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Influence of weave structure on low-stress mechanical properties and total hand values of cotton fabric

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Attempts have been made to produce other derivatives of cotton muslin fabric by altering its weave structure from plain to twill and sateen with higher pick insertions to make it dimensionally stable for its potential use in readymade garments, besides saris and ladies dress materials. Low-stress mechanical properties and total hand values of these fabrics are evaluated to understand their suitability for use in readymade garments. It is observed that sateen shows higher drape, higher compression resilience, lowest shear rigidity, moderate bending rigidity, and lowest surface smoothness & frictional values, finally showing best total hand values and higher gloss than the other two woven structures.

Keywords: Cotton, Gloss value, Low-stress mechanical properties, Muslin, Sateen, Total hand values, Twill

1 Introduction

Cotton muslin is the finest variety of handloom made plain fabric produced by using handspun finer variety of cotton yarn. Its transparent look, light weight and drapeable structure has a legacy for its special use, such as elegant sari and high value curtains. Another advantage of muslin is that it has easy to dye texture. Hence, manufacturing of such fine variety of cotton Khadi muslin fabric has got a socio- economic potential in the Indian subcontinent. However, for diversifying its uses in garment sector as ladies dress material and other specific uses, a higher drape and gloss may be obtained by changing its weave structure from plain to twill or sateen. Earlier, the properties of finer variety of cotton fabrics (muslin and its derivatives) were studied by varying woven structure (plain, twill and sateen)[1], mentioning the strength realization of fibre in the yarn and yarn in the fabric structure. In the present work, the suitability of such three woven finer muslin cotton fabrics plain, twill and sateen, for garment making has been studied by evaluation of hand and comfort values of these three fabrics.

If the performance of plain weave cotton muslin fabric and similar other woven structure of finer derivative of cotton muslin satisfies to a large extent garmenting objective, subject to desired level of comfort and hand values, then these fabrics can cater to the need of garment and readymade sectors.

Fabric performance in relation to better fitting to the human body, indicates is an essential requirement of this type of fine and delicate muslin and its derivative cotton fabrics, considering their mechanical properties, comfort and total hand values. Fabric performance study, either by a subjective method (called handle judgment) or by evaluation of THV data or by alteration of woven design of the fabric or by related fabric performance with regard to fabric handle is felt necessary.

The hand and comfort aspects of fabric performance are so important for the apparel manufacture with the change in the apparel-production system from a manual system to a line-production system, the inter-relationship between fabric mechanical properties and fabric process ability in tailoring as well as ease of making-up of garments have become essential to know. Hence, the present work assumes highest importance for evaluation of total hand values, low-stress mechanical properties and gloss values of three selective woven structures (plain, twill and sateen) of finer variety of cotton muslin fabric or its derivatives.

2 Materials and Methods

Suvin cotton fibre of 38.4 mm span length (2.5%), 17.1 mm span length (50%), 3.1 micronaire value, 32.3 cN/tex tenacity and 7.2% elongation-at-break was used for the preparation of yarn.

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2.1 Yarn Preparation

The sample of “Suvin” variety of cotton was collected and 2.7 tex (unsized) yarn was hand spun by following a series of traditional scientific processes like sorting and cleaning of Suvin cotton fibres including seed separation, followed by lap making through hand drafting by intermittently winding on wire drum and then drafting (pissai) on a rotating pair of wooden drum and steel roller to make uniform sliver and roving wound on the wooden bobbins. From this cotton roving bobbin, the finer variety of cotton yarn was spun on a 6/20 model -7 spindle modified Khagra Charkha. Then these 400 Nm (2.7 tex) cotton finer yarn was used for preparing cotton muslin fabrics and its derivatives with different other woven structures. Cares were taken in all steps, so that the variation in mass CV and other properties along the length of the yarn can be minimized. However, the mass CV (20-30%) and strength CV (12-15%) of such finer cotton yarns of 2.7 tex were found to be much higher than the usual range of mass CV and tensile strength CV of any common cotton yarn spun in a textile mill.

2.2 Preparation of Finer Cotton Fabrics

Before weaving, 2.7 tex warp yarns were sized manually using sizing mixture of starch and corn cooked properly in aqueous medium and then woven into plain (1 up 1 down), twill (one up three down) and sateen structures (4 end irregular) on conventional Santipuri handlooms. The reed used was 58 Stockport and the denting plan was 2 ends /dent. As the new structures of these three cotton finer fabrics were different, it was not possible to keep the number of picks per inch same in these three constructions to weave such delicate fabrics of 39-52 GSM. Such type of finer variety of muslin fabric is rarely made in mill sector. The fabric constructions are depicted in Table 1.

2.3 Bleaching and Dyeing

After conventional desizing and scouring, the bleaching of cotton muslin fabric was carried out traditionally following standardized treatment [2,3] with cow dung bleaching solution for 90 min followed by steaming for around 30 min. The bleached white fabric was then washed and air dried.

Dyeing of the cotton muslin fabric and its derivatives was carried out by following conventional normal reactive dyeing procedure [4].

2.4 Testing

KES-FB 1

Low-stress mechanical properties of fabrics were measured on KES-FB1 system[5] under standard testing condition. Tensile properties, bending properties, shearing properties, compression property, thickness and weight of the fabrics were thus measured.

Keeping the instrument (auto tensile and shear tester 2012) in the tensile testing mode, fabric (20cm × 5cm) was subjected to an applied unidirectional force up to a maximum of 500gf/cm. After reaching the maximum force, it was allowed to return to its initial state at a constant rate of strain. The deformation mode was "strip biaxial", where the fabric was stretched uni-directionally with restriction of transverse strain. The experiment was repeated with fabric mounted in the weft face in the direction of stretch. Linearity of load-extensive curve (LT), tensile energy (WT) and tensile resilience (RT) are calculated using the following relationship:

$$LT = {}_0\int^{Em} F\, dE/0.5\, FmEm$$

where Em is the extensibility at 500gf/cm; and Fm, the force applied.

$$WT = {}_0\int^{Em} F\, dE$$

$$RT = ({}_0\int^{EM} F\, dE/WT) \times 100$$

With the KES- FB-1 tester in the shearing mode, to begin with a unidirectional constant, extension force of 10 gf/cm was applied on the fabric and then the shear force was superposed in the fabric plane along the transverse direction up to 8 degree (the maximum shear angle). Thereafter, the fabric

Table 1 — Characteristics of plain, twill and sateen derivatives of muslin

Fabric	Yarn count tex	Ends/cm	Picks/cm	GSM	Fabric thickness (To), mm		Fabric thickness at max. pressure (Tm), mm		Fabric weight mg/cm^2	
					Grey	Dyed	Grey	Dyed	Grey	Dyed
Plain	2.7	47	61	39	0.346	0.339	0.151	0.151	3.95	3.60
Twill	2.7	47	94	51	0.502	0.362	0.207	0.198	5.09	4.40
Sateen	2.7	47	101	52	0.489	0.435	0.193	0.189	5.15	4.92

To – Thickness at 0.5gf/cm^2 and Tm – Thickness at 5gf/cm^2.

shear deformation was reduced/recovered by reducing the shear angle back to zero. Shear stiffness (G) for ϕ 0.5°-5°; and hyteresis values 2HG for ϕ 0.5° & 2HG5 for ϕ 5° were calculated.

KES FB2

The bending properties were determined in bending tester 1996 using following testing conditions. The deformation mode is pure bending. The curvature range varies from -2.5 cm^{-1} to + 2.5 cm^{-1}. Bending rigidity (B) for K between 0.5 and 5 & bending hysteresis (2HB) for K 0.5 were calculated.

KES-FB3

The compression properties of the selected fabrics were measured in an Auto compression tester 2012. A compression force was applied on fabric (20cm × 20cm) in the lateral direction up to a maximum 50 gf/cm^2 and then released under a constant rate of deformation.

KES-FB4

The surface properties indicating surface friction etc. for the selected fabrics was measured on a surface tester 1996. In this measurement, friction between the surface and the surface of a contactor is measured under a constant contact pressure. The contactor surface is made up of ten parallel steel wires. Each wire has a diameter of 0.5 mm and length 5 mm. Geometrical roughness is measured by contacting the side of a thin steel wire of 0.5 mm diameter and 5 mm length onto the fabric surface.

The surface friction and surface roughness deformation set-ups, characteristic curves and typical values are given below:

Characteristic values:

$$\text{MIU} = \frac{1}{x}\int_0^x \mu\, dx \; ; \; \text{MMD} = 1/X \int_o^x |\mu - \bar{\mu}|\, dx$$

MIU = Mean frictional Coefficient,

MMD = Mean deviation of frictional Coefficient

SMD = Mean deviation of Surface Contour

$$\text{SMD} = 1/X \int_o^x \left| T - T \right| dx$$

where μ is the frictional coefficient defined by frictional force/load P; x, the displacement of sensor on specimen; and X, the maximum of x, equal to 2 cm.

2.5 Gloss Value of Bleached Cotton Muslin Fabric

The gloss value of three types of cotton muslin fabric has been measured by means of a standard Gloss meter at 45^0 angle in terms of regular reflection occurring at that particular angle of measurement to know the final feel of the fabric[6].

3 Results and Discussion

3.1 Fabric Properties

Selective three differently woven (plain, twill and sateen) finer variety of cotton muslin and its derivative fabrics have been evaluated in the ex handloom stage grey state condition by KES-FB for low-stress mechanical properties. The corresponding results are given in Tables 2-6. Table 1 also represents the fabric dimension (thickness) and weight for the three fabrics, which indicate that both the twill and sateen varieties of selective derivative of cotton muslin are thicker than the existing plain woven

Table 2 — Tensile properties using tensile tester (KES-FB1A)

Fabric		Grey				Dyed			
		LT	WT $gf.cm/cm^2$	RT %	EMT %	LT	WT $gf.cm/cm^2$	RT %	EMT %
Plain	Warp	0.803	8.85	39.04	4.41	0.647	12.80	27.87	7.93
	Weft	0.841	6.15	48.82	2.93	0.757	9.08	31.56	4.80
	Avg	0.822	7.50	43.93	3.67	0.702	10.94	29.72	6.36
Twill	Warp	0.695	5.8	43.57	3.34	0.540	7.78	40.63	5.94
	Weft	0.83	7.33	41.2	3.53	0.724	8.45	34.02	4.69
	Avg	0.763	6.57	42.39	3.44	0.632	8.12	37.33	5.32
Sateen	Warp	0.744	5.85	43.19	3.15	0.695	9.73	32.10	5.60
	Weft	0.877	6.25	45.195	2.86	0.697	8.48	33.06	4.88
	Avg	0.811	6.05	44.20	3.01	0.696	9.11	32.58	5.24

LT – Linearity of load-extension curve, WT – Tensile energy, RT – Tensile resilience and EMT – Tensile strain.

Table 3 — Bending properties using pure bending tester (KES-FB2)

Fabric		Grey		Dyed	
		B gf.cm^2/cm	2HB, gf.cm/cm	B gf.cm^2/cm	2HB gf.cm/cm
Plain	Warp	0.0311	0.0205	0.0171	0.0089
	Weft	0.0167	0.0130	0.0129	0.0080
	Avg	0.0239	0.0167	0.0150	0.0085
Twill	Warp	0.0451	0.0251	0.0132	0.0082
	Weft	0.0232	0.0147	0.0118	0.0056
	Avg	0.0342	0.0199	0.0125	0.0069
Sateen	Warp	0.0372	0.0300	0.0149	0.0081
	Weft	0.0159	0.0162	0.0171	0.0092
	Avg	0.0265	0.0231	0.0160	0.0087

B– Bending rigidity and 2HB– Bending hysteresis.

Table 4 — Shear properties using shear tester (KES-FB1)

Fabric		Grey			Dyed		
		G gf/cm.deg	2HG gf/cm	2HG5 gf/cm	G gf/cm.deg	2HG gf/cm	2HG5 gf/cm
Plain	Warp	0.54	0.77	1.39	0.27	0.28	0.51
	Weft	0.54	0.67	1.32	0.27	0.33	0.57
	Avg	0.54	0.73	1.36	0.27	0.30	0.54
Twill	Warp	0.36	0.37	0.67	0.28	0.46	0.68
	Weft	0.38	0.46	0.84	0.27	0.29	0.47
	Avg	0.37	0.42	0.76	0.28	0.38	0.57
Sateen	Warp	0.33	0.36	0.62	0.27	0.41	0.59
	Weft	0.37	0.41	0.77	0.26	0.45	0.61
	Avg	0.35	0.38	0.70	0.27	0.43	0.60

G – Shear rigidity; 2HG – Hysteresis of shear force at 0.5° shear angle and 2HG5 – Hysteresis of shear force at 5° shear angle.

Table 5 — Compression properties using compression tester (KES-FB3A)

Fabric	Grey			Dyed		
	LC	WC, g.cm/cm^2	RC, %	LC	WC, g.cm/cm^2	RC, %
Plain	0.399	0.038	47.46	0.421	0.038	52.15
Twill	0.417	0.061	43.31	0.469	0.038	48.28
Sateen	0.407	0.060	50.05	0.425	0.052	51.70

LC – Linearity of compression-thickness curve, WC – Compressional energy and RC – Compressional resilience.

fabric. The same is true for both structures at minimum pressure (0.5gf/cm^2) and maximum pressure (5 gf/cm^2). The similar trend is observed for the fabric weight .This may be due to higher number of floats and less number of interlacement causing it to be fuller, showing higher thickness than the other fabrics. Higher weight of sateen and twill structures than the plain structure is due to higher number of picks inserted for generating equal level of binding effect to achieve dimensional stability of these fabrics at par with the plain woven structure. We would like to mention here that the same GSM fabric cannot be prepared with twill and sateen structures having less number of interlacement and woven from such a finer and delicate cotton warp and weft. Hence, with insertion of higher picks, both sateen and twill structures are possible to be weaved or with reasonable production rate having reasonable end and pick breaks on the loom. From commercial point of view, the existing variety of cotton muslin fabric and

Table 6 — Surface properties using surface tester (KES-FB4)

Fabric		Grey			Dyed		
		MIU	MMD	SMD μm	MIU	MMD	SMD pm
Plain	Warp	0.199	0.0293	4.19	0.171	0.0143	2.79
	Weft	0.189	0.0309	7.12	0.174	0.0183	3.76
	Avg	0.194	0.0301	5.66	0.173	0.0163	3.27
Twill	Warp	0.182	0.0152	4.01	0.187	0.0136	3.69
	Weft	0.197	0.0246	5.09	0.170	0.0101	3.08
	Avg	0.189	0.0199	4.55	0.178	0.0118	3.39
Sateen	Warp	0.165	0.0189	3.64	0.196	0.0140	4.19
	Weft	0.182	0.0190	4.82	0.216	0.0146	3.48
	Avg	0.173	0.0190	4.23	0.206	0.0143	3.84

MIU – Coefficient of friction; MMD – Deviation in coefficient of friction and SMD – Geometrical roughness.

two newer varieties (twill and sateen) have been woven and their low-stress mechanical properties and hand values are determined and compared hereunder.

Table 2 indicates the tensile properties (KES-FB1A) of the three fabrics, indicating tensile force/energy, tensile resilience, tensile strain/ elongation and linearity of load extension curve. Amongst the 3 grey fabrics (plain, twill and sateen), the sateen fabric shows somewhat lower tensile energy (6.05 gf.cm/cm^2) as compared to that of plain woven fabric (7.50 gf.cm/cm^2). Although twill grey fabric shows almost moderate level of tensile energy, it has lowest tensile resilience amongst these three fabrics. Linearity of load extension curve is somewhat lower for sateen fabric than for both twill and plain fabrics. Lowest tensile energy for sateen may be due to least number of interlacement and higher length of floats, though it shows higher fullness/thickness than that of plain fabric. The increase in tensile energy in case of dyed fabrics is due to swelling of the fibres and yarns after dyeing, wherein the warps and wefts are more uniformly rearranged amongst themselves giving a better cover factor of the fabric even if there is not much increase in linearity of load extension curve as compared to the grey fabrics. The weight loss attributes to the removal of starch after desizing and scouring and loosening of the fabric structure after dyeing.

Table 3 shows bending properties (KES-FB2) and Table 4 shows shear properties (KES-FB1) for the three fabrics. It is observed that the twill fabric has highest bending rigidity. As rigidity depends on thickness and structure, the twill fabric having higher thickness and higher weight show higher bending rigidity values. The sateen having similar weight, however, shows lower bending rigidity due to lesser thickness and higher floats. Dyed fabrics show reduction in bending rigidity values due to reduction in thickness and weight of the fabric. The shear rigidity of a fabric depends on the mobility of cross threads at the intersection point, which again depends on weave, yarn diameter and the surface characteristics of both fibre and yarn[6]. Shear properties (Table 4) indicate that shear rigidity is lowest for sateen variety along with lower shear force for shear hysteresis at both 0.5^0 and 5^0 shear angles. Lower the shear rigidity and bending rigidity, the softer is the fabric, giving better compliance ratio and bending comfort to the wearer. In case of dyed fabric, it is further reduced making the dyed fabrics, preferably sateen a better option for wearing flexibility. Hence, considering shear rigidity being minimum and bending rigidity moderate, the sateen fabric appears to be more amenable to bending and shear stress and, hence is a better option for its use in readymade garment.

Table 5 shows compression properties of the fabrics. The compressibility of a fabric mainly depends on yarn packing density and yarn spacing in the fabric. Compressibility provides a feeling of bulkiness and spongy property in the fabric. Compressibility has some correlation with the thickness of the fabrics. The higher the thickness, the higher is the compressibility[6]. Corresponding data in Table 4 indicate that compression energy/force for both twill and sateen fabric are higher than that of plain fabric, i.e. more energy will be required to compress the fabric under same load. As these two fabrics (twill and sateen) are having more thickness and weight than the plain fabric, the compression energy are higher, but due to higher floats and fullness with less number of interlacement, the compression resiliency is highest in sateen variety and exhibits similar value after dyeing also, which is an important requirement for easy fitting garments. Hence, sateen fabric shows its superiority for usage in garments than that of plain woven cotton muslin fabric.

Results of surface properties including coefficient of friction and surface roughness of the fabrics are given in Table 6. The surface roughness and friction are lowest for sateen fabric as compared to that for both plain and twill structures. The higher the number of interlacement, the higher is the number of contours in the fabric structure and hence, the higher is the frictional resistance. So, plain structure shows highest frictional resistance and surface roughness and these values get reduced with the reduction in number of contour/interlacement. Hence, these values are reduced to a maximum extent in sateen structure against the other two structures.

The lesser the surface friction and roughness, the higher is the wearer comfort, considering the smoothness of the fabric as it rubs to the skin to a lesser extent. This is desirable for readymade garments and bed linens. Due to the removal of size from the fabric during desizing process, the surface roughness decreases after dyeing. The coefficient of friction increases marginally for dyed sateen fabric over grey fabric which may probably be due to the generation of protruding fibres during dyeing because of more number and length of floats in the structure.

Table 7 shows total hand value (THV) of the three grey fabrics which may be estimated with the help of various primary hand values using the Kawabata system of equations. Corresponding data show that the THV is highest for sateen grey fabric (4.14) as compared to plain (3.44) and twill (4.12) THV values The low-stress compression parameters, such as (LC), (WC), (RC), and (T) affect the primary hand value (Fukurami or bulkiness) of the fabric. The overall smoothness (Numeri) and overall fullness and softness (fukurami) are also highest for sateen fabric, indicating its distinctive suitability for tailoring ability and comfortness for making readymade garments, though overall stiffness (Koshi) is, to some extent, lower for sateen fabric due to increased pick density. The same trend is observed in corresponding dyed fabrics also. The snake charts [Figs. 1(a), 2(a) & 3(a)] for plain, twill and sateen grey fabrics show the

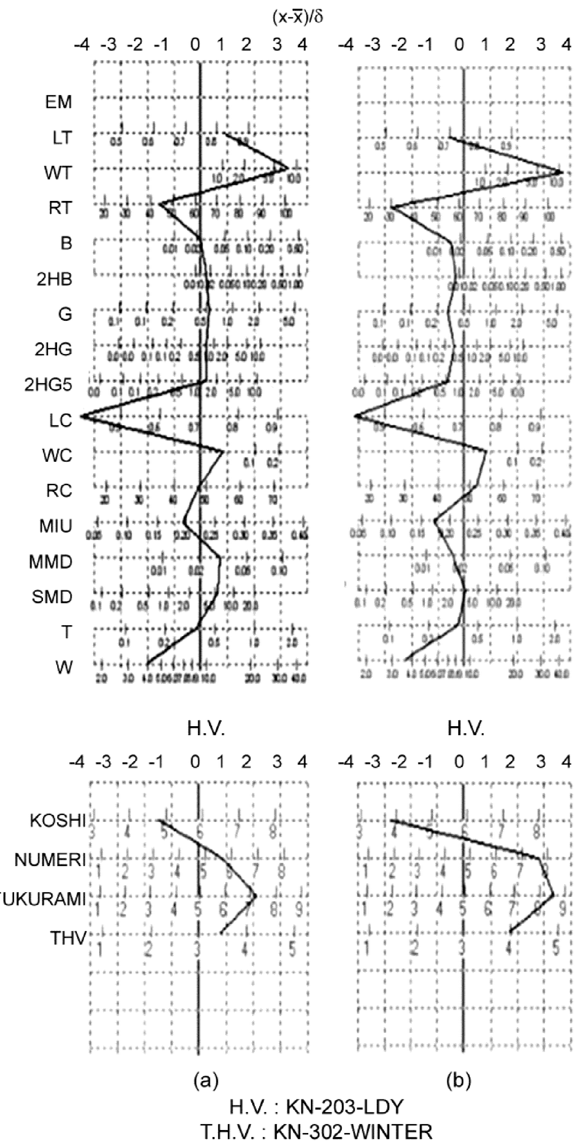

Fig. 1 — Snake diagram and THV of (a) grey, and (b) dyed plain cotton fabric

Table 7 — Total hand values of grey & dyed muslin fabrics

Fabric	Grey				Dyed			
	Koshi (Stiffness)	Numeri (Smoothness)	Fukurami (Fullness & Softness)	THV KN-203-LDY	Koshi (Stiffness)	Numeri (Smoothness)	Fukurami (Fullness & Softness)	THV KN-203- LDY
Plain	4.80	5.62	7.24	3.44	3.84	7.68	8.58	3.95
Twill	4.87	6.77	8.19	4.12	3.88	7.97	8.61	4.16
Sateen	4.58	7.06	8.35	4.14	3.96	7.79	8.81	4.17

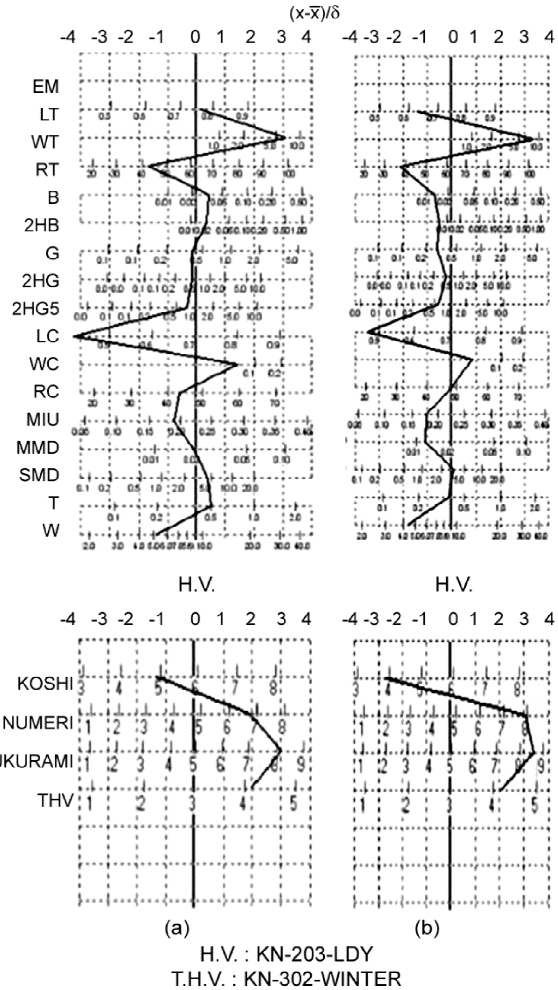

Fig. 2 — Snake diagram and THV of (a) grey, and (b) dyed twill cotton fabric

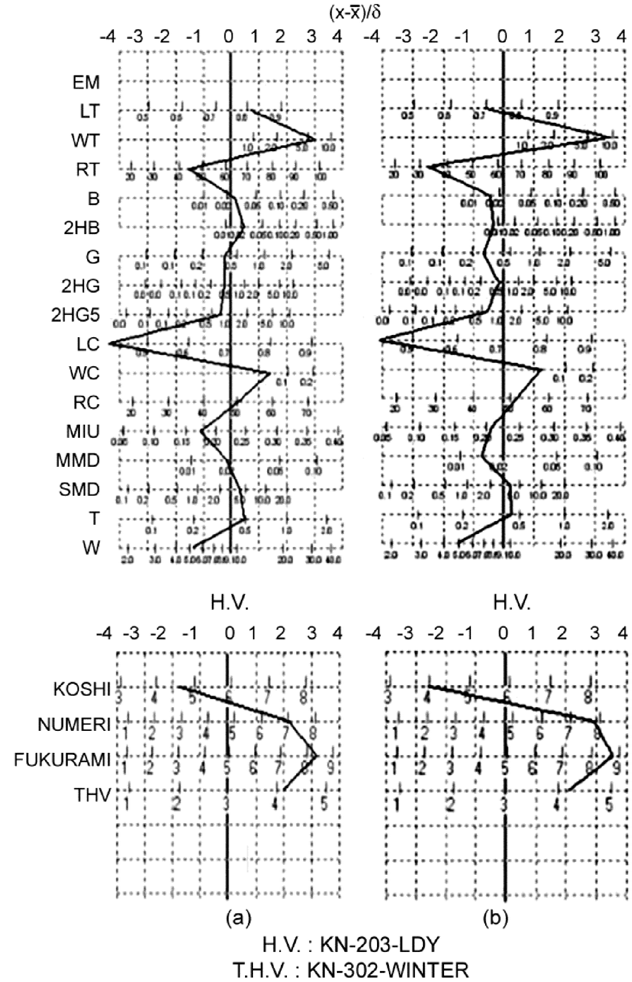

Fig. 3 — Snake diagram and THV of (a) grey, and (b) dyed sateen cotton fabric

mean values and deviations of each parameter to understand its suitability for potential use in readymade garment sector, particularly for ladies and kids dress materials. This helps in judging its formability, elastic potential, silhouette, dimension along with wearer's comfort by determining fullness, softness, smoothness and surface friction analysis. The snake charts [Figure 1(b), 2(b) & 3(b)] of the three dyed fabrics show better potential of the newer sateen derivative of cotton muslin fabric to be more suitable for readymade garment application.

3.2 Gloss of Fabric

The gloss values of plain, twill and sateen samples for grey cotton muslin fabric are 3.7, 4.1 and 4.3, whereas for dyed cotton muslin fabrics the values are 1.35; 1.51 and 1.6 respectively. Smooth and highly polished surfaces reflect images distinctly. Sateen fabric shows better gloss values as compared to twill and plain fabrics. However, dyed fabric as usual shows lesser gloss values due to poor refection of light.

4 Conclusion

It is observed that sateen fabric shows higher drape, higher compression resilience, lowest shear rigidity, moderate bending rigidity, lowest surface smoothness, surface frictional values, finally showing best total hand values and maximum gloss as compared to the other two woven structures (plain and twill). Thus, the 4 end irregular sateen weave structure of fine variety of cotton fabric with low GSM (52 g) is found to be more useful for garment making due to its higher softness, drape, fullness as compared to existing plain and even twill woven structure.

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