

Short Communications

Effect of fibre, plating and loop length variation on fabric tactile comfort

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Modified cellulose (tencel, modal and bamboo) lycra plated single jersey knitted fabrics have been developed with two different loop lengths (2.7mm and 3.4mm) and with different lycra plating (without, half and full plating) along with the cotton fabrics of same variables. The developed fabrics are tested for their tactile comfort properties. The tactile comfort properties of the fabrics depend on the areal density. The results show that the fabrics without lycra and with higher loop length show good grades for smoothness and softness values. The fabrics with higher elastane content exhibit the lowest grade for warmthness. The indices bending average rigidity and bending work of the bending module are low for the tencel single jersey fabrics without lycra and 3.4mm loop length. Compression indices are also low for the fabric which computes a higher grade of softness for the above fabric, which is attributed to the lower areal density of the fabric. It is observed that the indices of surface friction and roughness are also low for the tencel fabric having 3.4mm loop length and without lycra, thus giving the fabric a higher grade of smoothness. The 2.7mm loop length full plated bamboo fabric exhibits the highest Qmax value, indicating the cooler feeling. The value of Qmax descends towards the tencel fabrics. It is recommended from the warmthness grades that the insertion of lycra plating in the fabric reduces the warmthness by increasing the contact area. Fabric hand values computed from the above grades indicate that all the developed fabrics fall under the category of low to high grades, depending on the loop length and lycra insertion.

Keywords: Fabric comfort, Fibre, Loop length, Plating, Tactile comfort

In this era of technology intervention, there are many innovations being made every day in the clothing sector and many new fibres and fabric structures are designed to meet the customer requirements. Though the innovations are carried out in the clothing field, the

use of single jersey knitted fabrics in the apparel and clothing sector has become inevitable¹⁻³. This is because the comfort, lightweight and economical value of the single jersey fabrics has brought their importance in the manufacture of close-to-skin garments and of infant and baby wear. Hence, the research on the single jersey fabrics will not have any boundaries for years to go. As single jersey fabrics are inevitable in close-to-skin garments, the same can be applied for the use of cotton in these garments.

Knitted fabrics produced from non-elastomeric yarns, like cotton, do not recover when subjected to deformation, resulting in poor dimensional stability in knitted fabrics, especially in the case of single jersey knit fabrics. The introduction of elastane yarns in single jersey knitted fabrics has improved its dimensional properties along with its elasticity⁴⁻⁶. The use of elastane has not only improved the fabric's dimensional stability but also better fit and shape retention to the garments⁷. It is the right time to switch over to sustainable textile materials, which can replace the cotton textiles^{8,9}. The use of elastane yarns in single jersey fabrics has become unavoidable to retain the dimensional stability of the fabrics. Fabric Touch Tester (FTT) is a device that can rapidly measure fabric comfort properties within its four integrated modules, i.e. thermal, compression, surface and bending. It has now been used commercially for quicker testing of textiles for their fabric hand value. The use of the instrument has greatly reduced the time, space, and other manual errors caused by the Kawabata testing method.

Fabric handle is the most important feature of sensory comfort, and it is mostly determined by the basic mechanical and surface properties of fabrics (tensile, bending, shearing, compression and thickness), which include minor stresses. Bishop¹⁰ and Matsudaira¹¹ observed that these mechanical qualities help the skin's physical receptors perceive inputs. For example, low bending rigidity ensures a pleasant tactile sensation. Fibre deformation is directly proportional to the 3 times of the fibre length, and inversely proportional to the 4 times of its diameter, according to fibre mechanics analysed by Hes and Hu¹². Rehman *et al.*¹³ observed that the mechanical characteristics of cotton fabrics depend on the number of threads running

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in a specific direction rather than directly on the pore size. The findings of Umair *et al.*¹⁴ showed that the weft yarn type, weave pattern, and picking order, all significantly affect the woven fabric's thermal conductivity. In this work, the effect of fibre, plating and loop length variation on the various tactile properties of the fabrics has been studied.

Experimental

The experimental part is well explained in the article by Shobanasree *et al.*¹⁵

Fabric Tactile Properties

The fabric's tactile properties are well known as fabric physical properties or mechanical properties. The property is measured by using the Fabric Touch Tester (FTT) instrument developed by SDL-ATLAS (Fig. 1), which is correlated with the KES-FB evaluation.

The FTT is a device that measures the physical qualities of the fabric associated with the touch sensations. It includes four different modules, viz. compression, bending, thermal, and surface friction. The testing area of the FTT consists of an upper plate and a lower plate, and the specimen to be tested is prepared as per Fig. 2, which includes both the warp and weft directions. The samples to be tested are placed on the lower plate such that the center square portion of the sample will be lowered and the two arm parts extend horizontally. The center portion of the sample is measured for compression and thermal modules and the arm parts are examined for bending and surface modules.

The expected touch/hand feelings of samples are depicted by FTT principal hand values. A smoother surface is specified by a bigger value of fabric primary touch/hand – smoothness; a softer sample is specified by a bigger value of fabric prime touch/hand–softness, and a warmer sample is specified by a bigger value of fabric primary touch/hand – warmth hand. Primary hand feelings refer to the sensations experienced when actively contacting materials, i.e. hand evaluation. As a result, FTT tests the fabric's physical qualities on both the top and bottom sides. The results from the surface side are utilized to calculate hand feelings, while the results from the bottom side are used to calculate touch feelings. The whole level of comfort in both situations is also assessed. The 13 physical indices (Table 1), used for the calculation of smoothness, softness, and warmth are the primary sensory indices (PSI)¹⁶. The total hand touch value is calculated using PSI data. The

FTT instrument also provides the relevant grading (very low to extremely high).

Results and Discussion

Effect of Variables on Fabric Softness

The fabric softness is determined by the bending and compression module of the fabric touch tester. The bending behaviour of the specimen is determined by the bending average rigidity and bending work values in both the course and wale directions of the fabric. The bending average rigidity is the force required to bend the specimen and is expressed in gf mm /Rad. The higher the BAR value represents the higher rigidity of the fabric for bending. The bending work is the amount of work needed to bend the fabric sample and expressed in gf mm Rad. Table 1 gives the complete data of the FTT indices. It is observed from the table that the values of BAR and BW are high for cotton fabrics as compared to other fabrics. This may be due to the high hairiness of the cotton fibre which has increased the fabric thickness comparatively¹⁷ and



Fig. 1 — Fabric touch tester

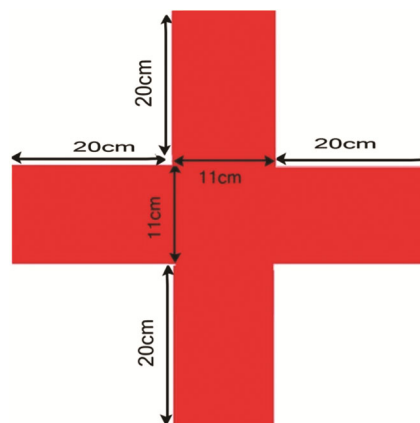


Fig. 2 — Fabric specimen dimension

for the elastane knitted fabrics the values of BAR and BW increase as compared to the fabrics without elastane. Further, the value increases with the increase of elastane content. This is due to the increase in compactness between the loops of elastane knitted

fabrics¹⁸. When considering the fabric tightness, the BAR and BW values decrease with an increase in loop length values. This may be due to the decrease in the areal density of the fabrics as the loop length increases (Table 2). Compression work (CW), compression

Table 1 — Indices of fabric touch tester

Fabric property	Index	Description	FTT software unit (SI unit)	Interpretations
Bending	BAR	Bending average rigidity	gf mm rad ⁻¹ (N m rad ⁻¹)	Force to bend per radian
	BW	Bending work	gf mm rad (Nmrad)	Work to bend specimen
Surface friction	SFC	Surface friction coefficient	-	Friction coefficient on surface with ribbed metal plate
Surface roughness	SRA	Surface roughness amplitude	µm (M)	Roughness irregular wave amplitude
	SRW	Surface roughness wavelength	mm (M)	Roughness irregular wave wavelength
Compression	CW	Compression work	gf mm (Nm)	Work to compress specimen
	CRR	Compression recovery rate	-	% of thickness change after compression
	CAR	Compression average rigidity	gf mm ⁻³ (Nm ⁻³)	Forces to compress per mm
	RAR	Recovery average rigidity	gf mm ⁻³ (Nm ⁻³)	Forces reflected for recovery per mm
	T	Thickness	mm (m)	Thickness of materials
Thermal conductivity	TCC	Thermal conductivity under compression	10 ⁻³ ×Wm ⁻¹ °C ⁻¹ (W m ⁻¹ °C ⁻¹)	Energy transmitted per degree per m per second under compression of specimen
	TCR	Thermal conductivity under recovery	10 ⁻³ ×Wm ⁻¹ °C ⁻¹ (W m ⁻¹ °C ⁻¹)	Energy transmitted per degree per m per second when specimen recovers
	Qmax	Thermal maximum flux	W mm ⁻² (Wm ⁻²)	Maximum energy transmitted during compression

Table 2 — Dimensional and thermal properties of cellulose single jersey knitted fabrics

Sample code	Yarn	Structure	Loop length, mm	WPI	CPI	Stitch density, / inch ²	Thickness mm	Areal density g/m ²	Thermal conductivity × 10 ⁻⁴ , W/cm°C	Thermal resistance × 10 ⁻⁴ W/cm°C
T1	Tencel	100%	2.7	31	32	1705	0.47	137.3	2.26	0.20
T2		(without lycra)	3.4	31	55	992	0.38	99.4	1.83	0.18
TH1		Half plated	2.7	34	44	2046	0.50	165.7	2.54	0.20
TH2			3.4	33	62	1496	0.48	142.8	2.14	0.18
TF1		Full plated	2.7	39	50	2516	0.62	202.0	3.10	0.20
TF2			3.4	37	68	1950	0.55	182.6	2.94	0.19
M1	Modal	100%	2.7	34	55	1870	0.45	141.8	2.32	0.20
M2		(without lycra)	3.4	33	45	1485	0.41	119.2	2.02	0.19
MH1		Half plated	2.7	37	43	2419	0.54	198.1	2.64	0.21
MH2			3.4	41	59	1998	0.51	152.9	2.30	0.20
MF1		Full plated	2.7	45	74	3330	0.85	277.3	3.32	0.22
MF2			3.4	45	61	2745	0.69	260.8	3.01	0.20
B1	Bamboo	100%	2.7	33	36	1998	0.45	161.3	2.52	0.19
B2		(without lycra)	3.4	37	54	1188	0.40	115.9	2.15	0.18
BH1		Half plated	2.7	37	54	2840	0.62	224.5	2.74	0.21
BH2			3.4	40	71	1591	0.57	196.1	2.62	0.21
BF1		Full plated	2.7	42	68	3416	0.84	310.3	3.86	0.22
BF2			3.4	41	76	2856	0.63	246.4	3.59	0.23
C1	Cotton	100%	2.7	40	43	1729	0.59	169.4	3.04	0.21
C2		(without lycra)	3.4	32	34	1090	0.47	134.6	2.35	0.21
CH1		Half plated	2.7	43	63	2717	0.82	278.2	3.90	0.23
CH2			3.4	34	50	1713	0.65	220.9	2.93	0.22
CF1		Full plated	2.7	45	66	2972	1.02	361.9	4.52	0.26
CF2			3.4	36	52	1874	0.81	278.1	4.09	0.23

Table 3 — Effect of variables on bending and compression indices

Sample code	BAR		BW		CW	CRR	CAR
	Course	Wale	Course	Wale			
T1	217.29	122.65	651.07	470.49	1025.49	0.26	106.10
T2	109.90	85.32	310.81	254.54	79.45	0.30	82.53
TH1	397.85	223.50	1253.97	1453.2	1672.94	0.2	122.54
TH2	276.68	154.30	881.20	574.32	1285.02	0.30	107.6
TF1	726.9	759.06	1729.3	2030.39	2212.68	0.1	163.31
TF2	569.95	646.50	1306.46	1583.19	1904.97	0.21	132.77
M1	268.68	145.60	712.02	521.61	1269.56	0.31	106.5
M2	174.74	103.94	533.41	304.85	825.09	0.33	105.6
MH1	628.84	720.5	1464.04	1827.76	2085.58	0.24	144.75
MH2	289.72	172.60	943.56	589.41	1348.08	0.27	110.23
MF1	997.14	1243.12	2306.49	2773.17	2505.98	0.22	275.41
MF2	977.81	1116.99	2275.84	2675.47	2496.2	0.19	225.02
B1	367.15	212.14	945.76	1031.98	1481.05	0.38	111.2
B2	114.70	94.87	411.08	303.91	536.23	0.35	85.02
BH1	874.68	794.3	2168.06	2418.4	2344.56	0.27	201.23
BH2	593.12	660.2	1452.72	1658.0	1960.52	0.30	142.82
BF1	593.12	660.2	1452.72	1658.0	1960.52	0.30	142.82
BF2	1279.94	1307.52	2843.3	3339.99	3055.96	0.30	318.17
C1	495.60	247.98	1285.74	1513.43	1854.35	0.3	126.35
C2	189.98	108.08	582.15	386.68	969.00	0.36	105.92
CH1	1157.1	1295.60	2470.65	3062.84	2548.77	0.27	309.29
CH2	826.21	759.94	2039.31	2290.3	2302.0	0.36	184.14
CF1	1325.8	1419.64	2872.71	4289.00	3125.19	0.19	526.69
CF2	1110.91	1290.13	2327.4	3054.23	2506.4	0.25	276.21

recovery rate (CRR), compression average rigidity (CAR), and recovery average rigidity (RAR) are the four indices computed in the compression module. It is well understood from Table 3, that the compression values also follow the same pattern as that of the bending indices. On interpreting the values of bending and compression modules, the fabric softness is graded in (Fig. 3). It is very well evident that the fabrics made of tencel yarns are softer than other fabrics. When compared with the plated structures, the elastane yarn affect the softness of the fabrics with full plated structures, showing lower grades for softness compared with the fabrics without lycra and the influence of loop length determines that the softness grades are high for the higher loop length fabrics as compared to the tight fabrics.

Effect of Variables on Fabric Smoothness

The smoothness of the fabrics is predicted by the values of friction and roughness modules. From Table 4, the values of SFC, SRA and SRW depict that

the SFC values are high for the fabrics made out of cotton yarns in comparison with the modified cellulose fabrics. This is due to the higher hairiness values of cotton yarns followed by bamboo, modal and tencel yarns. The value is also high for the fabrics with lycra as compared to the fabrics without lycra.

The trend is similar in case of the SRA and SRW values. From these values, the fabric smoothness grades are computed. The grades are visualized in Fig. 4, and it is found that the smoothness grades are high for fabrics produced from tencel yarns and low for cotton and bamboo fabrics which are in line with the findings of Vasile *et al.*¹⁹, stating that the smoothness decreases with the increase in fabric areal density. The fabrics with lycra plating established fewer smoothness grades due to their higher thickness and linear density¹⁷.

Effect of Variables on Fabric Warmthness

The warmthness of the fabrics is evaluated with the thermal module by determining the thermal

conductivity under compression (TCC), thermal conductivity under recovery (TCR) and the thermal maximum flux (Qmax). The obtained results of thermal properties are by the values of thermal conductivity determined by the constant flow method.

From Table 5, it is very well understood that the values of TCC, TCR and Qmax are higher for the fabrics with higher thickness values²⁰.

The values of Qmax are considered for the grading of the fabric warmth and it is depicted in Fig. 5. It

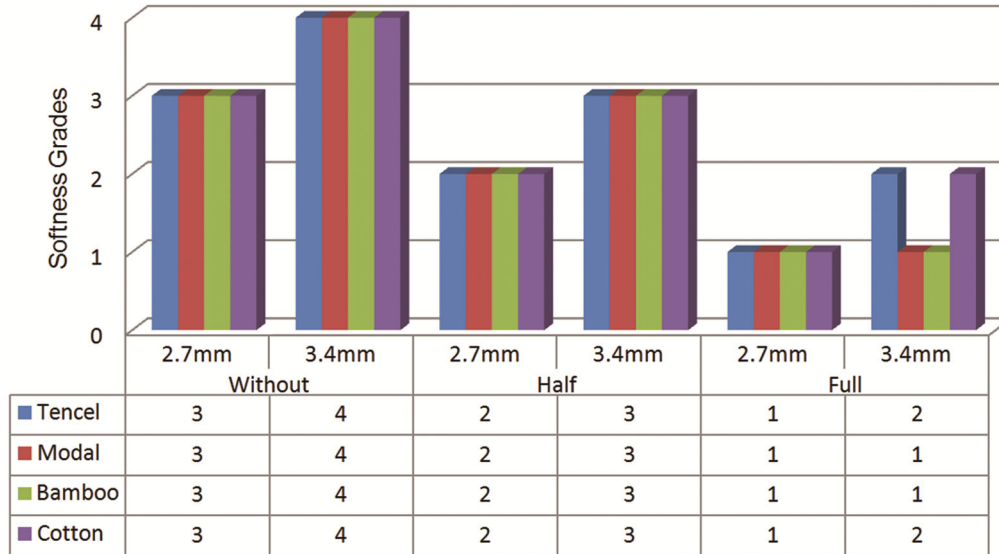


Fig. 3 — Effect of variables on fabric softness

Table 4 — Effect of variables on surface indices

Sample code	SFC		SRA		SRW	
	Course	Wale	Course	Wale	Course	Wale
T1	0.31	0.30	7.45	14.45	0.56	0.51
T2	0.14	0.32	8.4	13.12	0.42	0.36
TH1	0.40	0.34	21.21	25.40	1.45	1.44
TH2	0.34	0.30	12.40	19.08	0.77	1.22
TF1	0.43	0.39	43.93	35.56	2.34	1.78
TF2	0.41	0.38	22.54	29.42	1.50	1.54
M1	0.31	0.30	8.30	17.78	0.59	1.1
M2	0.26	0.28	0.0	6.18	0.00	0.1
MH1	0.43	0.39	33.43	34.39	2.21	1.66
MH2	0.36	0.31	13.10	21.37	1.13	1.22
MF1	0.48	0.49	51.02	46.65	3.77	2.74
MF2	0.45	0.49	47.61	41.17	3.46	2.63
B1	0.40	0.32	17.42	23.51	1.14	1.29
B2	0.15	0.25	21.6	35.4	1.26	1.48
BH1	0.5	0.45	44.78	38.4	2.7	2.14
BH2	0.42	0.38	26.32	31.13	2.03	1.65
BF1	0.5	0.57	117.41	104.5	7.62	3.24
BF2	0.45	0.5	44.9	40.45	3.07	2.28
C1	0.40	0.38	22.48	27.98	1.45	1.45
C2	0.3	0.29	5.26	6.8	0.53	0.4
CH1	0.51	0.57	69.81	100.7	5.30	3.17
CH2	0.45	0.4	44.32	37.04	2.60	1.79
CF1	0.65	0.58	83.3	142.45	2.76	8.79
CF2	0.50	0.49	53.58	53.92	4.79	3.00

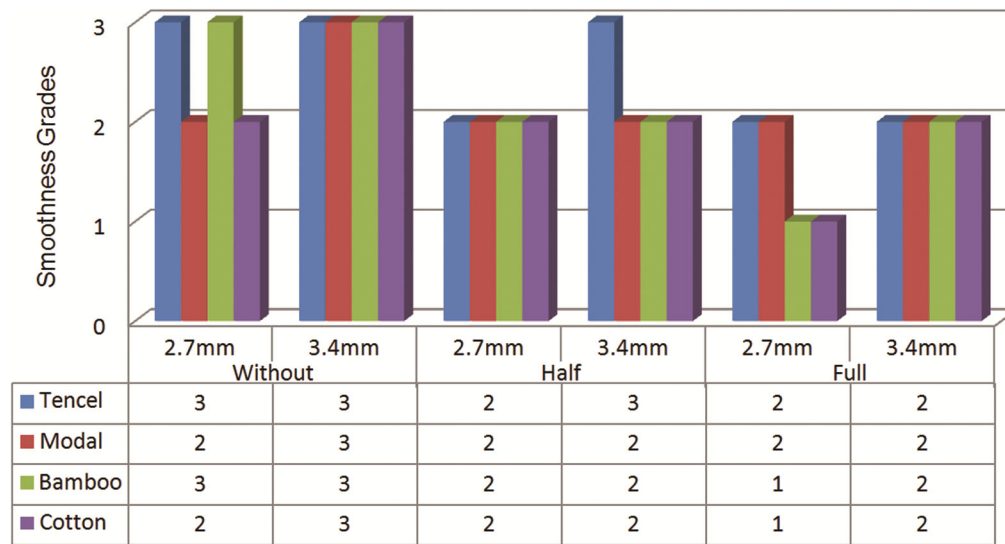


Fig. 4 — Effect of variables on fabric smoothness

Table 5 — Effect of variables on thermal indices

Sample code	TCC	TCR	Qmax
T1	57.7	60.4	454.59
T2	6.51	52.60	368.4
TH1	60.0	63.43	501.3
TH2	59.58	60.88	459.49
TF1	62.26	65.07	608.59
TF2	60.56	63.86	521.44
M1	58.29	60.61	459.49
M2	52.1	57.79	449.38
MH1	62.00	64.85	577.80
MH2	59.92	62.7	475.52
MF1	67.80	69.75	970.61
MF2	63.73	68.69	960.79
B1	59.97	63.11	482.8
B2	51.25	53.8	441.89
BH1	62.89	65.92	756.33
BH2	60.56	64.39	575.89
BF1	85.16	61.62	1028.99
BF2	68.02	76.89	979.77
C1	60.46	63.61	503.59
C2	56.7	58.6	452.9
CH1	75.88	84.52	1008.16
CH2	62.44	65.46	717.93
CF1	83.12	88.01	1011.42
CF2	63.00	66.69	785.40

is clear that the fabrics of cotton and bamboo have lower grades for warmth and in the case of plated structures, the fabric with full lycra plating has lower warmth values, which are related to the higher fabric areal density and thickness of the full plated fabrics²¹.

Total Hand Value

The results of grades obtained from the above modules are correlated with the KES-FB and the total hand values of the fabric samples are evaluated. It is understood from Fig. 6 that the fabrics of tencel with high loop length and without plating exhibit higher hand values and the cotton full plated 2.7mm loop length exhibits low hand values. The total hand values are correlated with the fabric bending, compression and friction values and hence this result is obtained from the prepared samples.

Minitab18 software was used to analyse the significance of the data and the interaction between the variables using the general linear model (Multiple factor-ANOVA) at the 95% confidence level. The effects of fibre, plating and loop length and the interactions between them are analysed for the cellulose single jersey knitted fabrics. The p values are inspected to analyse the significance of the effects. The statistical analysis reveals that the grades are significant for fibre, plating and the interactions between fibre and plating and loop length and plating factors, but there are few factors establishing non significance in their interactions. The reason for the non-significance may be due to the similarity in the grades obtained but there is a mild significance in terms of the values obtained in the results.

In this study, the effect of fibre, plating and loop length variation on the fabric's tactile properties are analyzed and it is found that the values of softness and smoothness grades are high for the fabrics made of tencel yarns, as these fabrics exhibit the lower

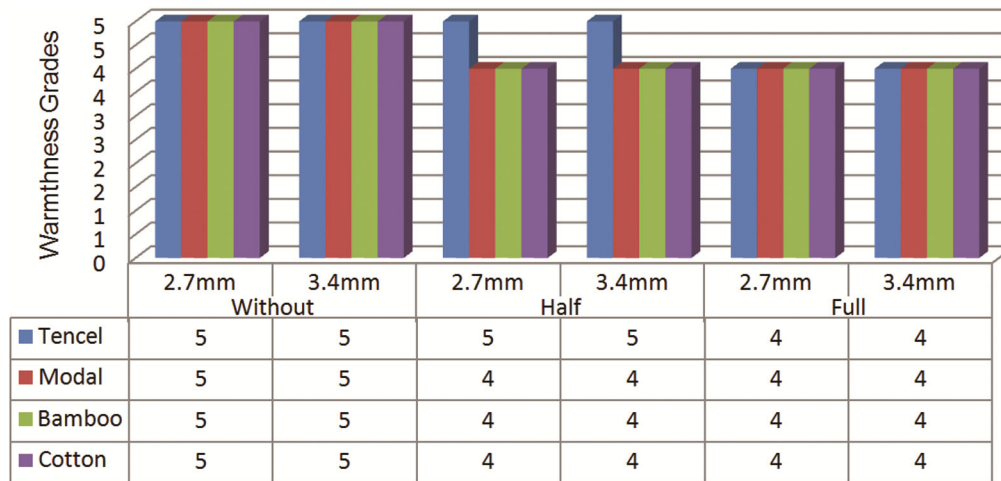


Fig. 5 — Effect of variables on fabric warmthness

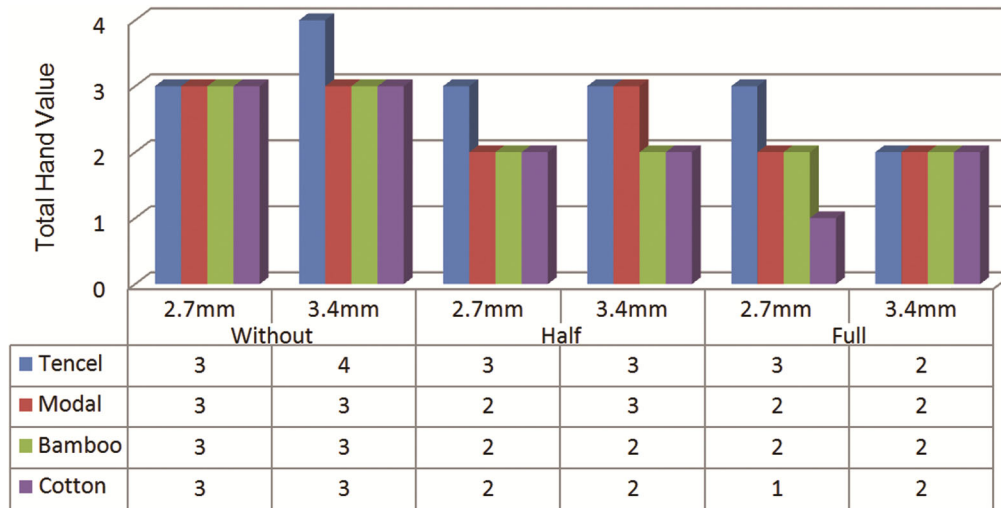


Fig. 6 — Effect of variables on total hand value

values for the bending, compression and roughness indices due to the fibrillar structure of tencel fibre showcasing the lower values of thickness and areal density. The grades are low for the fabrics made of cotton possessing a higher areal density. The grades of the softness and smoothness values are higher for the fabrics without lycra and the grades decrease with the increase of lycra, i.e. lower grades are noticed for the full plating fabrics due to the compactness of fabrics and increased value of thickness and areal density. The fabrics with lower loop lengths exhibit lower grades for the softness and smoothness values due to the higher values of bending rigidity and compression rigidity and surface friction values. The fabrics made of tencel yarns exhibit higher grades of warmthness, and the grades decrease towards cotton fabrics as they possess the highest Qmax values. The

higher Qmax values indicate a cooler feeling. The warmthness grade also depends on the lycra content. Higher the lycra content shows lower warmthness grade. Fabric hand values are high for the tencel knitted fabrics as compared to the other fabrics and also the hand values are high for the fabrics without lycra when compared to the full plated fabrics. It is also found that the THV values are high for higher loop length fabrics due to their loose structure.

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