Current Journal of Applied Science and Technology

40(10): 23-36, 2021; Article no.CJAST.65620
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Performance of Oak Tasar Silk Waste/ Viscose Blended Knitted Fabrics through Kawabata Evaluation System (KES) for Apparel use

Pooja[1*] and Sandeep Bains[1]

[1]Department of Apparel and Textile Science, College of Community Science, Punjab Agricultural University, Ludhiana, Punjab, India.

Authors' contributions

This work was carried out in collaboration between both authors. Author Pooja designed the study, managed the literature searches performed the statistical analysis, wrote the protocol and wrote the draft of the manuscript. Author SB managed the analyses of the study, read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2021/v40i1031356
Editor(s):
(1) Dr. David Morales-Morales, Ciudad Universitaria, Mexico.
(2) Dr. Ahmed Mohamed El-Waziry, Alexandria University, Egypt and King Saud University, Kingdom of Saudi Arabia.
Reviewers:
(1) Mehmet Ozyazicioglu, Atatürk University, Turkey.
(2) A. V. Gaur, Solapur University, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/65620

Original Research Article

Received 20 November 2021
Accepted 28 January 2021
Published 18 May 2021

ABSTRACT

Tactile sense or the sense of touch has been an important aspect of the human interactions with the environment. The study of tactile sense, or the haptics, has received tremendous attentions for its potential applications. This paper introduces a novel approach for evaluating fabric sensory responses. Attempt has been made to objectively assess the oak tasar silk waste/ viscose blended knitted fabrics of two different yarn counts in order to obtain the scores on various parameters of hand. The Kawabata Evaluation System (KES) used five highly sensitive instruments that measure fabric bending, shearing, tensile and compressive stiffness, as well as the smoothness and frictional properties of a fabric surface. The instrument also gave direct value of primary hand value and total value of the fabric. It the findings of the research revealed that, 40%OTW:60%viscose blended fabric of 15 Nm yarn count depicted best results for smoothness, uniformity, tactile sensation, aesthetic appearance and total hand value.

Keywords: Kawabata Evaluation System (KES); fabric handle; tactile sence; clothing comfort.

**Corresponding author: E-mail: poojakaundal0007@gmail.com;*

1. INTRODUCTION

Clothing comfort is one of the key attributes in consumers' perception of the desirability of apparel products in all markets. Requirements of consumers are changing along with products and wear situations. In a highly competitive textile and apparel market, in order to succeed in the market place, the market players have to meet or even exceed consumers' needs and expectations [1]. Clothing comfort is defined as a pleasant state arising out of physical, physiological and psychological harmony between a human being and the environment [2]. Testing of different parameters which determines the comfort properties of fabric and garment for different end uses includes Objective Evaluation i.e. Quantitative Evaluation of fabric comfort properties by the application of mechanical instruments and equipment and Subjective Evaluation which means Qualitative evaluation of fabric and garment based on human perception [3]. In general, fabric hand is primarily assessed subjectively in a few minutes. Although this is a fast and convenient sort of quality control, the subjective nature of fabric handle leads to serious variations in quality assessment [4]. Not only do the consumers use subjective evaluation techniques, but these techniques are also used in textile production, and consequently discrepancy between textile products' quality or hand-feel and the consumer's demand may result in serious quality variations [4]. In this situation, objective measurement of fabric handle is desirable to allow more accurate quality comparisons between different types of fabrics and to achieve the same quality level [5].

The Kawabata Evaluation System for Fabrics (KES–F) can be used to provide appropriate information of use for quality control, product development and product specification [6]. The Kawabata Evaluation System (KES) instruments measure mechanical properties that correspond to the fundamental deformation of fabrics in hand manipulation. The Kawabata Evaluation System (KES) includes five highly sensitive instruments that measure fabric bending, shearing, tensile and compressive stiffness, as well as the smoothness and frictional properties of a fabric surface. The system was developed by a team lead by Professor Kawabata in the department of polymer chemistry, Kyoto University Japan. The initial work started in 1968 and the system became commercially available in its present form since 1978 [7].

In the present study the authors have intended to evaluate fabric hand of oak tasar silk waste and viscose blended knitted fabrics. Low stress mechanical and surface properties of fabrics have been evaluated by using KES. In the study fabric handle is computed by measuring tensile, bending, shearing, compression and surface properties.

2. MATERIALS AND METHODS

2.1 Raw Materials

Oak tasar reeling waste in hank form and viscose fibers in sliver form were taken. Before processing fibers were washed in soft water and dried under room temperature for 48 hours.

2.2 Blending and Construction of Yarns

worsted spinning system was used to prepare oak tasar silk waste and viscose blended yarns in three different proportions, viz. 60% OTW: 40% V, 50% OTW: 50% V and 40% OTW:60% V, for the development of two different yarn counts (15 Nm and 20 Nm) for each blend ; maintaining yarn twist constant at the rate of 10 twists per inch for both the yarn counts. Oak tasar silk waste was opened properly by hand and then was fed into carding machine. Further, the fibers were blended using gillbox. At this step, fibers were blended into different proportions. After this, drawing procedure was carried out. Since, twist per inch is a parameter that influences output behavior of yarns; it was viewed as being held constant.

2.3 Construction of Fabrics

Development of single jersey knitted fabrics using circular knitting machine by using suitable blended yarns viz. 60%OTW:40%V (20 Nm), 50%OTW:50%V (15 Nm) and both the counts of 40%OTW:60%V on knitting machine of gauge 10 using creel with 36 cones. The developed fabrics were assigned codes as given in Table 1, for ease of discussion and interpretation.

2.4 Methods

The fabric's low stress mechanical properties, including tensile, shear, bending, compression, roughness and friction, were measured on a Kawabata fabric evaluation system (KESF) under the standard testing conditions. A specimen of 20 x 20 cm fabric was used for testing. Fabrics were subjected to Kawabata testing in both wale-wise and course-wise directions for all the parameters except compression.

- Tensile testing: Test specimen was clamped between two jaws and subjected to a constant force of 10 gf/cm in one direction (wale-wise or course-wise). Force was applied by a weight which was fixed to the drum on which one jaw was mounted.
- Shear: Stability of fabric to withstand in plane mechanical distortion was measured at 0.5º and 5° shear angles.
- Bending: Test specimens were bent between the curvatures–2.5 and +2.5cm-1.
- Surface: The parameter was measured by using a sensor which simulates human finger. A load of 50 gf was applied on the mounted swatch and coefficient of friction was calculated. Geometrical roughness was also determined under this category.
- Compressional properties: The sample was placed between two plates and pressure was increased continuously 0.5 to 50 gf /cm2. The impact of pressure was measured on an area of 2 cm2 .

The Kawabata Evaluation System (KES) was used to make objective measurements of hand properties. The Kawabata Evaluation System (KES) includes five highly sensitive instruments that measure fabric bending, shearing, tensile and compressive stiffness, as well as the smoothness and frictional properties of a fabric surface. KES provides a unique capability, not only to predict human response, but also to provide an understanding of how the variables of fiber, yarn, fabric construction and finish contribute to the perception of softness. The fabric feel or sense has been simulated in Kawabata Evaluation System (KES) instrument and converted into numerical values. This instrument gives direct primary hand value and total value of the fabric. Total handle is a final judgement of fabric sensation and calculated by means of linear regression equation with the help of various primary hand values [8].

Fabrics were tested for total hand value on low mechanical stress using Kawabata Evaluation System (KES) instrument.

KES values of all the developed fabrics were tested. The scales used for PHV and THV are as follows (Kawabata and Niwa 1975).

Value of the Primary Hand (HV)

Hand value	Feeling Grade
10	The strongest
5	Medium
1	The weakest
0	No feeling

Total Hand Value (THV)

Total Hand Value (THV)	Feeling Grade
5	Excellent
4	Good
3	Average
2	Fair
1	Poor
0	Not useful

3. RESULTS AND DISCUSSION

The Kawabata Evaluation System (KES) was used to make objective measurements of hand properties. The Kawabata system of instruments, measures properties of textile fabrics and predicts the aesthetic qualities perceived by human touch.

3.1 Evaluation of Low-Stress Mechanical and Surface Properties of Blended Fabrics

Data pertaining to Table 3 shows the low stress mechanical and surface properties of blended fabrics.

3.1.1 Tensile properties

3.1.1.1 Tensile strain (EMT%)

The EMT (Tensile extension) value indicates fabric extension at a fixed maximum load and is related to crimp removal process during tensile loading [9]. Course wise extensibility was found higher among all the fabrics in comparison to wales wise direction. Fabric sample S1 exhibited highest extensibility followed by S4, S3 and S2 fabrics in wales wise direction whereas, in course wise direction fabric sample S3 showed maximum extensibility followed by S1, S2 and S4 fabrics. Higher value of EMT indicates a stretchier material, hence provides wearing comfort but also creates problem during stitching and seam pressing Nayak et al [10].

3.1.1.2 Linearity of load- extension curve (LT)

This parameter is a measure of the deviation of the load- extension curve from the straight line and indicates the wearing comfort of a fabric. Lower value of LT indicates higher extensibility in initial strain hence better comfort but the fabric dimensional stability decreases [11]. Course wise linearity of load was higher for all the fabrics, except for fabric S2, in which wales wise linearity was higher. Fabric S2 showed highest value of linearity in wales wise direction indicating lowest comfort, followed by fabrics S1, S3 and S4, whereas in course wise direction highest value of linearity was depicted by fabric S2, followed by fabrics S3, S1 and S4. Therefore highest comfort was exhibited by fabric S4 in both the directions.

3.1.1.3 Tensile resilience (RT %)

The tensile resilience indicates the recovery of fabric after extension when the applied force is removed. A higher value indicates greater recovery from having been stretched [12]. Course wise tensile resilience of all the fabrics was higher in comparison to wales wise resilience. Fabric S1 exhibited highest value of RT followed by fabric S3 in both the directions, whereas, lowest value of RT was shown by fabric S4 in wales wise direction and fabric S2 in course wise direction.

3.1.1.4 Tensile energy (WT)

WT represents the energy required to extend a fabric to the fixed maximum load. A higher amount of tensile energy was exhibited in course wise direction in all the fabrics [5]. Higher tensile energy was found in course wise direction as compared to wales wise direction for all the fabrics. fabrics S1 and S4 showed highest amount of WT in wales wise direction, with same values, followed by fabrics S2 and S3 whereas, fabric S3 depicted highest WT followed by fabrics S1, S2 and S4 in course wise direction.

3.1.2 Bending properties

3.1.2.1 Bending rigidity (B)

Bending rigidity of the threads and mobility of warp and weft threads within the fabric is responsible for the bending rigidity of a fabric [13]. Wales wise bending rigidity was higher among all the fabric samples as compared to course wise direction. Fabric S2 showed highest bending rigidity in both the directions followed by fabric S4 whereas lowest bending rigidity was exhibited by S1 in wales wise direction and fabric S3 in course wise direction.

3.1.2.2 Bending hysteresis (2BH)

Bending hysteresis is a measure of recovery from bending deformation. Wales wise bending rigidity was higher among all the fabric samples as compared to course wise direction. The results of bending hysteresis show a similar trend as that of bending rigidity.

3.1.3 Shear properties

3.1.3.1 Shear rigidity (G)

Shear properties are measure of inter –yarn friction force, that represent the stability of fabric to withstand in plane mechanical distortion. Course wise shear rigidity was higher than wales wise in all the fabrics. Fabric S2 exhibited highest shear rigidity in wales wise direction, followed by fabric S4, S3 and S1 whereas, fabric S4 showed highest shear rigidity in course wise direction followed by, fabric S2, S3 and S1.

3.1.3.2 Hysteresis of shear force at 0.5º (2GH) and 5º (2HG5)

It is measurement of energy loss during shear deformation. This energy loss is mainly caused by the yarn to yarn friction at cross over points. A similar trend was observed for hysteresis of shear force at 0.5° and 5°. Course wise hysteresis of shear force was higher than wales wise direction. Highest hysteresis of shear force was observed for fabric S2, followed by fabrics S4, S3 and S1 in both the directions.

3.1.4 Surface properties

The surface properties of a fabric influence the handle, comfort and aesthetic characteristics of the developed fabric [14].

3.1.4.1 Coefficient of friction (MIU)

It measures the resistance or drag of the sample. Higher values indicate greater friction, resistance and drag [15]. Coefficient of friction was higher in wales wise direction as compared to course wise direction. Highest value of MIU was shown by fabric S1 followed by fabrics S2, S4 and S3 in wales wise direction. Whereas, in course wise direction highest coefficient of friction was observed in fabric S2 followed by fabrics S1, S4 and S3.

3.1.4.2 Deviation in the coefficient of friction (MMD)

It indicates the variation in MIU. All the fabrics showed more deviation in the coefficient of friction in wales wise direction. Fabric S2 exhibited highest value of MMD followed by fabric S3 in both the directions. Lowest value of MMD was reported in fabric S4 in wales wise direction and fabric S1 in course wise direction.

3.1.4.3 Geometrical roughness (SMD)

It measure the surface contour, a higher values indicates a geometrically rough surface. Highest value of SMD was found in fabric S2 followed by fabrics S4, S1 and S3 in wales wise direction, whereas, in course wise direction fabric S1 showed highest value followed by fabrics, S3, S4 and S2. When compared average values of both wales wise and course wise geometric roughness, it was observed that, as the proportion of viscose in the blend increased, there was reduction in geometric roughness. This may be due to more rough texture of oak tasar silk waste.

3.1.5 Compression properties

3.1.5.1 Linearity of compression- thickness curve (LC)

Compressibility provides a feeling of bulkiness and spongy property to the fabric and mainly depends on the fabric thickness and compressional characteristics of the yarn [16]. LC measures the deviation of the load thickness curve from a straight line. The highest LC value of fabric S1 implies that it is highly compressible, followed by fabric S4. Lowest value of LC was observed in fabric S2.

3.1.5.1 Compressional resilience (RC %)

It represents the extent of recovery, or regain in the thickness, when the force is removed. Higher values indicate a better recovery from being compressed [17]. Highest compressional resilience was found in fabric S1, followed by, fabric S2 and lowest value was shown by fabric S3. It was observed that, finer count (20 Nm) i.e. fabrics S1 and S4 showed better recovery from being compressed.

3.1.5.2 Compressional energy (WC)

Represent the energy required to compress the fabric to be prefixed maximum load level. Compressional energy increases with increase in thickness of the fabric. Highest compressional energy was found in fabric S3 followed by fabric S2. Lowest compression energy was required in case of fabric S3.

3.1.6 Thickness of the fabric at 0.5 gf/cm^2 (T_{o}) and at 5 gf/cm^2 (T_m)

Thickness of fabric S3 was highest followed by fabric S2 whereas lowest thickness was found in fabric S4 at 0.5 gf/cm^2. The thickness of finer yarn count (20 Nm) was less as compared to yarn count of 15 Nm. In case of fabric thickness at maximum pressure i.e. 5 gf/cm^2 (T_m), it was found that, fabric S4 exhibited maximum thickness followed by fabric S2, S1 and S3.

3.1.7 Fabric weight

Fabric weight was highest in case of fabric S2 followed by fabrics S4, S3 and S1. Yarn count and blend proportion were responsible for fabric weight. Viscose fibre contributed to fabric weight due to its heavier denier.

3.2 Primary Hand Values and Total Hand Values of Developed Fabrics

All the developed fabrics were evaluated for primary and total hand values and the results are shown in Table 4.

Hand value of primary hand	**Japanese term**	**English equivalent**
10- strongest, 5- medium, 1- weakest	Koshi	Stiffness
Total hand value	Fukurami	Fullness & softness
5- Excellent, 4- Good, 3- Average, 2- Fair, 1- Poor	Numeri	Smoothness

The data presented in Table 4 depicts that, the values have been studied in terms of kosi, fukurami and numeri which means stiffness, fullness and softness; and smoothness respectively. The scale used for Primary hand values was 10- strongest, 5-medium 1- weakest, whereas, that of total hand values was 5- exc+ellent, 4- good, 3- average, 2- fair and 1- poor.

The values for koshi (stiffness) represented that fabric S2 exhibited highest rate of stiffness followed, by fabric S4 with mean values of 7.62 and 7.39 respectively. Stiffness decreased to 6.25 in case of fabric S3and lowest stiffness rate was found in fabric S1 with mean value of 5.66. Fukurami means fullness and softness which was highest in case of fabric S4 (7.60) and decreased slightly to 7.58 in case 0f fabric S2. Further it decreased to 6.35 in case of fabric S3 and lowest fukurami was found in fabric S1 with mean value of 5.96. Numeri exhibits rate of smoothness in fabric and highest value was found in fabric S3 (5.72) followed by fabric S4 (5.48), fabric S1 (5.39) and lowest in case of fabric S2 with mean value of 5.17.

The results for total hand values show that, all the fabrics exhibited total hand value of average to good with very slight difference among all the fabric samples. Highest THV was found in fabric S4 (3.52) followed by fabrics S2 (3.50), S3 (3.45) and 3.35 as lowest in case of S1 fabric sample.

Table 1. Developed fabrics with codes

Fabric code	Fibre Content	Yarn count (Nm)	Yarn Density (WPIxCPI)
S1	60OTW%: 40%viscose	20	20x16
S2	50OTW%: 50%viscose	15	20x15
S3	40%OTW: 60%viscose	15	20x15
S4	40%OTW: 60%viscose	20	20x16

CPI- Courses per inch, WPI- Wales per inc

Table 2. Measurement parameters for Kawabata Evaluation System

Properties	Parameter	Measuring conditions
Tensile	LT	Linearity of load extension curve
	WT	Tensile energy
	RT	Tensile resilience
Shear	G	Shear rigidity
	2HG	Hysteresis of shear force at 0.5º
	2HG5	Hysteresis of shear force at 5º
Bending	B	Bending rigidity
	2HB	Hysteresis of bending moment
Later compression	LC	Linearity of compression thickness curve
	WC	Compressional energy
	RC	Compressional resilience
Surface characteristics	MIU	Coefficient of friction
	MMD	Mean deviation of MIU
	SMD	Geometrical roughness
Fabric construction	W	Fabric weight per unit area
	To	Fabric thickness

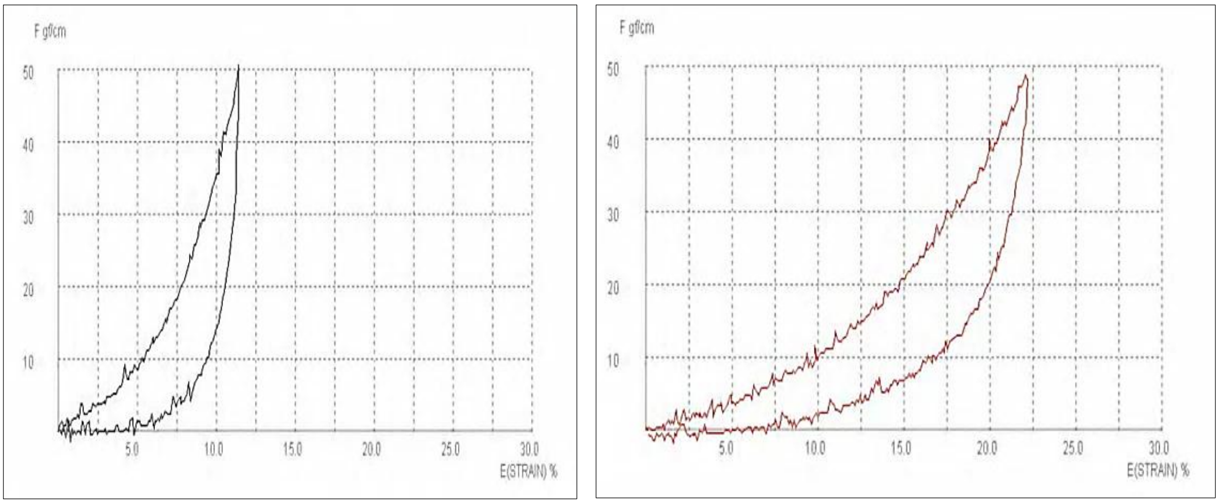

Fig. 1. Tensile properties of fabric S1 wales wise and course wise

Table 3. Evaluation of low stress mechanical and surface properties of blended fabrics

Properties		**S_1**		**S_2**		**S_3**		**S_4**	
		Waleswise	**Coursewise**	**Waleswise**	**Coursewise**	**Waleswise**	**Coursewise**	**Waleswise**	**Coursewise**
Tensile Properties	EMT(%)	11.40	21.85	9.75	18.35	10.75	23.75	10.80	18.00
	LT[-]	0.621	0.663	0.716	0.693	0.630	0.656	0.654	0.680
	RT(%)	33.93	43.35	28.12	39.65	28.98	40.49	27.76	40.18
	WT(g.cm/cm^2)	1.77	3.62	1.74	3.17	1.69	3.89	1.77	3.06
Bending Properties	B[g.cm^2]	0.0275	0.0168	0.0487	0.0290	0.0339	0.0152	0.0415	0.0265
	2HB[g.cm/cm]	0.0284	0.0171	0.0476	0.0316	0.0359	0.0149	0.0462	0.0290
Shear Properties	G[g/cm.deg]	0.43	0.46	0.51	0.58	0.44	0.51	0.50	0.59
	2HG[g/cm]	1.79	1.81	2.63	2.84	2.15	2.34	2.51	2.74
	2HG5[g/cm]	1.67	1.74	2.47	2.64	1.92	2.21	2.38	2.54
Surface Properties	MIU[-]	0.248	0.213	0.227	0.215	0.209	0.189	0.215	0.202
	MMD[-]	0.0247	0.0181	0.0278	0.0198	0.0266	0.0189	0.0224	0.0185
	SMD[micron]	12.91	13.44	13.44	12.52	11.88	12.76	13.25	12.35
Compression Properties	LC[-]	0.561		0.457		0.508		0.537	
	RC[%]	41.71		56.06		57.70		53.79	
	WC[g.cm/cm^2]	0.118		0.094		0.079		0.103	
	T_0[mm]								
	T_m[mm]								
Weight	W[mg/cm^2]	12.04		17.32		12.05		16.09	

S_1 = Blended fabric made from 60 OTW/40 V, 20 Nm yarn
S_2 = Blended fabric made from 50 OTW/50 V, 15 Nm yarn
S_3 = Blended fabric made from 40 OTW/60 V, 15 Nm yarn
S_4 = Blended fabric made from 40 OTW/60 V, 20 Nm yarn

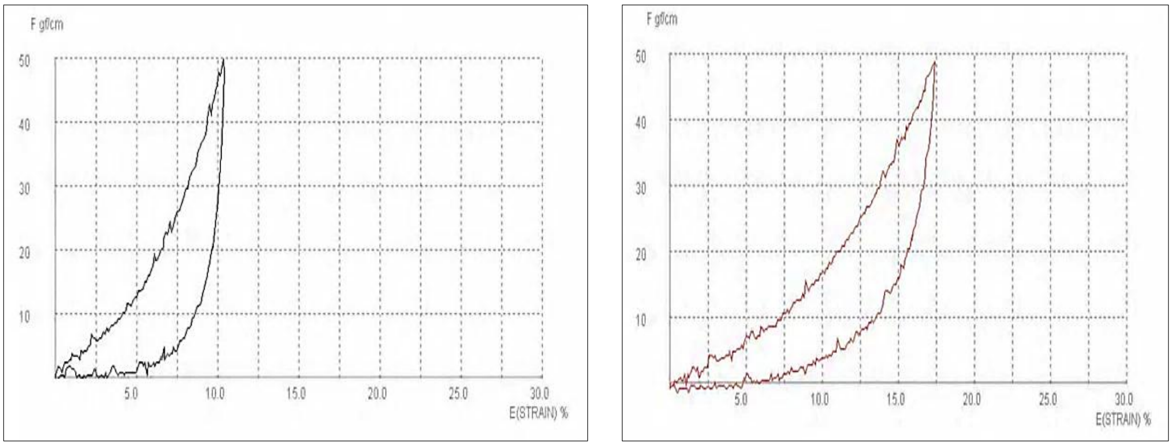

Fig. 2. Tensile properties of fabric S2 wales wise and course wise

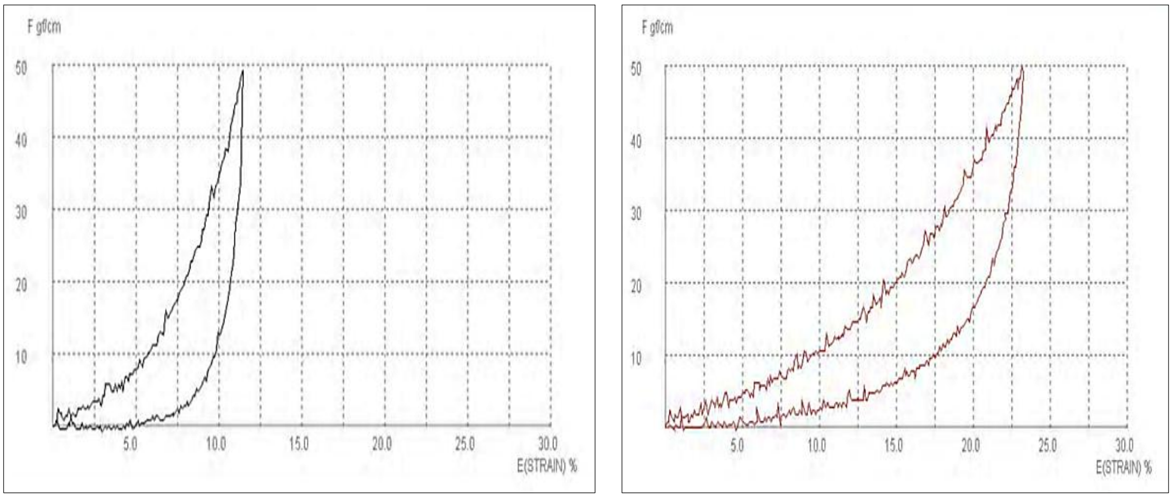

Fig. 3. Tensile properties of fabric S3 wales wise and course wise

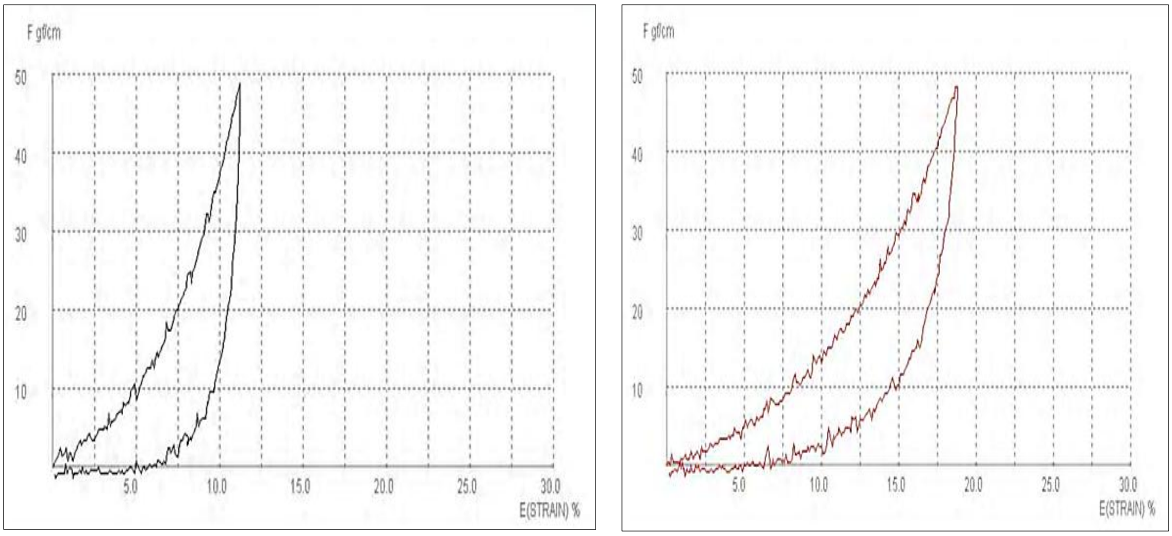

Fig. 4. Tensile properties of fabric S4 wales wise and course wise

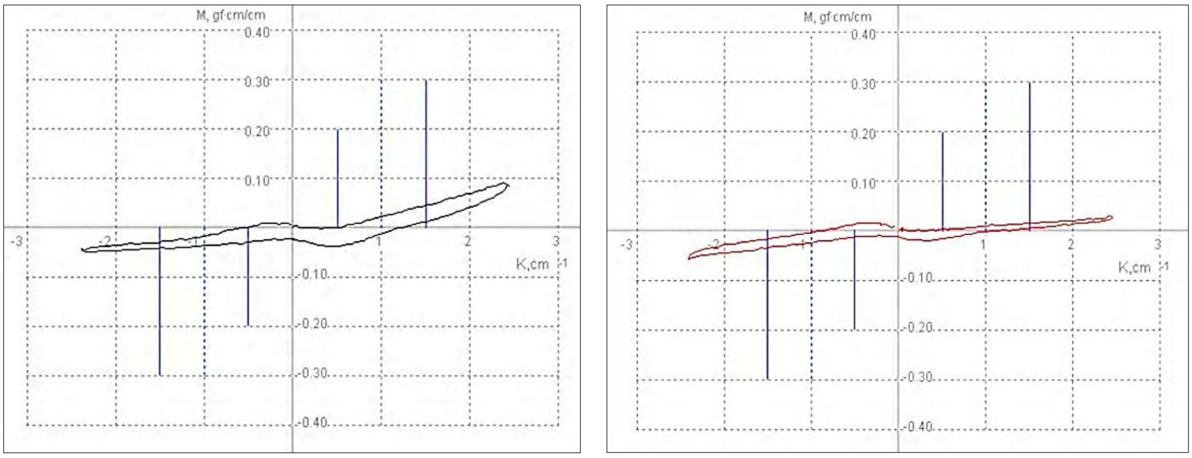

Fig. 5. Bending properties of fabric S1 wales wise and course wise

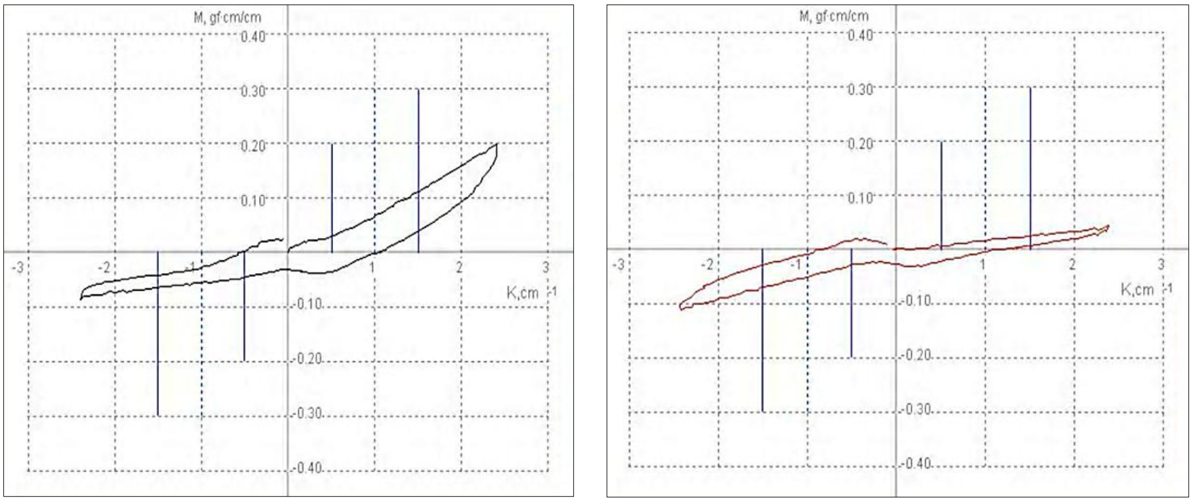

Fig. 6. Bending properties of fabric S2 wales wise and course wise

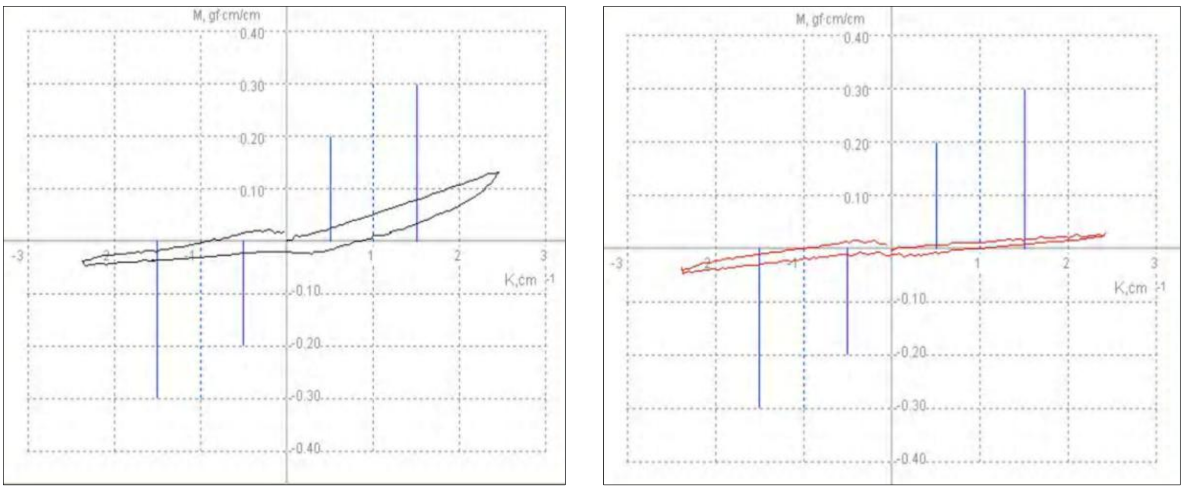

Fig. 7. Bending properties of fabric S3 (wales wise and course wise)

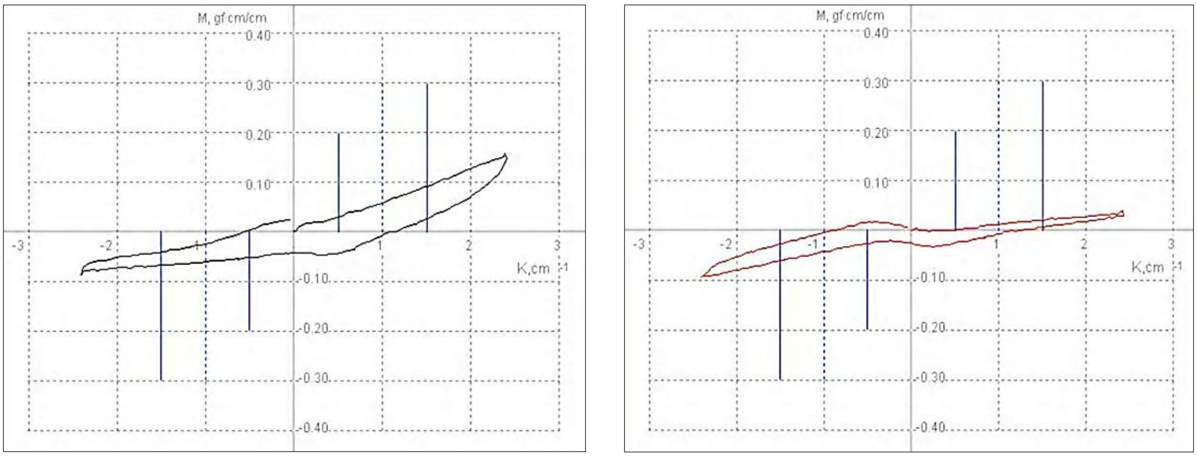

Fig. 8. Bending properties of fabric S4 (wales wise and course wise)

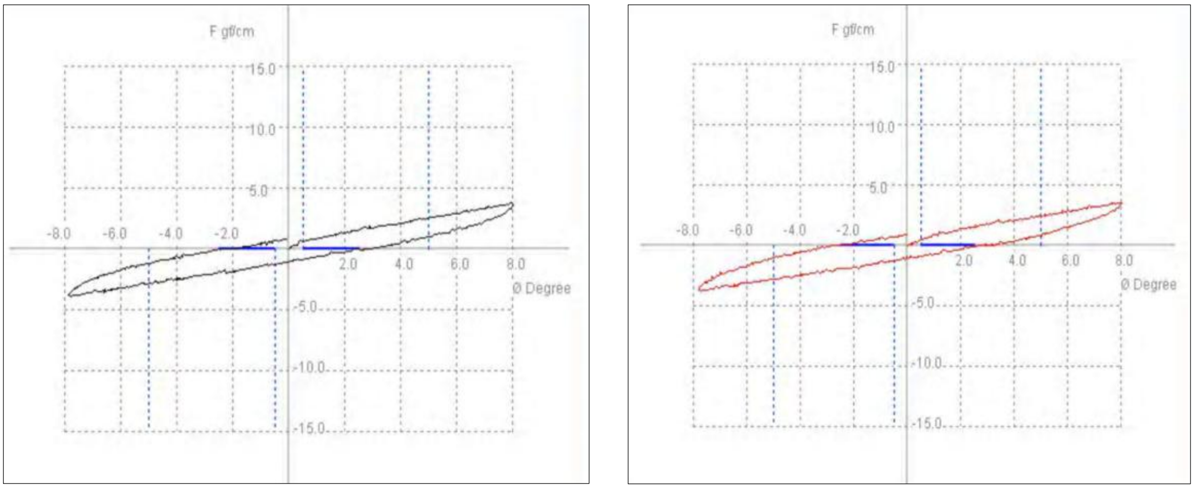

Fig. 9. Shear properties of fabric S1 (wales wise and course wise)

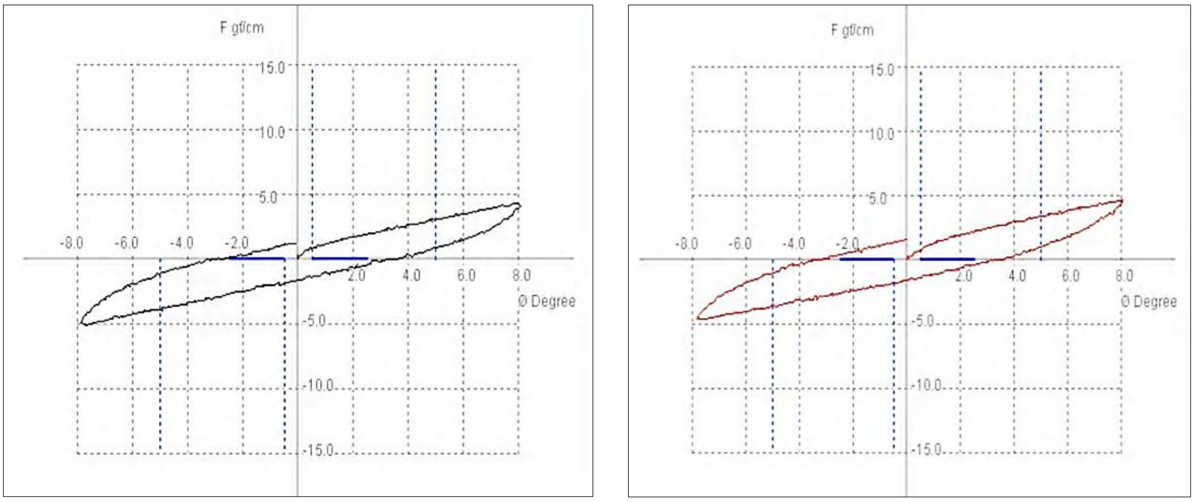

Fig. 10. Shear properties of fabric S2 (wales wise and course wise)

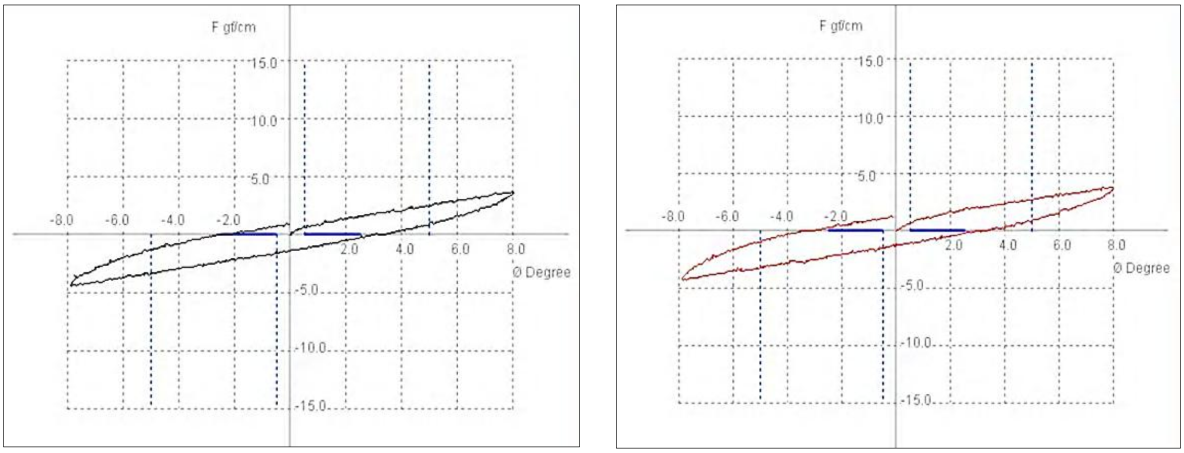

Fig. 11. Shear properties of fabric S3 (wales wise and course wise)

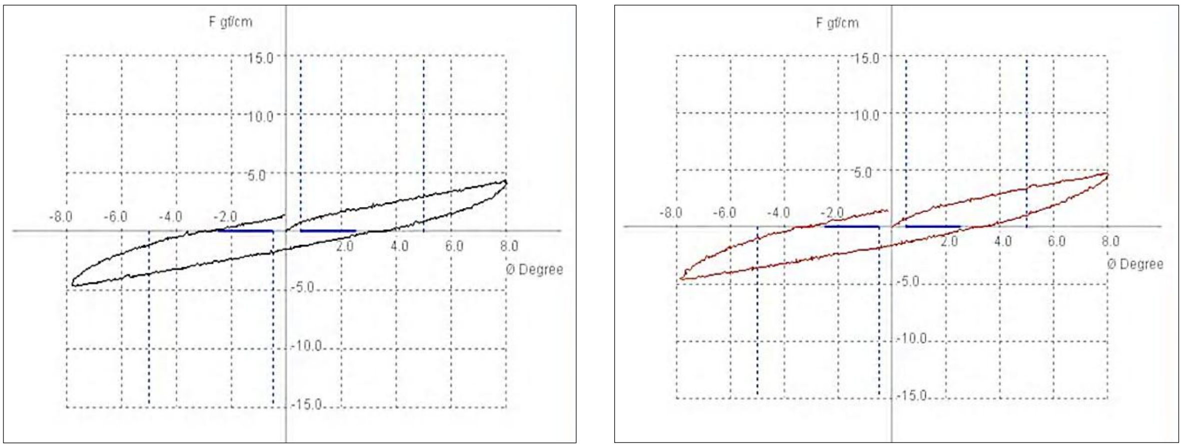

Fig. 12. Shear properties of fabric S4 (wales wise and course wise)

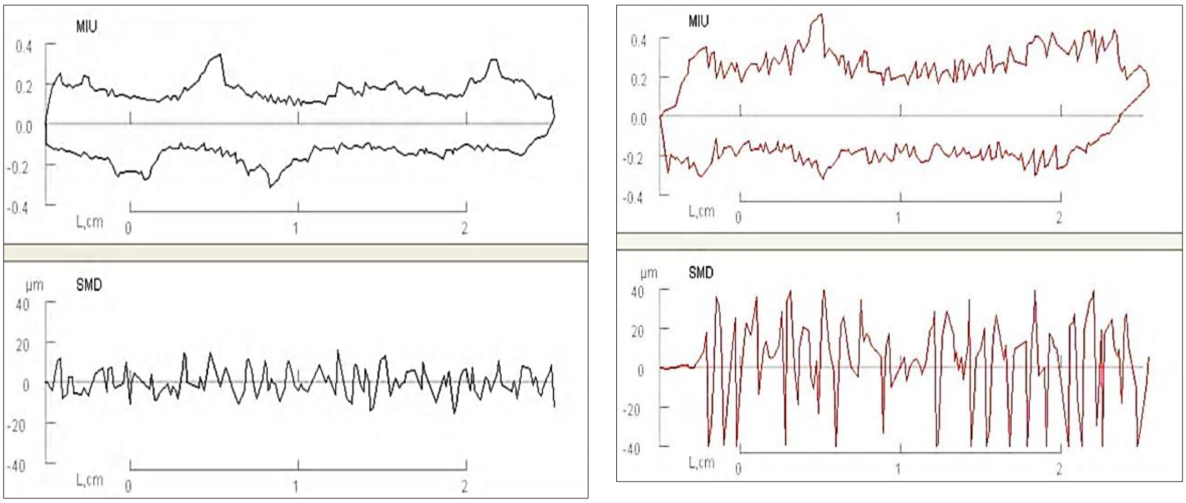

Fig. 13. Surface properties of fabric S1 (wales wise and course wise)

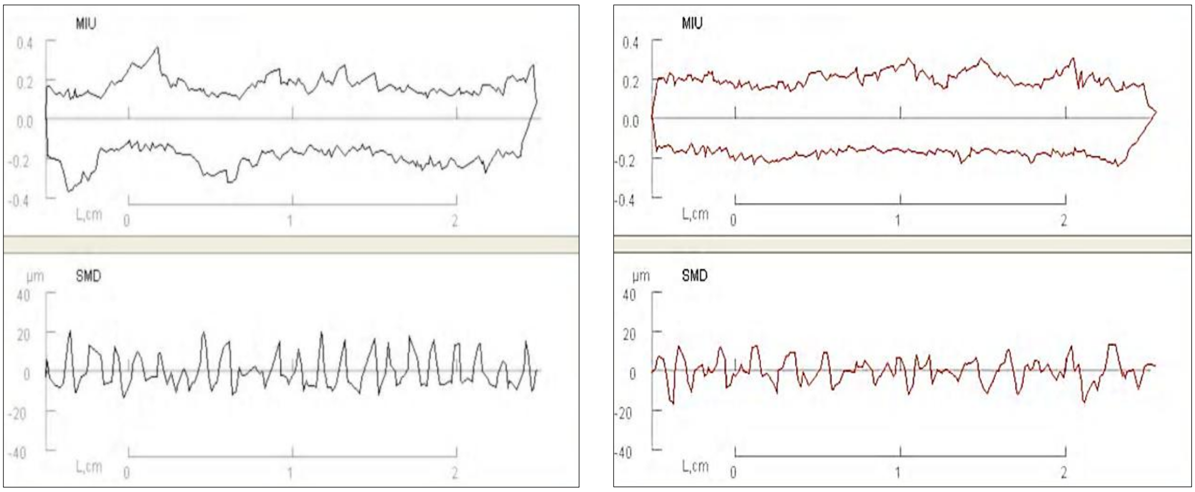

Fig. 14. Surface properties of fabric S2 (wales wise and course wise)

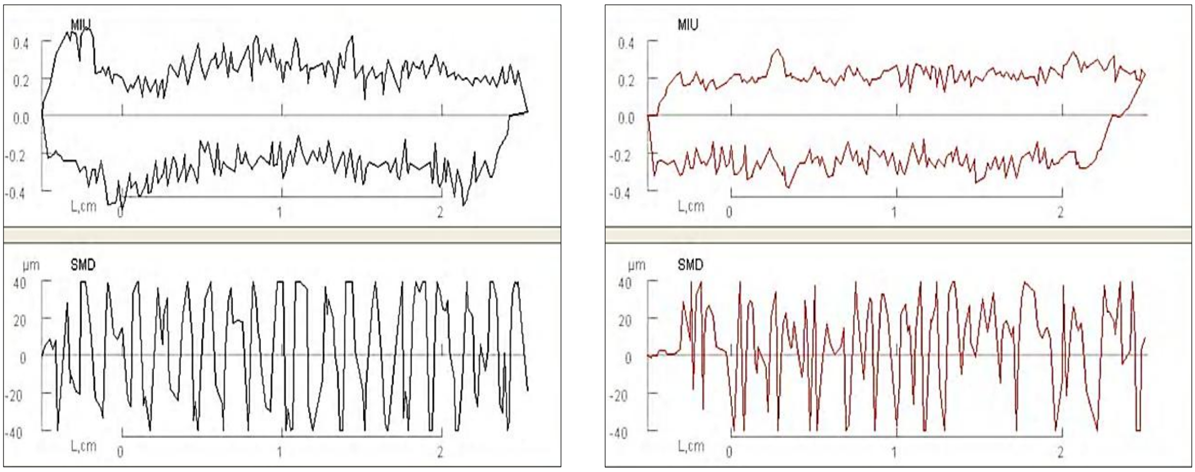

Fig. 15. Surface properties of fabric S3 (wales wise and course wise)

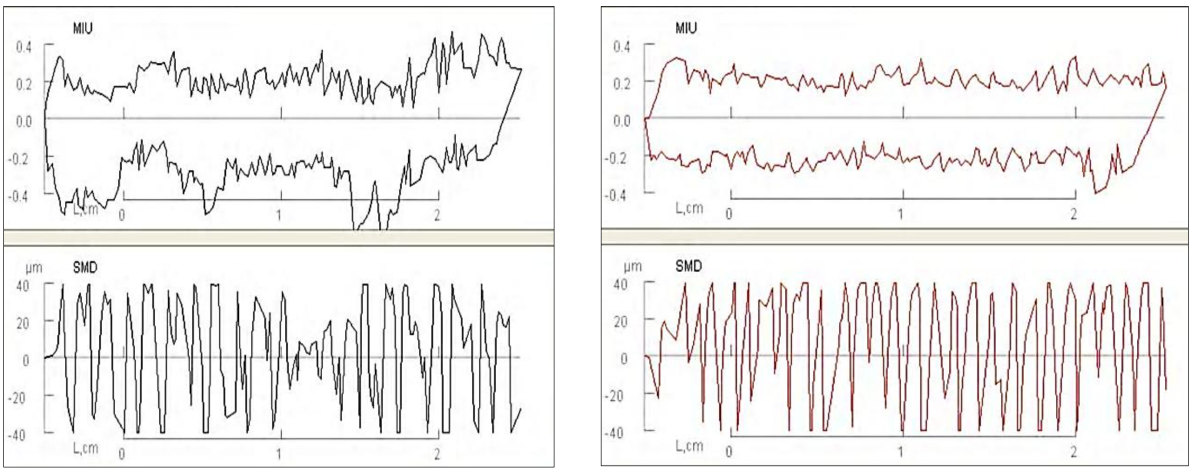

Fig. 16. Surface properties of fabric S4 (wales wise and course wise)

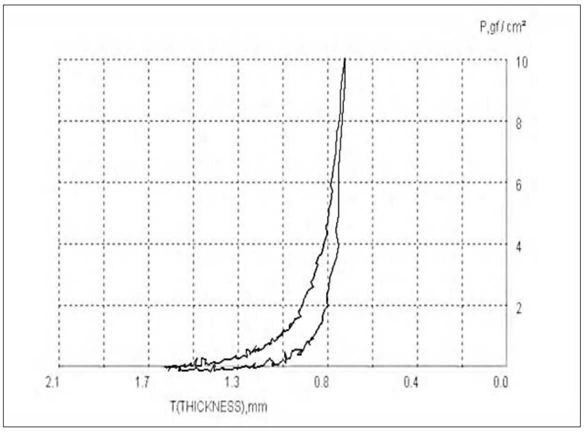

Fig. 17. Compression properties of fabric S1

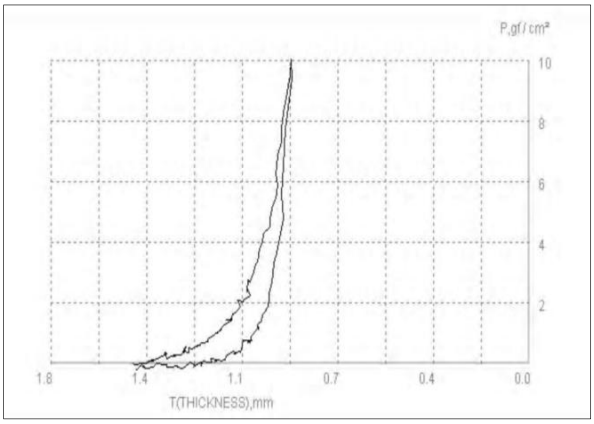

Fig. 18. Compression properties of fabric S2

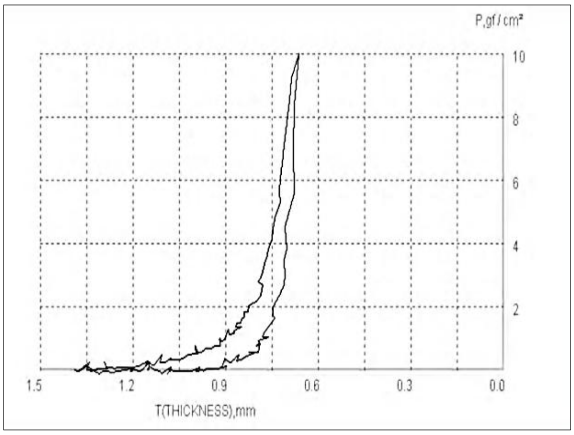

Fig. 19. Compression properties of fabric S3

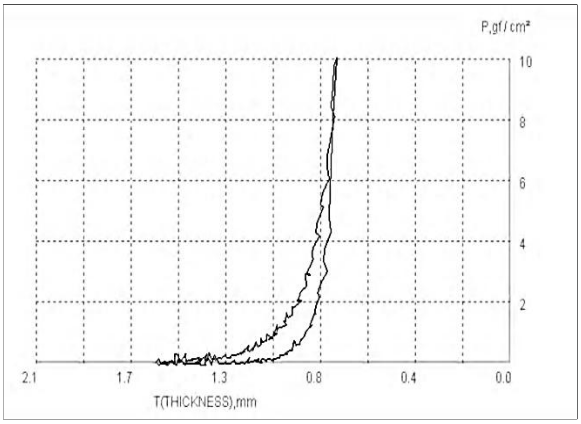

Fig. 20. Compression properties of fabric S4

Table 4. Primary hand values and total hand values of blended fabrics

Properties	S 1 60OTW:40viscose (20 Nm)	S 2 50OTW:50viscose (15 Nm)	S 3 40OTW:60viscose (15Nm)	S 4 40OTW:60viscose (20 Nm)
Primary hand values				
Koshi	5.66	7.62	6.25	7.39
Fukurami	5.96	7.58	6.35	7.60
Numeri	5.39	5.17	5.72	5.48
Total hand value	3.35	3.50	3.45	3.52

4. CONCLUSION

The Kawabata Evaluation System (KES) is a series of instruments used to measure those textile material properties that enable predictions of the aesthetic qualities perceived by human touch. KES instruments quantify garment material tactile qualities through objective measurement of the mechanical properties related to comfort perception. KES provides a unique capability, not only to predict human response, but also to provide an understanding of how the variables of fiber, yarn, fabric construction and finish contribute to perceptions of comfort. The results of the research findings revealed that blending oak tasar silk waste with viscose fibre improves the comfort properties of fabric. Addition of viscose fibre enhances the properties of resultant fabrics. It can be concluded that 40%OTW:60%viscose blended fabric of 15 Nm represents best results for smoothness, uniformity, tactile sensation, aesthetic appearance and total hand value. The results of primary hand values revealed that Fukurami (Fullness & softness) was highest in case of fabric S4 and Numeri (Smoothness) was found to be highest in fabric S3(5.72) followed by fabrics S4 (5.48). The results for total hand values show that, all the fabrics exhibited total hand value of average to good with very slight difference among all the fabric samples. Highest THV was found in fabric S4 (3.52).

ACKNOWLEDGEMENT

The authors are grateful to staff members of M.S. Randhawa library, Punjab Agricultural University, Ludhiana, for their co-operation in successful completion of the work. This work was part of the PhD study for first author and financed by University Grant Commission, New Delhi, India, through National Fellowship for OBC JRF.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FS. Kilinc-Balci. Improving comfort in clothing. Wood head publishing, Canada; 2011.
2. Li Y. The science of clothing comfort. Textile progress. 2001;32:1-2.
3. Mitsuo M. Fabric handle and its basic mechanical properties. J Text Eng. 2006;52:1–8.
4. Sular V, Okur A. Sensory evaluation methods for tactile properties of fabrics. Journal of sensory studies. 2007;22(1): 1-16.
5. McLoughlin J, Sabir T. High-performance apparel: materials, development, and applications. Woodhead publishing limited, UK; 2017.
6. Harwood RJ, Weedall PJ, Carr C. The use of the Kawabata Evaluation Systemfor product development and quality control. Journal of the Society of Dyers and Colourists. 1990;106(2)64-68.
7. Moiz A, Iqbal M, Ahmed A, Farooq K. Kawabata Evaluation System; 2010. Accessed: September 19, 2020) Available: https://www.fibre2fashion.com
8. RJ Weedall PJ, Carr C. The use of the Kawabata Evaluation System for product development and quality control; 2020. Available:http://onlinelibrary.wiley.com Accessed:12 November 2020
9. Bajaj S, Bains S. Evaluation of tactile comfort of mulberry silk waste and viscose blended knitted fabrics by using Kawabata Evaluation System (KES) for Apparel Use. Current Journal of Applied Science and Technology. 2019;38:1-15.
10. Nayak RK, Punj SK, Chatterjee KN. Comfort properties of suiting fabrics. Indian Journal of Fibre & Textile Research. 2009;34:122-128.
11. Beheraa BK, Shakyawar DB. Structure property relationship of fibre, yarn and fabric with special reference to low stress mechanical properties and hand value of fabric. Indian Journal of Fibre and Textile Research. 2000;25:232-237.
12. Elkholy GA, Hafny S. Study of fabrics properties for intimate apparel. International Journal of Science and Engineering Investigations. 2017;6(62): 139-144.
13. Dawes VH, Owen JD. The assessment of fabric handle, part I: Stiffness and liveliness. Journal of Textile Institute. 1971; 62:233-241.
14. Pan N. Quantification and evaluation of human tactile sense towards fabrics. International Journal of Design and Nature. 2006;1:48-60.
15. Sülar V, Okur A. Sensory evaluation methods for tactile properties of fabrics. J Sens Stud. 2007;22(1):1–16.
16. Katkar PM, Patil LG, Dhoot NS. Compressional behaviour of woven fabric. Textile Asia. 2012;43(6):33-36
17. Naik SD. Performance properties of organic cotton fabrics by objective evaluation (KES-F). Journal of Farm Science. 2016;29(5):804-809.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/65620