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Factors Affecting the Geometric and Tensile Properties of Stretch-Knitted Cotton Fabrics

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Abstract. The present paper attempts to investigate the effect of elastane concentration and knitting processing variables, such as tightness factor and take-down tension upon spirality and density of rib and single jersey fabrics. Five different concentrations of elastane (0-7%), three different take-down tensions (2, 3 and 5 kg) and four levels of tightness factors (12, 13.5, 15, and 16.5) were selected. Fabric density has a direct relationship with the concentration of elastane and tightness factors. Weight of both types of knitted fabrics increased with the increase in the tightness factor and the percentage of elastane. It was also found that with the increase in take-down tension and reduction in the tightness factor, the spirality increased.

Keywords: knitted fabrics, spirality, elastane, tightness factor, fabric strength

Introduction

There has been an extraordinary development in the scope and applications of knitted fabrics during the recent years. The principal reason behind this growth is to be found in the structure of the knitted fabric itself. The most important development has been in the increasing applications of lycra and other elastane yarns. Elastane spandex yarns are used to provide fitness and comfort in garments, made mainly in fabrics produced by circular knitting. The form, amount and arrangement of the spandex yarn used in the fabrics depends upon the type and construction of the garments, the fabric weight and the amount of stretch (Corbman, 1983). The major knitting parameters that influence strength, dimension, stretch, and weight of such fabrics are yarn count, tightness of construction, tension on the spandex, and frequency of the spandex on the machine (Abou-iiana, 1998; Buehler and Haid, 1986). Also, fabric's extensibility affects its bursting strength and increases inversely with the tightness factor (Ertugrul and Nuray, 2000).

There are difficulties to be encountered in knitting such fabrics that provide garments with the desired combination of properties. The problem of spirality (spirality is the deviation of the courses and the wales line angle from 90°) greatly affects the knitted fabrics when they are made into garments. The spirality increases with the decrease in tightness factor, while greater take-down tension results in greater angle of spirality (Tariq, 1998; Banerjee and Alaiban, 1988a). Higgins *et al.* (2003) have carried out studies on the length and width shrinkages, skewness, and spirality of three weft-knitted cotton structures during tumble drying. Significant length and width shrinkages occurred in all the three structures. The tumbling action in a tumble drier has a significant influence on the dimensional stability and distortion of weft-knitted cotton fabrics. Jeon *et al.* (2003) have investigated the mechanical properties of warp-knitted fabrics that had differences in knitting structure, knitting density and yarn composition. Fabric weight showed the tendency of gradually decreasing as the number of abrasion cycles increased. It was due to the fact that pill was removed after the abrasion cycles. Tensile strength to rupture decreased with increasing the number of abrasions. The arrangement of yarn input to the machine principally affected this property.

This study attempts to examine the effect of the elastane concentration, tightness factor, the take-down tension on fabric density and spirality of the single jersey and 1/1 rib knitted fabrics.

Material and Methods

Source and characteristics of the yarn. The carded 20^s hosiery yarn (yarn count: 20 single) required for this study was obtained from the running stocks of Masood Textile Mills, Faisalabad, Pakistan. To assess the inherent potential of the raw stocks being utilized for knit fabric construction, the yarn was evaluated for the spinning parameters because physical characteristics of the yarn have a direct bearing on the knitting process. Lea-strength of the yarn was 122.2 lbs, count lea-strength of the product was 2426; thick and thin, places and neps were recorded as 51, 14 and 133 per kilometer, respectively. The hairiness value was 7.88, while 3.7 twists per inch were recorded in the sample yarn.

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Knitting process. The machines of Pailung brand of 30-inch dia were used for the construction of 1x1 rib and single jersey fabrics. Keeping all other knitting parameters standard, the variables selected for the study of their effects on both types of the fabric (rib and single jersey) are given in Table 1.

After making all possible combinations of the variables, samples were knitted and placed on a flat surface for 24 h at 65±2% relative humidity and 27±2 ˚C temperature for the purpose of conditioning. The following fabric characteristics were evaluated.

Fabric spirality. Spirality is the deviation of the courses and the wales line angle from 90˚. More the angle deviates, more will be the angle of spirality. It was measured in the tube form of fabric according to the procedure suggested by ASTM Committee (1997a).

Fabric density. It is the weight of one square metre of fabric expressed in grams. The weight of the fabric did not vary by more than ±5% according to the standard given by ASTM Committee (1997b).

Fabric strength. Fabric strength is the force expressed in pounds per square inch (PSI), which is used to burst the fabric and was determined according to the ASTM Committee (1997c).

Table 1. Knitting variables used to study their effects on rib and single jersey fabrics

Concentration of elastane (C)	Tightness factor (F)	Take-down tension (T)	Fibre type (S)
C0 = 0%	F1 = 12	T1 = 2kg	S_1 = rib fabric
C1 = 1%	F2 = 13.5	T2 = 3kg	S_2 = single jersey
C2 = 3%	F3 = 15	T3 = 5kg	
C3 = 5%	F4 = 16.5		
C4 = 7%			

Analysis of data. Completely randomized design was applied in the analysis of variance for testing differences among the various quality characteristics studied in these investigations (Steel and Torrie, 1984). Significance was checked at 1 and 5% confidence levels. The new Duncan's multiple range test was also applied for individual comparison of mean values among the various quality characters. M-stat microcomputer package was employed for statistical manipulation of the results (Freed, 1992).

Results and Discussion

Fabric density. The statistical analysis and individual comparison of fabric density are shown in Table 2a. The statistical analysis indicated that the effect of fabric type, concentration of elastane, tightness factor, take-down tension and the interactions SxC, CxF, CxT were highly significant, the interaction FxT was only significant, whereas all the remaining interactions were non-significant.

Table 2a. Analysis of variance for fabric density

SOV	DF	SS	MS	F-value	Probability
S	1	28999.12	28999.12	1374.74	0.00**
C	4	96454.14	24113.53	1143.13	0.00**
F	3	144333.16	48111.05	2280.76	0.00**
T	2	13848.59	6924.30	328.25	0.00**
SxC	4	458.68	114.67	5.43	0.00**
SxF	3	19.40	6.47	0.31	ns
CxF	12	1625.61	135.47	6.42	0.00**
SxT	2	100.61	50.31	2.38	0.09 ns
CxT	8	464.34	58.04	2.75	0.006**
FxT	6	284.00	47.33	2.24	0.04*
SxCxF	12	141.83	11.82	0.56	ns
SxCxT	8	126.92	15.86	0.75	ns
SxFxT	6	4.89	0.83	0.038	ns
CxFxT	24	19.89	0.83	0.039	ns
SxCxFxT	24	7.24	0.30	0.01	ns
Error	240	5062.62	21.09		
Total	359	291951.07			

S: fibre type; C: conc of elastane; F: tightness factor; T: take-down tension; **: highly significant; *: significant; ns: non-significant

Duncan's multiple range test for individual comparison of mean values of different elastane percentage values recorded maximum fabric density at 7% elastane feed (C_4), followed by C_3 (5%), C_2 (3%), C_1 (1%) and control (C_0) with their respective values as 170.62, 158.13, 146.13, 134.77 and 124.49 g/m^2 (Table 2b). All these values differ significantly from each other. The present results depicted a direct relationship between the concentration of the elastane with fabric density, indicating that more the elastane concentration, the greater the density of the fabric. This was so because of the fact that addition of elastane drew both the courses and wales closer, consequently the weight per unit area of the fabric also increased. Some earlier researchers (Abou-iiana, 1998; Corbman, 1983) reported the major knitting parameters that influenced power, stretch, and yield (ounce per square yard) of the fabric as yarn count and tension on the spandex and frequency of the spandex on the machine.

The individual comparison of mean values, regarding the tightness factor, indicated that the maximum value for fabric density was recorded at F_4, followed by F_3, F_2, and F_1, with their respective mean values as 174.53, 154.86, 137.08 and 120.82 g/m^2 (Table 2b). All these values differ significantly from each other. The present observations depicted a direct relationship between the tightness factor and the fabric density, indicating that an increase in tightness factor resulted in an increase in the weight per unit area of the knitted fabric. It has been reported that if the size of the yarn remained constant, the increase of loop size produced a decrease in weight per unit area (Raz, 1993; Brackenbury, 1992).

Table 2b. Comparison of individual mean values for fabric density (g/m^2)

Concentration of lycra (C)	Tightness factor (F)	Take-down tension (T)	Fabric construction (S)
124.49 e	120.82 d	155.32 a	155.80
134.77 d	137.08 c	144.48 b	137.85
146.13 c	154.86 b	140.67 c	
158.13 b	174.53 a		
170.62 a			

values with different alphabets significantly different from each other at p = 0.05 (Duncan's multiple range test)

The values of fabric density given in Table 2b, varied from 155.32, 144.48, 140.67 g/m^2 for different levels of take-down tension varying from 2 kg (T_1), 3 kg (T_2), and 5 kg (T_3), respectively. These results indicate that fabric density of the knitted fabric was inversely proportional to the take-down tension. When the take-down tension was increased, the count for courses per inch retrograded and ultimately the fabric weight per unit area decreased (Mumtaz, 2001; Gill, 2000).

The fabric density under rib (S_1) and plain fabrics (S_2) was recorded as 155.80 and 137.85 g/m^2, respectively. These results show that the rib fabric was heavier than the single knit fabric. It was due to the fact that rib fabric had loops on both the sides, whereas single knit fabric had loops only on one side. Similarly, rib structures are bulkier and heavier than plain knit structures made of similar yarn thickness on machines of similar gauge (Raz, 1993).

Table 2c represents the combined effect of the fabric type and elastane share (SxC) upon fabric weight. Under rib fabric, maximum weight, 179.11 g/m^2 was observed in the combination S_1xC_4, whereas minimum value of the fabric density 135.38 g/m^2 was achieved for combination S_1xC_0. Similarly, for single jersey fabric, the maximum fabric density (162.14 g/m^2) was noted under combination S_2xC_4 and minimum fabric density (113.57 g/m^2) was determined for combination S_2xC_0. However, the overall best combination was S_1xC_4 with 179.11 g/m^2 fabric density, whereas the combination S_2xC_0 represented the minimum fabric density (19.29 g/m^2).

Table 2c. Interactions (SxC) of fabric type (S) and concentration (C) of elastane for fabric density (g/m^2)

	C_0	C_1	C_2	C_3	C_4
S_1	135.38 g	143.73 f	155.24 d	165.56 b	179.11 a
S_2	113.57 i	125.80 h	137.04 g	150.71 e	162.14 c

S_1 : rib fabric; S_2 : single jersey

The interaction study of the elastane share and tightness factor (CxF) are shown in Table 2d. It depicts that in the control, the maximum fabric density (148.73 g/m^2) was achieved in combination C_0xF_4, which the minimum value of fabric density (101.92 g/m^2) was observed in combination C_0xF_1. Similarly, for 1% elastane (C_1), the maximum fabric density of 159.80 g/m^2 was noted in combination C_1xF_4, and the minimum weight (111.59 g/m^2) was noted in combination C_1xF_1. Under 3% elastane, the maximum fabric density (173.64 g/m^2) was achieved in the combination of C_2xF_4, whereas the minimum weight per unit area (120.20 g/m^2) was noted under combination C_2xF_1. Likewise, under 5% elastane, the maximum fabric density (187.87 g/m^2) was noted for combination C_3xF_4, whereas the minimum fabric density (130.21 g/m^2) was observed for combination C_3xF_3. For 7% elastane, the maximum fabric density of 202.63 g/m^2 was noted for the combination of C_4xF_4, and the minimum fabric weight (140 g/m^2) was determined for combination C_4xF_1. However, the overall best combination was C_4xF_4, whereas combination C_0xF_1 represented the minimum fabric density (101.92 g/m^2).

Table 2d. Interactions (CxF) of concentration (C) of elastane and tightness factor (F) for fabric density (g/m^2)

	F_1	F_2	F_3	F_4
C_0	101.92 p	115.70 n	131.53 k	148.73 h
C_1	111.50 o	125.80 l	141.97 i	159.80 f
C_2	120.20 m	136.46 j	154.25 b	173.64 d
C_3	130.21 k	147.66 h	166.78 e	187.64 b
C_4	140.27 i	159.80 f	179.80 c	202.63 a

Table 2e represents the interaction study of the elastane share and take-down tension (CxT). The interaction study reveals the best combination was C_4xT_1, with 181.01 g/m^2 fabric density, whereas combination C_0xT_3 represented the minimum fabric density (119.74 g/m^2). Table 2f represents the interaction study of the tightness factor F and take-down tension (FxT). It depicts that under take-down tension T_1 (2 kg) the maximum fabric density (184.76 g/m^2) was determined for combination F_4xT_1, whereas minimum fabric density 127.77 g/m^2 was found for combination F_1xT_1. Under take-down tension T_2 (3 kg), the maximum fabric density (171.67 g/m^2) was noted for combination F_4xT_2, whereas minimum (118.94 g/m^2) was observed for combination F_1xT_2. Similarly, under T_3 (5 kg), the maximum weight per unit area (167.18 g/m^2) was found for combination F_4xT_3 and the minimum (115.76 g/m^2) was found for combination F_1xT_3. However, the best overall combination was F_4xT_1 of fabric weight (184.76 g/m^2), whereas the combination F_1xT_3 represented the minimum fabric weight per unit area (115.76 g/m^2).

Table 2e. Interactions (CxT) of concentration (C) of elastane and take-down tension (T) for fabric density (g/m^2)

	T_1	T_2	T_3
C_0	131.62 g	122.01 h	119.74 h
C_1	142.06 f	132.31 g	129.93 g
C_2	154.14 d	143.46 f	140.80 f
C_3	167.71 b	156.15 d	150.54 e
C_4	181.01 a	168.49 b	162.37 c

Table 2f. Interactions (FxT) of tightness factor (F) and take-down tension (T) for fabric density (g/m^2)

	T_1	T_2	T_3
F_1	127.77 j	118.94 k	115.76 l
F_2	144.94 g	134.92 h	131.40 I
F_3	163.80 d	152.42 e	148.37 f
F_4	184.76 a	171.67 b	167.18 c

Spirality. The statistical analysis and individual comparison of spirality are shown in the Table 3a, which indicates that the effect of fabric type (S), tightness factor (F), take-down tension (T) and the interactions SxC, SxF, SxCxT were highly significant. However, only the interaction SxT was significant, whereas concentration of elastane (C) and remaining interactions exerted non-significant effects.

The comparison of mean values for spirality showed that for different percentages of elastane C_0, C_1, C_2, C_3 and C_4, the spirality was 4.66, 4.49, 4.48, 4.52 and 4.50 degree (Table 3b). These results show that the spirality was independent of elastane concentration in the fabric. Spirality is the deviation of the courses and the wales line angle from 90^0. It greatly affects the knitted fabrics when they are made into garments (Banerjee and Alaiban, 1988b).

Duncan's multiple range test (Table 3b), for individual comparison of means for different levels of tightness factor recorded minimum spirality at F_4, followed by F_3, F_2, and F_1, with their respective values as 4.11, 4.41, 4.63 and 4.97 degree. The results of present study show an inverse relationship between the tightness factor and spirality, indicating that more the tightness factor, the lower the spirality. The

Table 3a. Analysis of variance for spirality

SOV	DF	SS	MS	F-value	Probability
S	1	3454.02	3435.02	14519.24	0.00**
C	4	1.61	0.40	1.69	0.15 ns
F	3	35.34	11.78	49.52	0.00**
T	2	14.97	7.48	31.46	0.00**
SxC	4	17.53	4.38	18.42	0.00**
SxF	3	4.72	1.57	6.61	0.00**
CxF	12	0.80	0.07	0.28	ns
SxT	2	1.74	0.87	3.65	0.03*
CxT	8	3.46	0.43	1.81	0.07 ns
FxT	6	0.50	0.08	0.35	ns
SxCxF	12	0.74	0.06	0.26	ns
SxCxT	8	6.42	0.80	3.37	0.00**
SxFxT	6	0.16	0.02	0.11	ns
CxFxT	24	0.70	0.03	0.12	ns
SxCxFxT	24	0.70	0.03	0.13	ns
Error	240	57.094	0.24		
Total	359	3600.55			

S: fibre type; C: conc of elastane; F: tightness factor; T: take-down tension; **: highly significant; *: significant; ns: non-significant

Table 3b. Comparison of individual mean values for spirality (degree of spirality)

Concentration of elastane (C)	Tightness factor (F)	Take down tension (T)	Fabric construction (S)
4.66	4.97 a	4.28 c	1.43
4.49	4.63 b	4.55 b	7.63
4.48	4.41 c	4.77 a	
4.52	4.11 d		
4.50			

values with different alphabets significantly different from each other at p = 0.05 (Duncan's multiple range test)

alteration of spirality for equal changes of stitch length varied from one machine to another machine. When the stitch length was increased the tightness factor decreased and hence spirality increased (Banerjee and Alaiban, 1988a & b). The properties of raw materials and tightness of construction significantly affect fabric dimension.

The individual mean values for the data pertaining to spirality given in Table 3b, varied from 4.28, 4.55, and 4.77 degree for different levels of take-down tension, varying from 2, 3, and 5 kg, respectively. These results depicted a directly proportional relationship between the take-down tension and spirality, indicating that more the take-down tension the higher the spirality. The take-down tension is responsible for most of the lengthwise distortions of the fabric (Saleem, 2003; Black, 1974).

A comparison of individual means for spirality under rib (S_1) and single jersey (S_2) fabrics in the present study revealed

1.43 and 7.63 degree spirality, correspondingly. These results show that rib fabrics have less spiral degree than that of plain knit fabrics. In fact, 1x1 rib is balanced by alternate wales of face loops in each side. The plain-knitted fabrics made from single cotton yarn are most prone to spirality, the degree being related to the number of twists/unit length in the yarn. Spirality does not occur in 1x1 rib and interlock fabrics; the loops formed in opposite direction cancelling out the distortions. The lighter fabrics were more deformed in manufacturing than the heavier fabrics (Raz, 1993).

The interaction of the fabric type and the elastane concentration (SxC) is given in Table 3c, from which it is evident that for S_1, higher concentration of elastane reduced the spirality of the rib fabric. On the other hand, for the fabric type S_2, higher concentration of elastane increased the spirality of plain knit fabric.

Table 3d represents the interaction study of the fabric type and tightness factor (SxF). It depicts that under rib fabrics (S_1), the maximum 1.74° spirality was achieved for the combination S_1xF_1, and the minimum value of spirality (1.17°) was observed for combination S_1xF_4. Similarly, for single jersey fabric, the maximum spirality of 8.21° was noted under combination S_2xF_2, whereas minimum spirality of 7.06° was noted for combination S_2xF_4. However, the overall best combination was S_1xF_4 of spirality (1.17°), whereas combination S_2xF_1 represented the maximum spirality (8.21°).

Table 3c. Interactions (SxC) of fabric type (S) and concentration (C) of elastane for spirality (degree of spirality)

	C_0	C_1	C_2	C_3	C_4
S_1	1.86 c	1.53 d	1.43 de	1.27 ef	1.08 f
S_2	7.46 b	7.45 b	7.53 b	7.78 a	7.94 a

S_1: rib fabric; S_2: single jersey

Table 3d. Interactions (SxF) of fabric type (S) and tightness factor (F) for spirality (degree of spirality)

	F_1	F_2	F_3	F_4
S_1	1.74 e	1.46 f	1.38 f	1.17 g
S_2	8.21 a	7.81 b	7.45 c	7.06 d

S_1: rib fabric; S_2: single jersey

Table 3e shows the interaction of fabric type and the take-down tension (SxT) for spirality. It is evident from these observations that by increasing the take-down tension the fabric spirality increased gradually. Maximum spirality was recorded for S_2xT_3, while the combination S_1xT_1 produced the fabric with minimum spirality. Higgins *et al.* (2003) reported that the tumbling action in a tumble drier has the greatest influence on the dimensional stability and distortion of weft-knitted cotton fabrics. Spirality increased with decrease in the tightness factor and greater take-down tension resulted in greater angle of spirality (Tariq, 1998; Banerjee and Alaiban, 1988a; b).

Table 3e. Interactions (SxT) of fabric type (S) and take-down tension (T) for spirality (degree of spirality)

	T_1	T_2	T_3
S_1	1.27 e	1.44 de	1.60 d
S_2	7.28 c	7.66 b	7.95 a

S_1: rib fabric; S_2: single jersey

Table 3f represents the interaction study of the fabric type, the elastane share, and take-down tension (SxCxT). It depicts that under rib fabrics, minimum spirality (1.08°) was achieved under the combination, $S_1xC_4xT_1$, at maximum concentration of elastane and minimum level of take-down tension, whereas maximum value of spirality (2.14°) was observed for plain knit fabric. Minimum spirality (6.68°) was noted under combination $S_2xC_0xT_1$, whereas the maximum (8.5°) was obtained at combination $S_2xC_4xT_3$. However, the overall best combination was $S_1xC_4xT_1$ with spirality (1.08°), whereas the combination $S_2xC_4xT_3$ represented the maximum spirality (8.5°).

Fabric strength. The statistical analysis and individual comparison of the fabric strength are shown in the Table 4a, which indicates that the effect of fabric type (S), the concentration of elastane (C), the tightness factor (F), and the interactions SxC, SxT were highly significant, whereas the take-down tension (T), along with all the remaining interactions were non-significant.

Duncan's multiple range test for individual comparison of mean values for different elastane percentages recorded

Table 3f. Interactions (SxCxT) of fabric type (S), concentration of elastane (C) and take-down tension (T) for spirality (degree of spirality)

	S_1					S_2				
	C_0	C_1	C_2	C_3	C_4	C_0	C_1	C_2	C_3	C_4
T_1	1.56 ghi	1.27 ij	1.27 ij	1.17 ij	1.08 j	6.84 e	7.44 d	7.48 d	7.35 d	7.24 d
T_2	1.89 fg	1.50 ghij	1.42 hij	1.31 ij	1.08 j	7.55 d	7.44 d	7.55 d	7.74 cd	8.01 bc
T_3	2.14 f	1.83 fgh	1.61 ghi	1.34 ij	1.08 j	8.00 bc	7.46 d	7.55 d	8.23 ab	8.5 a

S_1: rib fabric; S_2: single jersey

Table 4a. Analysis of variance for fabric strength

SOV	DF	SS	M S	F-value	Prob
S	1	12822.96	12822.96	520.83	0.00**
C	4	21044.05	5261.01	213.68	0.00**
F	3	614.56	204.85	8.32	0.00**
T	2	147.62	73.81	2.99	0.053 ns
SxC	4	1193.36	298.38	12.12	0.00**
SxF	3	19.83	6.61	0.27	ns
CxF	12	157.25	13.10	0.53	ns
SxT	2	317.77	158.88	6.45	0.00**
CxT	8	199.00	24.87	1.01	0.43 ns
FxT	6	9.91	1.65	0.07	ns
SxCxF	12	85.73	7.14	0.29	ns
SxCxT	8	170.03	21.25	0.86	ns
SxFxT	6	36.55	6.09	0.25	ns
CxFxT	24	97.52	4.06	0.16	ns
SxCxFxT	24	111.35	4.06	0.19	ns
Error	240	5908.88	24.62		
Total	359	42936.38			

S: fibre type; C: conc of elastane; F: tightness factor; T: take-down tension; **: highly significant; ns: non-significant

maximum fabric strength at 7% elastane feed, followed by C_3, C_2, C_1 and control (C_0), with their respective values as 101.32, 97.79, 91.12, 85.25, 85.10 and 80.75 lbs (Table 4b). All these values differ significantly from each other. The present results depicted a direct relationship between feed of elastane and fabric strength, indicating that more the concentration of elastane, more the strength of the fabric. It has been reported that the elastomeric yarns may be used where excessive elasticity and grip are required, such as in welt of hose or half hose, elastic stockings, corsets and brassiers (Chamberlain, 1951). The strength of the fabric is also dependent upon the yarn, and on the length of the loop, fabric weight, yarn breaking strength, whereas yarn breaking elongation are the major parameters that affect the bursting strength of the plaink-nitted fabrics (Ertugrul and Nuray, 2000). Lycra provides a superb route for achieving surface effects in both single and double jersey fashion knits through the techniques for differential collapse.

Table 4b. Comparison of individual means for fabric strength (lbs)

Lycra percentage (C)	Tightness factor (F)	Take-down tension (T)	Fabric construction (S)
80.75 e	89.60 c	91.95	85.25
85.10 d	90.49 bc	91.30	97.18
91.12 c	91.69 ab	90.39	
97.79 b	93.08 a		
101.32 a			

values with different alphabets significantly different from each other at p = 0.05 (Duncan's multiple range test)

The individual comparison of mean values regarding tightness factor indicates that the maximum fabric strength was recorded at F_4, followed by F_3, F_2 and F_1, with their respective values as 93.08, 91.69, 90.49 and 89.60 lbs (Table 4b). All these values differ significantly from each other. These results indicate that fabric strength of a knit is directly proportional to the tightness factor. The reason is that at lower stitch length, the number of the loops in unit area is greater and consequently more strength will be required to burst all loops. As the stitch length increases the tightness factor decreases and the bursting strength of the fabric also decreases for both states of fabric relaxation (full relaxation and finished relaxation).

The comparison of mean values for fabric strength showed that at different levels of take-down tension T_1, T_2 and T_3, the fabric strength was 91.95, 91.30 and 90.39 lbs. These results show that the fabric strength is independent of the take-down tension. Jeon *et al.* (2003) investigated the mechanical properties of warp-knitted fabrics which had differences in the knitting structure, knitting density and yarn composition. Fabric weight showed the tendency of gradually decreasing as the number of abrasion cycles increased. It was due to the fact that pill was removed after the abrasion cycles. Tensile strength to rupture decreased with increasing the number of abrasions. The arrangement of yarn input to the machine principally affected this property.

Comparative study of individual mean values for the fabric strength under rib and plain knit fabrics revealed, 85.25 and 97.19 lbs strength, respectively. These results depicted that the bursting strength of the rib fabric was less than that of the plain knit fabric. The 1x1 rib-knitted fabrics have been shown to be slacker structures in comparisin with plain-knitted fabrics (Jong and Postle, 1977), that is, the yarn interlocking forces were generally lower ($PrL^2/B = 3.3$), as compared with the plain-knitted structure ($PL^2/B = 7$). The 1x1 rib structure is, therefore, generally knitted to a greater tightness factor than those used for plain-knitted fabrics. The 1x1 rib structure is naturally jammed between the ribs with a force ($RL^2/B = 2.25$) in interlocking region, the yarn within the 1x1 rib fabric cross each other at an angle much closer to 90° and consequently the force of distribution are much more peaked than those for the plain-knitted fabrics.

Table 4c represents the interaction study of the fabric type and elastane share (SxC). It depicts that under rib fabrics, the maximum fabric strength, 98.11 lbs, was achieved at the maximum percentage of elastane, at the combination S_1xC_4, whereas the minimum value of fabric strength (73.77 lbs) was observed for combination S_1xC_0. Similarly, for single jersey fabric, the maximum fabric strength (104.54 lbs) was noted under combination S_2xC_4, whereas the minimum fabric strength (87.73 lbs) was observed for combination S_2xC_0. However, the overall best combination was S_2xC_4 with 104.54 lbs fabric strength, whereas combination S_1xC_0 represented the minimum fabric strength (73.77 lbs).

Table 4c. Interactions (SxC) of fabric type (S) and concentration (C) of elastane for fabric strength (lbs)

	C_0	C_1	C_2	C_3	C_4
S_1	73.77 g	77.90 f	83.13 e	93.34 c	98.11 b
S_2	87.73 d	92.30 c	99.11b	102.23 a	104.54 a

S_1: rib fabric; S_2: single jersey

Table 4d represents the interaction study of the fabric type and take-down tension (SxT). This interaction observations indicate that the best combination was S_2xT_2 of 97.82 lbs fabric strength, whereas the combination S_1xT_3 represented the minimum fabric strength (83.65 lbs).

Table 4d. Interactions (SxT) of fabric type (S) and take-down tension (T) for fabric strength (lbs)

	T_1	T_2	T_3
S_1	87.31 b	84.78 c	83.65 c
S_2	96.60 a	97.82 a	97.13 a

S_1: rib fabric; S_2: single jersey

Conclusions

The results of this study depicted a direct relationship between feed of elastane and fabric strength, indicating that more the concentration of elastane the more will be the strength of the fabric. The spirality was found to be independent of elastane concentration in the fabric, and a direct relationship was recorded between the concentration of the elastane with fabric density, thus indicating that more the elastane concentration the greater will be the density of the fabric. The weight per unit area of the fabric increased with the addition of elastane. This was so because of the fact that addition of elastane draws both the courses and the wales closer.

The bursting strength of the rib fabric was less than that of the plain-knitted fabric. The 1x1 rib-knitted fabrics were shown to be of slacker structure in comparison with plain-knitted fabrics. The results also showed that rib fabrics were less spiral than the plain-knit fabrics. In fact, 1x1 rib was balanced by alternate wales of face loops on each side. The plain-knitted fabrics, made from single cotton yarn, were the most prone to spirality.

The strength of both the rib and plain-knitted fabrics was directly proportional to the tightness factor. The take-down tension was found to be responsible for most of the lengthwise distortions of the fabric; more the take-down tension, the higher was the spirality for both types of fabrics (rib and single jersey). The results also showed an inverse relationship between the tightness factor and spirality, indicating that more the tightness factor, the lower will be the spirality. A direct relationship between the tightness factor and the fabric density was also observed, indicating that if tightness factor was more, the more was the weight per unit area of the knitted fabric.

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