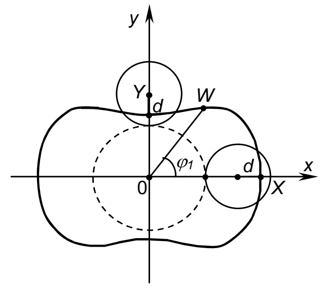


Fig. 2. Pulling curves of tested materials

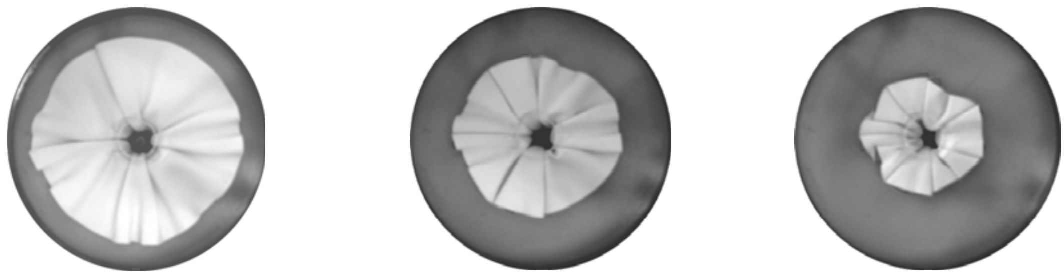


a) epicycloid shape of woven specimen



b) Cassini oval shape of knitted specimen

reverse side R



$H = 10$ mm $H = 20$ mm $H = 30$ mm

c) three stages of L-20 material pulled through a rounded hole

Fig. 3. Typical shapes of specimens pulled through a rounded hole

oval (Fig. 3, b) and they depend upon anisotropy level of tested materials [8]. Meanwhile the investigations with fabric + polymer film systems have shown that the shape of such specimens in pulling through a rounded hole process becomes shapeless and this asymmetricity increases with the increase of pulling height H, i. e. at the end of pulling the shape of the specimen turns into sharp-edged square (Fig. 3, c).

It was defined that H / Rz (pulling height/specimen radius) dependency for all tested materials is linear because of their high rigidity due to which no residual deformations are observed in pulling through a hole process. Also the obtained results allowed to conclude that pulling test performed by Griff-Tester provides new scientific information concerning the analysis of coated textiles behaviour, which is different in respect to the tested side of the material. On the other hand, the behaviour of such materials can be investigated only at low loading which is approximately close to performance, because then the shape of the outer contour of deformed specimen does not loose its regular shape described as sine curve.

Further testing methods were orientated towards sensory analysis and materials evaluation. To study the effect of weave structure, nine fabrics have been selected. The samples were woven with nine classical weft effect patterns on a Jacquard loom. The yarns were 100 % cotton, 14 tex for the warp and 25 tex for the weft. Saturation index was the same for all samples $I = 52$ %. Characteristics of the investigated fabrics are given in

Table 3, where: CFF is the crossing-over firmness factor, and FYF is the floating yarn factor [33]. Two types of instruments for objective measurement of fabrics mechanical properties were used: KES-F automated testing equipment and Griff-Tester device operating together with the standard tensile testing machine. With the later device specimen pulling curve *P–H* (force – deflection) was recorded when disc shaped specimen $R = 56.5$ mm was extracted through a rounded hole $r = 10$ mm of the stand. Distance *h* between limiting plates was selected in respect to the limitation $h = 5.6\delta$, where δ is the thickness of fabric. Values of *r* and *h* parameters were chosen taking into account not only specimen jamming conditions between the limiting plates, but in the pads hole, also. Specimen extraction through a hole velocity was 100 mm/min.

Table 3. Characteristics of tested fabrics

Weave type	No. of weft/cm	No. of warp/cm	Area density g/m²	CFF	FYF
plain	20.9	37.4	124.8	2.00	0.00
3-twill	24.4	38.4	140.0	1.33	0.44
4-twill	26.6	38.4	140.8	1.00	0.75
4-satin	26.6	38.1	141.8	1.00	0.75
5-satin	28.1	40.1	141.6	0.80	0.96
6-satin	29.2	39.0	147.0	0.67	1.11
12-satin	32.5	38.2	147.2	0.33	1.53
waved twill	30.1	38.8	150.2	0.57	1.26
crêpe	24.4	39.0	135.6	*	*

During testing, extraction curves *H–P* were registered on the basis of which three parameters were defined: maximal force P_{max}, slope angle of the initial part of the extraction curve $\mathrm{tg}\alpha$ and extraction work *A*.

Griff-Tester polar diagrams were plotted and area *S* was calculated for each tested material (Figure 4). Relative criterion *Q* was determined as ratio S / S_0, where plain weave was taken as a reference weave S_0. As it is shown in Table 5, *Q* criterion can distinguish different types of weave.

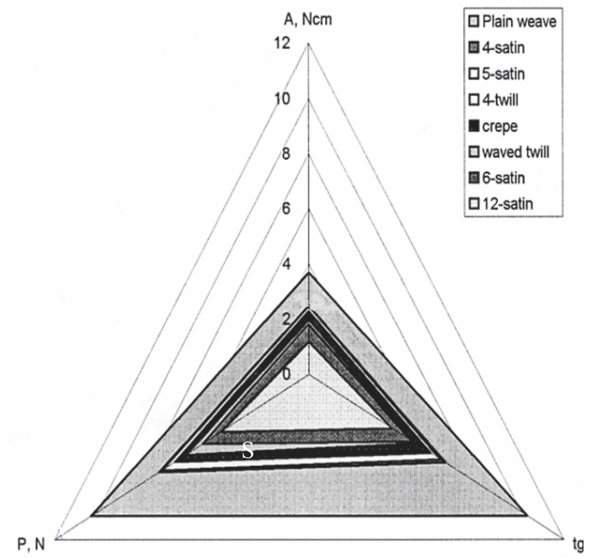


Fig. 4. Principle of polar diagram to define complex criterion *Q*

In the other side sensory analysis was applied to control the quality of investigated materials. Tests were performed at textile laboratory of ENSISA, France [33]. In this research a panel of 10 persons was evaluating sensory criteria. The panel distinguished such attributes as: falling, cold – warm, supple – rigid, responsive and crumple like which showed rather high relationships with shear stiffness: *2HG5*, *2HG*, *G* and bending rigidity: *2HB*, *B* mechanical parameters define by KES-F testing devices. These relationships could be described by linear or power dependencies.

Table 6 highlights the dependencies between complex criterion *Q* and the same sensory attributes. As it was in the previous case these relationships could be described by linear or power dependencies with quite significant coefficients of determination.

Further, comparative analysis was done between Griff-Tester and KES-F mechanical parameters as it is shown in Table 7. Significant dependencies were obtained between *Q* criterion and such KES-F parameters as: shear stiffness (*G*, *2HG*5, *2HG*), bending rigidity (*B*, *2HB*) and compression (T_0, T_M).

Table 4. Coefficients of determination between KES-F mechanical parameters and sensory evaluation attributes

Tactile attributes	KES-F dir.	*2HG5* (N/m)	*2HG* (N/m)	*G* (N/m°)	*B* (Nm^2/m)	*2HB* (Nm/m)	*2HG5* (N/m)	*2HG* (N/m)	*G* (N/m°)	*B* (Nm^2/m)	*2HB* (Nm/m)
		$y = a + bx$					$y = a + bx^c$				
falling	warp	0.887	0.884	0.880	–	–	0.882	0.878	–	–	–
	weft	0.902	0.891	0.886			0.896	–	–		
cold-warm	warp	0.656	0.660	0.694	–	–	0.711	0.713	0.681	–	–
	weft	0.675	0.695	0.710			0.723	0.741	–		
supple-rigid	warp	0.868	0.868	0.853	0.459	0.311	0.910	0.909	0.927	0.997	0.311
	weft	0.889	0.882	0.879	0.787	0.890	0.924	0.921	0.921	0.932	0.898
responsive	warp	0.627	0.629	0.647	0.568	0.180	0.774	0.773	0.832	0.670	0.184
	weft	0.634	0.627	0.618	0.535	0.180	0.767	0.765	0.760	0.857	0.181
crumple like	warp	0.776	0.777	0.734	–	–	0.932	0.933	0.959	–	–
	weft	0.780	0.780	0.766			0.920	0.929	0.924		

Table 5. Characteristics of Griff-Tester extraction process

Weave type	A, Ncm	tgα	P, N	Q
plain	36.77	10.26	10.29	1.00
4-satin	24.87	6.39	7.09	0.44
5-satin	21.61	5.54	6.44	0.34
6-satin	18.20	4.84	5.04	0.23
12-satin	11.73	3.90	4.15	0.14
3-twill	28.08	6.23	7.82	0.49
4-twll	24.65	6.14	6.93	0.41
waved twill	19.79	5.01	5.84	0.28
crepe	22.84	5.70	6.35	0.35

Table 6. Coefficient of determination between complex criterion Q and sensory evaluation attributes

Tactile attributes	$y = a + bx$	$y = a + bx^c$
falling	0.867	0.921
cold-warm	0.706	0.862
supple-rigid	0.841	0.968
responsive	0.614	0.911
crumple like	0.671	0.967

Table 7. Coefficients of determination between Q criterion and KES-F mechanical parameters

KES-F parameters	$y = a + bx$		$y = a + bx^c$	
	warp	weft	warp	weft
2HG5 (N/m)	0.922	0.920	0.966	0.966
2HG (N/m)	0.923	0.928	0.966	0.920
G (N/m°)	0.960	0.928	0.980	0.972
2HB (Nm/m)	–	0.804	–	0.949
B (Nm^2/m)	–	0.867	–	0.879
T_0 (%)	0.735	–	0.930	–
T_M (%)	0.645	–	0.886	–

In conclusion it must be noted that Griff-Tester device can distinguish different weave types on the basis of Q criterion due to fabric deformation under complex loading. This phenomenon is proved by the dependencies between Griff-Tester and KES-F parameters defined in two main directions and dependencies between such sensory attributes as: falling, responsive, crumple like, supple-rigid and cold-warm.

4. FURTHER DEVELOPMENTS

In long-time perspective, virtual processes of products development will start new relationship between textile and clothing manufacturers and will initiate the strategies of open manufacturing, allowing the consumer to become the designer and producer of his own garment. The information provided by 3D CAD systems will help to realize effective communication and cooperation between different sectors, i. e. researchers, industry and traders of textile and clothing industries through specifying the performance requirements and transactions based on fabric properties data. In this respect further developments in Griff-Tester application are purposive with the aim to apply complex criterion Q in virtual fabric development and rapid garment prototyping in order to respond to consumer sensory expectations.

Acknowledgments

The article was prepared under support of the European Social Fund Agency implementing measure VP1-3.1-ŠMM-05-K of the Human Resources Development Operational Programme of Lithuania 2007–2013 3rd priority "Strengthening of capacities of researchers and scientists" (project No. VP1-3.1-ŠMM-05-K-01-003).

REFERENCES

1. **Bishop, D. P.** Fabrics: Sensory and Mechanical Properties *Textile Progress* 29 1996: p. 62.
2. **Hennrich, L., Seidel, A., Reider, O.** Griffprüfung au Maschenwaren *Maschen – Industrie* 7 1999: pp. 46 – 47.
3. **Seidel, A.** Griffgewertung von Strumpfwaren mit dem ITV-Griff-Tester *Melliand Textilberichte* 6 2001: pp. 491 – 494.
4. **Martišiūtė, G., Gutauskas, M. A.** New Approach to the Evaluation of Fabric Handle *Medžiagotyra* (*Materials Science*) 17 2001: pp. 186 – 190.
5. **Martišiūtė, G., Gutauskas, M.** On the Optimization of the Conditions for the Establishment of the Textile Handle *International Journal of Clothing Science and Technology* 16 2004: pp. 110 – 112.
6. **Strazdienė, E., Martišiūtė, G., Gutauskas, M., Papreckienė, L.** Textile Hand: New Method for Textile Objective Evaluation *Journal of the Textile Institute* 94 2003: pp. 245 – 255.
7. **Nakajama, M.** Sensory Measurements of Fabric Hand / Mechanical Properties. Part 1 – Worsted Fabrics; Part 2 – Knitted Fabrics *International Journal of Clothing Science and Technology* 12 2000: pp. 49 – 65.
8. **Daukantiene, V., Gutauskas, M.** Textile Hand: an Analysis of Knitted Fabric Behaviour *Materials Science* (*Medziagotyra*) 8 2002: pp. 299 – 303.
9. **Yick, K. L., Cheng, K. P. S., How, Y. L.** Subjective and Objective Evaluation of Men's Shirting *Fabrics International Journal of Clothing Science and Technology* 7 1995: pp. 17 – 29. http://dx.doi.org/10.1108/09556229510094832
10. **Paek, S. L.** An Analysis of Sensory Hands as Identified by Selected Consumers *Textile Research Journal* 49 1979: pp. 698 – 704.
11. **Barker, R. L., Scheininger, M. M.** Predicting the Hand of Nonwoven Fabrics from Simple Laboratory Measurements *Textile Research Journal* 52 1982: pp. 615 – 620.
12. **Kim, C. J., Piromthamsiri, K.** Sensory and Physical Hand Properties of Inherently Flame-Retardant Sleepwear Fabrics *Textile Research Journal* 54 1984: pp. 61 – 67. http://dx.doi.org/10.1177/004051758405400113
13. **Zeng, X., Koehl, L.** Fabric Hand Evaluation: Subjective and Objective Methods *5th International Conference TEXSCI* Liberec, Czech Republic, 2003: pp. 265 – 268.
14. **Postle, R.** Fabric Objective Measurement Technology: 1. Historical and Background Development *Textiles Asia* 5.7 1989: pp. 64 – 66.

15. **Kirk, W., Ibrahim, S. M.** Fundamental Relationships of Fabric Extensibility to Anthropomorphic Requirements and Garment Performance *Textile Research Journal* 36 1966: pp. 156 – 165.

16. **Harlock, S. C.** Fabric Objective Measurement Technology: 2, Principles of Measurement *Textiles Asia* 5.7 1989: pp. 66 – 71.

17. **Curiskis, J. I.** Fabric Objective Measurement Technology: 5, Production Control in Textile Manufacture *Textiles Asia* 6.7 198: pp. 42 – 59.

18. **Kawabata, S.** The Standardization and Analysis of Hand Evaluation // The Hand Evaluation and Standardization Committee: The Textile Machinery Society of Japan, 1980: p. 100.

19. **Chollakup, R.** Etude des mélanges soie-coton en filature fibres courtes: caractéristiques des fils et analyse sensorielle des tricots *PhD Thesis* Université de Haute Alsace, Mulhouse, 2004.

20. **Chollakup, R., Sinoimeri, A., Philippe, F., Schacher, L., Adolphe, D.** Tactile Sensory Analysis Applied to Silk/Cotton Knitted Fabrics *International Journal of Clothing Science and Technology* 16 2004: pp.132 – 140. http://dx.doi.org/10.1108/09556220410520423

21. **Daukantienė, V., Papreckienė, L., Gutauskas, M.** Simulation and Application of Pulling Textile Fabric through a Central Hole *Fibres and Textiles in Eastern Europe* 11 2003: pp. 38 – 42.

22. **Martišiutė, G., Gutauskas, M.** A New Approach to Evaluation of Fabric Handle *Materials Science* (*Medziagotyra*) 7 2002: pp. 186 – 190.

23. **Philippe, F.** Contribution a l'évaluation tactile des produits textiles par analyse sensorielle *PhD Thesis* Université de Haute Alsace, Mulhouse, 2002.

24. **Philippe, F., Abreu, M., Schacher, L., Adolphe, D., Cabeco Silva, M.** Influence of the Sterilisation Process on the Tactile Feeling of Surgical Gowns *International Journal of Clothing Science and Technology* 15 2003: pp. 268 – 275.

25. **Philippe, F., Schacher, L., Adolphe, D., Dacremont, C.** The Sensory Panel Applied to Textile Goods – a New Marketing Tool *Journal of Fashion Marketing and Management* 7 2003: pp. 235 – 248.

26. **Philippe, F., Schacher, L., Adolphe, D., Dacremont, C.** Tactile Feeling: Sensory Analysis Applied to Textile Goods *Textile Research Journal* 74 2004: pp. 1066 – 1072.

27. **Strazdienė, E., Gutauskas, M.** New Method for the Objective Evaluation of Textile Hand *Fibres and Textiles in Eastern Europe* 13 2005: pp. 35 – 38.

28. **Strazdienė, E., Daukantienė, V., Gutauskas, M.** Bagging of Thin Polymer Materials: Geometry, Resistance and Applications *Materials Science* (*Medziagotyra*) 9 2003: pp. 262 – 265.

29. **Strazdienė, E., Papreckienė, L., Gutauskas, M.** New Method for the Objective Evaluation of Technical Textile Behaviour *Proceedings of the 6th Dresden Textile Conference* CD edition, 2002.

30. **Daukantienė, V., Zmailaitė, E., Gutauskas, M.** Infuence of Concentrated Liquid Softeners on Textile Hand *Indian Journal of Fiber and Textile Research* 30 2005: pp. 200 – 203.

31. **Domskiene, J., Strazdiene, E., Bekampiene, P.** Development and Optimisation of Image Analysis Technique for Fabric Buckling Evaluation *International Journal of Clothing Science and Technology* 23 2011: pp. 329 – 340.

32. **Strazdiene, E., Ben Saïd, S., Gutauskas, M., Schacher, L., Adolphe, D. C.** The Evaluation of Fabric Treatment by Griff Tester and Sensory Analysis *International Journal of Clothing Science and Technology* 18 2006: pp. 326 – 334.

33. **Ben Saïd, S., Osselin, J. F., Schacher, L., Adolphe, D. C.** The Effect of Pattern Construction on the Tactile Feeling Evaluated through Sensory Analysis *Journal of Textile Institute* 97 2006: pp. 137 – 145. http://dx.doi.org/10.1533/joti.2005.0146