www.fibre2fashion.com

Comparative Analysis of Low-Stress Mechanical Properties of Woven and Knitted Apparel Fabrics

By: Gurumurthy Ramaiah, Radhalakshmi.Y.C & Dr.R.P.Nachane

Comparative Analysis of Low-Stress Mechanical Properties of Woven and Knitted Apparel Fabrics

By: Gurumurthy Ramaiah[1], Radhalakshmi.Y.C[2] & [3] Dr.R.P.Nachane

[1]Lovely Professional University, Department of Fashion Technology, Jalandhar-Delhi G.T.Road, Phagwara
[2]Central Silk Board, Central Silk Technological Institute, B.T.M.Layout, Madivala, Bangalore
[3]PS & Head QEID, CIRCOT, Adenwala Road, Matunga, Mumbai

Apparels are one of the basic needs for mankind. In addition to protection, apparels have to be comfortable to wear. Knitted clothing is preferred by consumers for their easy care and comfort features. There are two main aspects of comfort, viz., tactile and sensorial. While tactile comfort is measured as fabric hand, sensorial comfort depends on heat and moisture transport properties of fabrics. Kawabata Evaluation System for Fabrics (KES-FB) is developed for assessing handle properties of fabrics objectively without the help of experts who traditionally do this assessment. The KES-FB system uses tensile, shear, compression, bending and surface properties of fabrics measured under low stress levels and predicts the hand value objectively. Present paper investigates low-stress mechanical properties of different products of woven and knitted cotton apparel fabrics using Kawabata Evaluation System for Fabrics (KES-FB).

Keywords: Fabric hand, hand evaluation, bending rigidity, Hysteresis, formability, linearity compression (LC), Elasticity

1 Introduction

Fabric hand is an important property of apparel fabrics and it influences the final quality of the apparel to a great extend. Fabric hand depends on both fabric structure and low stress mechanical properties of the materials used (1-18). Fabric hand is a complex property, related to the behavior of fabric during tensile, shear, compressional, and bending deformations. In addition to this, surface features of fabrics like friction and roughness are also important. When we feel a fabric between our fingers, we are, in fact, subjecting the fabric to all the above mentioned deformations. Nerve endings at the finger sense the resulting sensations and produces by the fabrics and as a result we get a subjective feel of hand. The KES-FB system simulates this condition by way of measuring low stress mechanical properties of the fabrics and can predict perceptions such as softness, crispness, etc. with the help of a set of transformation equations developed for it. Kawabata and coworkers have developed a set of transformation equations linking the low stress mechanical properties of fabrics to the subjective hand assessment by expert judges. Thus, KES-FB system can predict Total Hand Value (THV) for specified end use from the measured properties of a fabric.

2 Materials and Methods

2.1 Objective evaluation of fabric hand

Measurement of the mechanical properties of apparel fabrics during small deformations are the basis for objective evaluation of fabric hand. The KES-FB system is used to characterize low-stress mechanical properties of fabrics and from which the objective determination of fabric hand can be made. The Instrument is composed of four units, viz. (a) Tensile and shearing tester, (b) Pure bending tester, (c) compression tester and (d) surface tester. These units are connected to a data processing computer for data processing. Each one of the tester module sends the required number of inputs to the data processing computer.

After the measurement of low stress mechanical properties belonging to tensile, shear, bending, compression and surface is completed, the system proceeds with the calculation of Primary Hand Value (PHV) and Total Hand Value (THV). A set of transformation equations developed for each end use type is used for these calculations. While Primary Hand Values (PHV) represents rudimentary fabric attributes like stiffness, softness, etc., Total Hand Value (THV) gives an index indicating quality of the fabrics for a specified end use. While PHV are in the range of 1-10, THV has values between 0 and 5.

The objective evaluation of fabric is based on the recommendations of the Hand Evaluation and Standardisation committee (HESC). This committee has generated fabric descriptors through discussion with a panel of expert judges in the context of specific fabric end uses. Total hand is usually expressed in terms of KOSHI, NUMERI, and SHARI, etc. These Primary hand expressions and their definition are shown in Table 1

Table 1: Primary hand expressions and their definition

Japanese	English	Definition
Koshi	Stiffness	A feeling related with bending stiffness, springy property promotes this feeling. The fabric having compact weaving density and woven by springy and elastic yarn makes this feeling strong
Numeri	Smoothness	A mixed feeling that comes from smooth, limber and soft feeling. The fabric woven from cashmere fiber gives this feeling strongly
Fukurami	Fullness and softness	A feeling that comes from bulky, rich and well formed feeling. Springy property in compression and thickness accompanied with warm feeling are closely related with this feeling(FUKURAMI means "swelling")
Namerakasa	Smoothness	A mixed feeling that comes from smooth and dry feeling, having slippery touch without hitching to fingers
Sofutosa	Soft feeling	Soft feeling, a mixed feeling of bulky, flexible and smooth feelings.

2.2 Testing of samples on KES-FB system

The mechanical and surface properties of knitted innerwear (100% cotton), knitted outerwear (95% cotton/5 % polyurethane), woven shirting (100% cotton), woven bottom (100% cotton were tested on KES-FB system. These fabrics were dyed but unfinished. In addition to low stress mechanical properties Primary Hand Value (PHV) and Total Hand Values (THV) of these fabrics were also calculated. Tests were carried out as per standard procedures under standard atmospheric condition of 65 ± 2 %, RH 27 $\pm 1^0$ C. The results of the tests, i.e. parameters of fabric mechanical /surface properties were expressed in the form of 16 parameters as listed in Table 3. Each value represents the mean of 10 tests on five different test specimens. Details of specimens are given in Table 2.

Table 2: Specimen details and identification

Fabric No.	Fabric code	Description
C-08206	A	Knitted innerwear- single jersey – 100% cotton – unfinished
C-08207	B	Knitted outerwear – single jersey – 95% cotton/5%polyurethrane- solid dyed and unfinished
C-08208	C	Woven shirting – plain – 100% cotton – solid dyed and unfinished
C-08209	D	Woven plain – suiting

		100% cotton- solid dyed and unfinished

3 Results and Discussion

Table 3 summarizes and compares the mean values of fourteen Low Stress Mechanical properties obtained for samples analyzed in this study. In addition to the parameters measured using KES-FB Instruments, fabric thickness and fabric weight are also measured [15]. Subsets of these sixteen parameters are used for prediction of PHV and THV by the KES-FB data processing system.

Table 3: Fabric mechanical properties and surface properties as measured using KES-FB system

	Property	Symbol	A	B	C	D
1	Linearity of load-Extension curve	LT	0.632	0.849	0.597	0.667
2	Tensile Energy	WT	32.78	6.72	9.91	10.50
3	Tensile Resilience	RT	19.76	42.09	49.94	38.00
4	Bending rigidity	B	0.0066	0.0162	0.0270	0.1249
5	Hysteresis of Bending Moment	2HB	0.0081	0.0432	0.0277	0.1820
6	Shear stiffness	G	0.47	0.48	0.52	1.58
7	Hysteresis of shear force at 0.5 deg of shear angle	2HG	2.49	1.88	1.24	3.54
8	Hysteresis of shear force at 5 deg of shear angle	2HG5	2.30	1.81	1.79	7.74
9	Linearity of Compression	LC	0.341	0.3141	0.242	0.340
10	Compressional Energy	WC	0.378	0.313	0.181	0.376
11	Compressional Resilience	RC	39.47	31.91	37.84	34.31
12	Coefficient of friction	MIU	0.205	0.280	0.191	0.188
13	Mean Deviation of MIU	MMD	0.0100	0.0170	0.0208	0.0173
14	Geometrical roughness	SMD	4.61	3.77	9.43	11.67
15	Thickness	T	0.919	0.943	0.610	1.022
16	Weight	W	12.55	15.86	12.52	24.60

3.1 Effect of Fabric construction on low stress mechanical properties

3.1.1 Tensile Properties

Low stress tensile properties measured are Linearity of load extension curve (LT), Tensile energy (WT) and Tensile Resilience (RT). Their values are graphically shown in Figure 1, 2 and 3 and 4 respectively. Figure 4 shows typical load extension curve during the experiment. OAB and BCO correspond to loading and unloading respectively.

$$Linearity is defined as = \frac{area under OABDO}{area under triangle OBD}$$

Tensile energy = area under the curve OAB giving the energy used for deformation and

$$Tensile\ Resilience = \frac{area under OCBDO}{area under OABDO} X100$$

The linearity of tensile curve (LT) for fabrics tested varied from 0.597 to 0.849. LT values indicate the non- linear behavior of load extension curve of fabrics. A value close to 1 indicates the linear tensile curve typical of an elastic material[16][7][6]. The higher value of tensile energy in knitted innerwear fabric is due to higher extensibility. The extensibility of non-woven fabric was the lowest. The variation in tensile resilience of fabrics is significant and is highest for finished non-woven fabric. The tensile resilience for woven fabrics is relatively constant and is expected to increase when the fabric is finished.

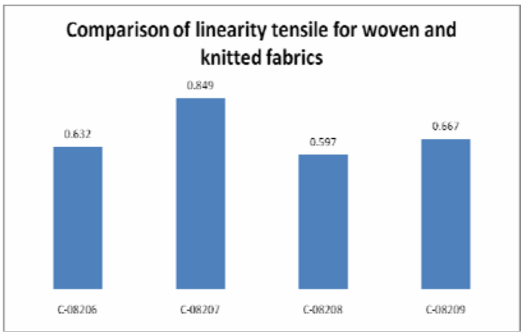

Figure 1 – Linearity Tensile

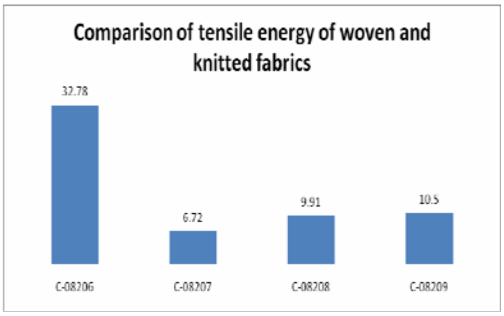

Figure 2 – Tensile Energy

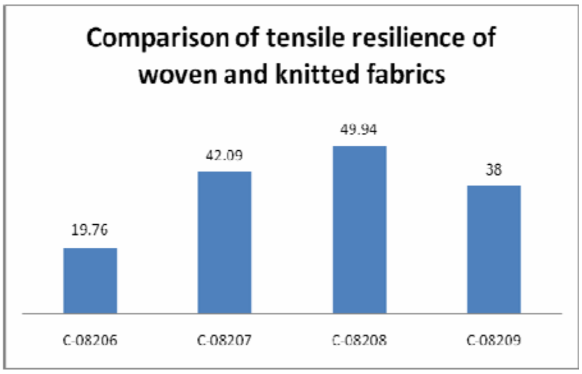

Figure 3-Tensile resilience of apparel fabric

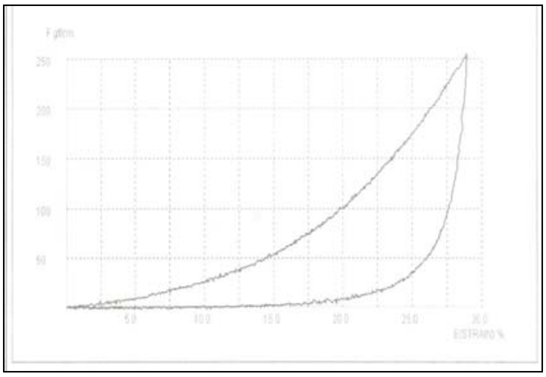

Figure 4 - Tensile curve of apparel fabric

3.1.2 Shear Properties

Figures 5, 6, 7 and 8 depict the shear properties obtained using KES-FB instrument. The values measured were G (shear rigidity) and Shear hysteresis at 0.5 deg of shear angle and at 5 deg of shear angle[16]. The G value is higher for woven bottom fabrics. Other fabrics gave reduced G values indicating the importance of fabric finishing for successful draping and fabric forming qualities that are necessary for successful tailoring and garment wear. Furthermore, the unfinished fabrics exhibit a high degree of inelasticity in shear (large values of shear hysteresis) as shown in figure 7. These results indicate that in order to have a better handle, we have to reduce the inter-yarn pressures in the fabrics by subjecting them to finishing processes like stentering and pressing.

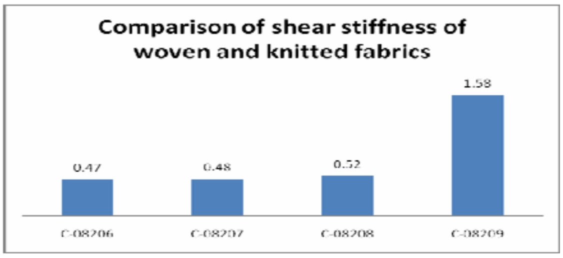

Figure - 5 - shear stiffness

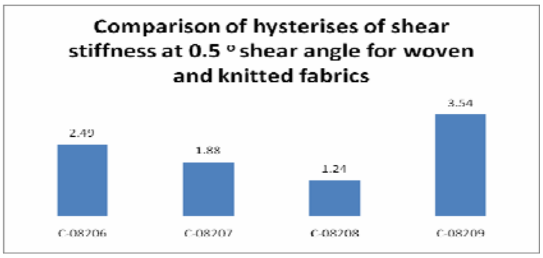

Figure 6 – Shear hysteresis

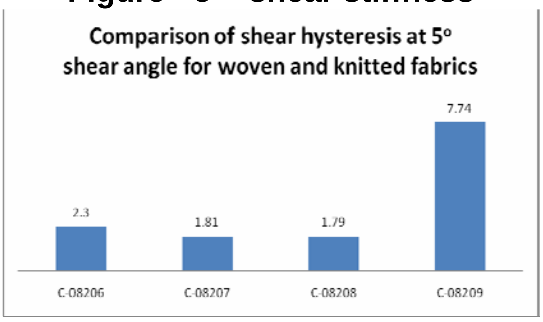

Figure 7 – Shear hysteresis

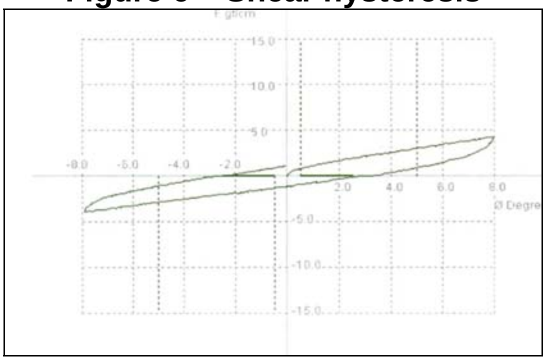

Figure 8 - Shear curve of apparel fabric

3.1.3 Bending Properties

Differences observed in bending parameters are evident from fabric 4 and 5 (Figure 9, 10 and 11). Higher B means the sample is stiff and drapability is low. Similarly two low a value of B means the fabric would be too flexible as supply. For good drapability some minimum bending rigidity is required. For imparting higher B (Bending rigidity) and hysteresis (2HB), it is necessary to subject the fabric for finishing treatment like stentering and pressing. These treatments increase in fabric rigidity and elastic recovery from bending. A larger value of 2HB means a greater fabric inelasticity and woven bottom fabric (C-08209)). The variation in results of bending properties of knitted fabrics (Nos.C-08206 and C-08207) and woven fabrics can be observed in Figure 9 and 10.

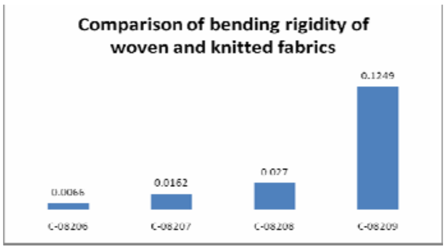

Figure 9 – bending rigidity

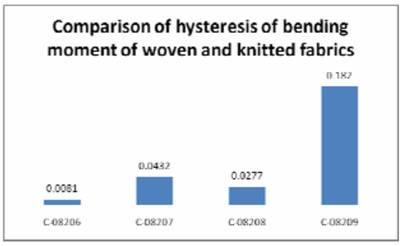

Figure 10 – Bending hysteresis

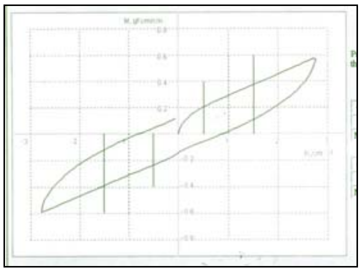

Figure 11 – Bending curve

3.1.4 Compression properties

Typical compression curve is similar to that obtained for tensile curve as shown in Fig.4. LC, WC and RC are defined in the same day as LT, WT and RT are defined respectively.

Figures 12, 13, and 14 are the values obtained from compression test of the fabrics. LC values are a measure of linearity of compression curve. WC describes fabric compressive toughness. RC indicates the rate of fabric elastic recovery. A large value of RC indicates good elastic recovery. Finishing would result in changes in compressibility of fabrics.

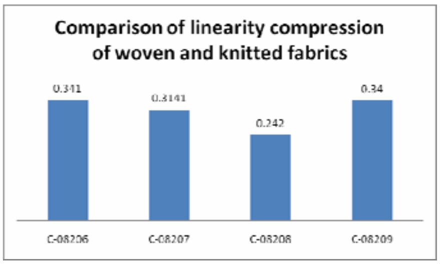

Figure 12 – Linearity compression

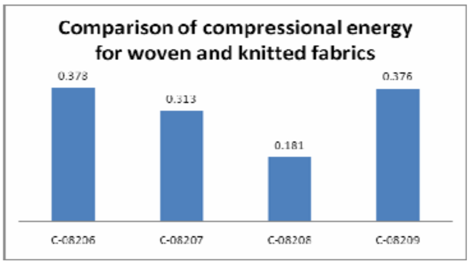

Figure 13 – Compression energy

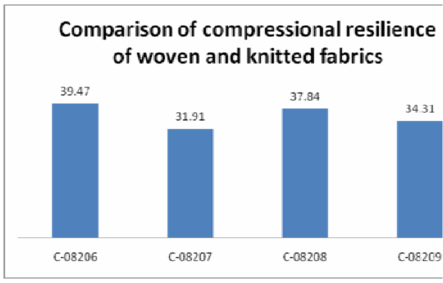

Figure 14 – Compression resilience

3.1.5 Surface Properties

Fig.18 given a typical determination of frictional force in both the directions of relative movement. MIU is the ratio of average frictional force to the normal load. Mean deviation of MIU gives the variability in the MIU value along the fabric. Geometrical roughness given the average vertical displacement of the wire figure tip with reference to the mean surface layer of the fabric. The variation in fabric surface roughness is depicted in Figures 15, 16, 17 and 18 respectively. Roughness of fabric varies with the type of structure. Higher value of roughness is seen in woven fabrics as compared to knitted fabrics. This is expected as woven structure has larger amplitude of crests and traiphs. Higher value of MIU (coefficient of friction) is observed in knitted fabrics. The mean deviation of MIU i.e. MMD is highest for woven fabric sample indicating larger variation of friction.

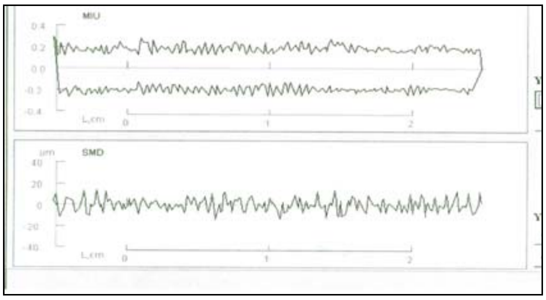

Figure 15- Friction curves

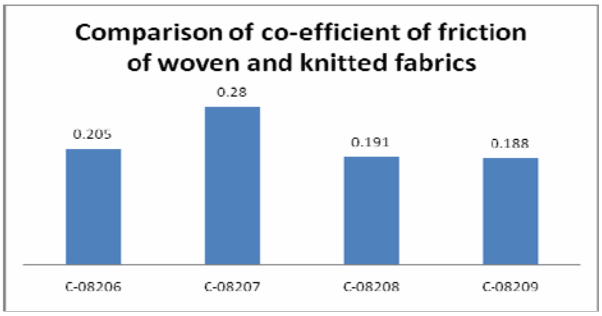

Figure 16 – Coefficient of friction

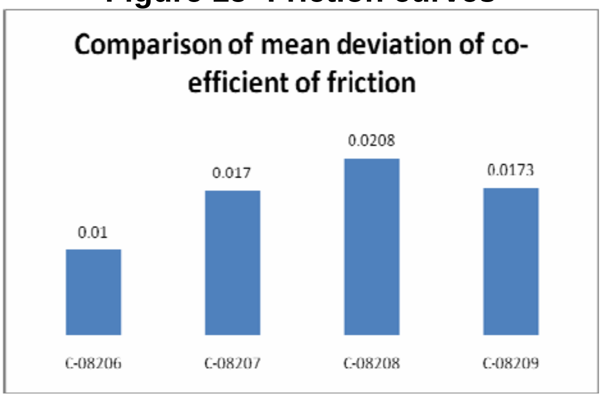

Figure 17- Mean Deviation of MIU

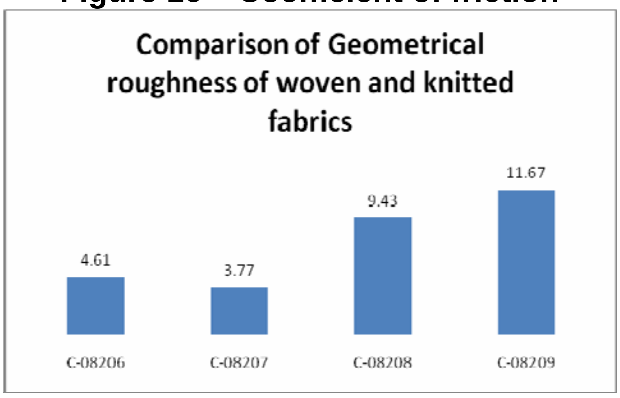

Figure 18 – Geometric roughness

3.1.6 Thickness and Fabric Weight

Fabric thickness (T) is greatly affected by the finishing process and the thickness of the fabric was least for woven shirtings which are due to the finer yarns used and tight construction. However fabric thickness was highest for woven bottom weight fabric. Figure 19 shows fabric thickness of different fabrics used in this study.

The variations in fabric weight between knitted and woven fabrics is due to their structure and utilization of different configurations of fabric making. The variation in fabric weight of different fabrics used in this study is shown in figure 20.

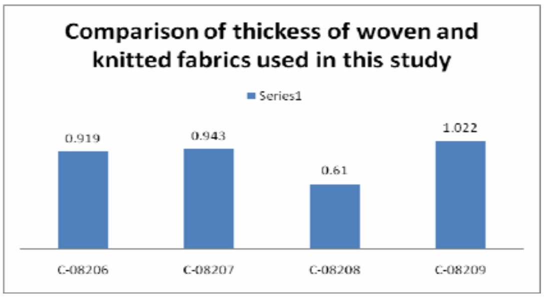

Figure 19 - Fabric Thickness

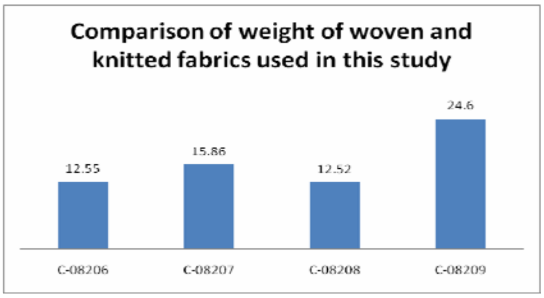

Figure 20 – Fabric weight

3.1.7 Evaluation of Fabric Hand

The Primary Hand Values (PHV) and Total Hand Values (THV) are evaluated for samples chosen in this study (Table 4 and Table 5)[14]. KN-402-KT equations were used for Hand value calculations for knitted fabrics(A and B). A negative value of Koshi was observed possibly due to a loose fabric construction. Koshi is property associated with a feeling related with bending stiffness and a springy feel that promote a soft feeling. Fabric that has a compact weave density and woven by springy and elastic yarn makes this feeling strong. However, the knitted fabrics reported negative koshi that improved with subsequent finishing treatments. For woven fabrics KN-203-LDY equations are used for evaluation of PHVs. The PHVs that influence the Total Hand value in this case are Koshi, Numeri and Fukurami. It can be seen that a tightly woven construction gave positive values of Koshi, Numeri and Fukurami.

Table 4: Primary Hand values obtained in laboratory

Hand values	A	B	C	D
Koshi	-3.66	-1.24	5.13	4.66
Numeri	8.18	6.59	7.34	4.59
Fukurami	3.72	0.65	9.60	6.48
Namerakasa	-	-	-	-
Sofutosa	-	-	-	-

Knitted fabrics were evaluated using KN-301-winter equations. These fabrics showed a THV of 0.13 and -0.19. Low THV could be due to the loose nature of knit structures affecting the magnitude of Koshi. However this could be improved if the knitted fabrics were subjected to proper finishing treatments.

For evaluation of total hand values of woven shirting fabrics KN-302-winter equation were used and a THV value of 4.84 was obtained. PHVs showed excellent hand values despite the fabric being unfinished. In case of woven bottom fabrics KN- 301-winter equations were used and a THV of 3.07 indicates that the handle value could be improved by imparting finishing to fabrics. THV values of fabric samples are given in Table 5.

Table 5: Total Hand Values obtained in laboratory

Fabric Samples	THV
A	0.13
B	-0.19
C	4.84
D	3.07

4 Conclusions

In this study comparative evaluation of low-stress mechanical properties of knitted, woven and non-woven fabrics is made from the structural view point. The results show that there exists wide difference in law stress mechanical properties of different fabrics measured. Mechanical properties are main factors that contribute to the Primary Hand Values and Total Hand Values. It appears that determination of Koshi for knitted fabrics using KES-FB system may not be proper. Also, it affects the THV of knitted fabrics giving absurd results. Using KES-FB for knits may be carried out only after some modifications.

5 Acknowledgements

This work was performed under financial assistance from CSIR-India, Extra mural research, Library Avenue, opp Institute of Hotel Management, Pusa, New Delhi-12 and at Central Silk Board, Central Silk Technological Research Institute, Ministry of Textiles, Madivala, and Bangalore – 68. The KESF tests and Hand value calculations were performed at Central Institute for Research on cotton technology (CIRCOT), ICAR, Mumbai. We express our thanks to Dr.Mitsuo Matsudaira, Kanazawa University, for providing Hand evaluation and standardization committee materials for evaluation and analysis of results.

References

1. Daniela Zavec pavlinic and Jelka Gersak.,"Investigations of the relation between fabric mechanical properties and behaviour." International Journal of clothing science and technology,Vol.15,No.3/4.2003,pp.231-240
2. Christopher G.Provatids, Savvas.G.Vassiliadis."On the performance of the geometrical models of fabrics for use in computational mechanical analysis", International journal of clothing science and technology, vol.16.No.5, 2004.pp.434-444
3. B.K.Behera and S.B.Muttagi.,"Engineering design of woven fabrics – A recent approach", Indian Journal of Fibre and Textile Research, vol.27, September 2002, pp.315-322
4. K.Thangamani and T.Sasireka."Low-stress mechanical properties of viscose/spandex plated fabrics." Journal of the Textile Association",Sept-Oct, 2006.
5. M.de Araujo.R.Fangueiro and H.Hong,"Modelling and Simulation of the mechanical behaviour of weft-knitted fabrics for Technical Applications," Part I: General considerations and experimental analyses,"Autex research journal, Vol.3, No.3, September 2003.
6. R.C.Dhingra, D.Liu, and R.Postle."Measuring and Interpreting low-stress fabric mechanical and surface properties", Part II: Application to Finishing, Drycleaning and Photodegradation of wool fabrics", Textile Research Journal, pp357-367, June 1989
7. R.C.Dhingra, D.Liu, and R.Postle."Measuring and Interpreting low-stress fabric mechanical and surface properties", Part II: Application to Finishing, Drycleaning and Photodegradation of wool fabrics", Textile Research Journal, pp357-367, June 1989
8. Dominique dupuis, Gueorgui popov, perre viallier,"Compression of Grey state fabrics as a function of yarn structure", Textile Research journal, 65(6), pp 309-316(1995)
9. Mitsuo matsudaria and masahiko kubo,"Objective evaluation of hand for futon cloth", Journal of the Textile Machinery society of Japan, vol.42, No.1, 2(1996)
10. Hiroko Yokura, Masakao Niwa,"Objective hand measurement of nonwovens used for top sheet of disposable diapers", International Journal of clothing science and Technology, vol.3/4, 2002, pp.230-237.
11. Mitsuo Matsudaira and Momoko sugimura,"Objective evaluation equation for the appearance of swinging flared skirts", Textile Research Journal, 74(11), pp 1007-1012(2004).
12. Savvas G.Vassiliadis, Demetrios T.Venetsanos and Christopher G.Probatidis,"Optimization aspects on the hand of the fabrics", Textile Research Journal, 75(9), pp653-661(2005).
13. D.V.Parikh, T.A.Calamari, and W.R.Goynes, Y.Chen, O.Jirsak,"Compressibility of cotton blend perpendicular- laid non-wovens", Textile research journal, pp.74 (1), 7-12(2004).

14. Sueo Kawabata,"The standardization and analysis of hand evaluation", 2nd Edition
15. D.P.Bishop,"Fabrics: Sensory and mechanical properties", Textile progress, volume 26, N.3.
16. Sit-Lun Yick, K.P.S.Cheng, R.C.Dhingra, and Y.L.How,"Comparison of mechanical properties of shirting materials measured on the KES-F and FAST Instruments," Textile Research Journal, 66(10), pp.622-633(1996).
17. Youngjoo Na and Haeqon Chung,"Subjective hand and compressional property values of woolen fabrics", Textile Research Journal, 70(10), pp.932-936(2000).
18. B.K.Behera and Ajay Sardana and B.C.Verma,"Studies on polypropylene- cotton spun yarns and their fabrics," Indian Journal of Fibre and Textile Research", Vol.26, September 2001, pp.280-286.