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Effect of elastane-cotton core-spun yarn liveliness on woven modified mock leno fabric properties

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The present study is aimed at accessing the impact of elastane core liveliness on physical and mechanical properties of elastane-cotton core-spun yarn fabric. The yarn liveliness is altered by changing draw ratio on ring frame and thus the elastane core % in the yarn. The 4 samples of 30^s Ne elastane core-spun cotton yarn have been produced using 40 den elastane having 5, 7, 9 and 11% elastane core adjusted by using suitable draw ratio on ring frame. These elastane core-spun cotton yarns are used in weft direction to produce fabric sample. These fabric samples are tested for various physical and mechanical properties as per ASTM standards. The findings reveal that the yarn core liveliness has significant effect on various physical and mechanical properties of fabric.

Keywords: Air permeability, Core-spun yarn, Draw ratio, Elastane-cotton yarn, Mock leno fabric, Tensile strength, Tear strength

1 Introduction

The stretchable yarns and fabrics are more popular because of their wide scope applications. Therefore it is a topic of researcher's interest to understand the behaviour of elastane core-spun yarn and its impact on fabric properties. Most of researchers have used simple weaves like plain, twill, etc.

Ab Mourad *et al.*[1] studied the effect of ratio of cotton/spandex core-spun yarn to 100% spun yarn in weft direction on weftway physical properties of plain woven fabric. They found that the increase in number of cotton/spandex core-spun yarn in weft results in increase in fabric contraction, breaking elongation, fabric stretch and recovery % along with the decrease in fabric tensile strength, air permeability and tearing strength. Qadir *et al.*[2] studied the effect of elastane denier and draft ratio of core-spun cotton weft yarn on the mechanical properties of 3 up 1 down Z-twill woven fabric. They concluded that the fabric with high denier elastane in the core shows high stretch and recovery after stretch. The fabric shows high tear strength but low tensile strength. Furthermore, high draw ratio improves fabric tensile strength and stretchability but reduces fabric tear strength and recovery after stretch. Rahman Al-ansari[3] studied the effect of 30s Ne cotton-spandex core-spun weft with 4, 5, 7, 9 and 11% spandex on mechanical and physical properties of plain woven fabric. He found that the fabric with high spandex ratio shows improved extensibility and air permeability, whereas it has negative impact on fabric tensile strength, shrinkage and growth of fabric.

The studies were also done by various researchers with elastane yarn and fabric manufacturing[4-11]. In these studies, the interaction effect of elastane core-spun weft on warpway and weftway fabric properties are analysed for fabric having more weft float than warp float. The longer weft float will augment the impact of elastane core-spun weft on fabric's warpway and weftway properties. Also weave has been selected in such way that it gives fabric a cord-like appearance. Therefore, the present study has been done to understand the behaviour of warpway and weftway mechanical and elastic properties of elastane-cotton core-spun yarn fabric with modified mock leno structure using different elastane core lively spun yarn in weft direction.

2 Materials and Methods

2.1 Materials

In order to study the effect of elastane core liveliness on fabric properties, 4 yarns of 30^s Ne elastane core-spun cotton samples were produced from 1 hank cotton roving and 40 den elastane filament having 5, 7, 9 and 11% elastane core % with

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22 twists per inch. The elastane core % was changed by using suitable draw ratio on ring spinning machine. Table 1 shows the yarn and fabric sample codes and process parameters used for preparing a yarn.

These yarn samples were used as weft to produce 4 fabric samples. The modified mock leno weave (Fig. 1) was used so that the fabric has more weft float and cord-like structure. The apparel grade fabric was produced using Rapier technology with following parameters: loom speed 335 rpm, reed width 64 inch, warp count 40^s Ne, EPI 104, weft count 30^s Ne and PPI 55. Table 1 shows the yarn code, yarn specifications and fabric code used in this experimental work.

2.2 Methods

2.2.1 Evaluation of Physical Properties of Yarn

The testing of yarn was carried out as per ASTM standards. The tensile properties of the yarns were determined on Instron tensile tester. The specimen length was taken as 100 mm and testing speed was maintained at 300 mm/min. The count of yarn was tested using wrap reel method. The actual elastane % present in the yarn was checked by dissolving elastane in DMF solution.

2.2.2 Evaluation of Fabric Properties

The fabric was tested for its areal density, width, thickness and air permeability as per ASTM standards. The tear strength was checked on Elemendrof tear tester. The fabric strength and extension were tested on Tensolab tensile strength tester working on CRT principle. The abrasion resistance was tested on Martindale abrasion tester using fabric weight loss and fabric thickness loss after predefined number of abrasion cycles. The fabric elastane % was calculated using the following equation:

$$F_e, \% = \frac{W_{wf} \times E_f}{F_w} \quad \dots (1)$$

where F_e is the fabric elastane %; W_{wf} , the weight of weft material in gsm; E_f , the fraction of elastane in the weft yarn; and F_w , the fabric weight in gsm.

The fabric was also tested for its immediate stretch and recovery % on Magsolvics stretch Tester as per BS 4294 standard. The fabric samples were loaded with dead weight of 0.5, 1, 1.5, 2, 2.5 and 3 kg sequentially and immediate stretch % was measured directly on machine scale. The same sample was unloaded to measure its recovery %. The immediate fabric set % was calculated using the following equation:

$$\text{Immediate fabric set \%} = \frac{\text{Area under unloading cycle-Area under loading cycle}}{\text{Area under loading cycle}} \times 100 \quad \dots (2)$$

The fabric width contraction was calculated using the following equation:

$$\text{Fabric widthwise contraction \%} = \frac{\text{Actual fabric width on loom-Actual fabric width off loom}}{\text{Actual fabric width on loom}} \times 100 \quad \dots (3)$$

2.2.3 Statistical Analysis

The test results were analysed using one way ANOVA technique with 95% C.I. The regression analysis was also carried out to understand the effect of variables on fabric properties. R^2 value and p value were checked to avoid the misinterpretation of results.

Table 1 — Nominal yarn elastane % and draw ratio used on ringframe

Sample code	Elastane core, %	Draw ratio	Fabric code
Y1	5	4.56	F1
Y2	7	3.31	F2
Y3	9	2.53	F3
Y4	11	2.36	F4

X				X	X	X	
				X	X	X	X
			X		X	X	X
X	X	X		X			
X	X	X	X				
	X	X	X				X

Fig. 1 — Fabric weave structure (X mark – warp up, blank mark – warp down)

3 Results and Discussion

3.1 Nominal and Actual Elastane % of Yarn

Actual elastane % is calculated using DMF technique. The yarn elastane % set on the machine and actual elastane % in the yarn is found well within the limits.

3.2 Breaking Strength and Breaking Elongation of Yarn

The yarn strength and its CV% increases with the reduction in yarn elastane core %. The higher yarn strength may be due to the contribution of high tenacity cotton sheath material. The nature of low tenacity stretched elastane filament may result in higher variation in yarn strength.

Figure 2 shows that there is a strong correlation between yarn breaking strength (R^2 value = 0.96) and breaking elongation (R^2 value = 0.95) with yarn elastane core %. The ANOVA table shows that there is no statistically significant difference in yarn strength of different yarn samples (p value = 0.079). This conflict in result of yarn breaking strength may be due to the high CV% for yarn breaking strength. But there is statistically significant difference found in the yarn breaking elongation (p value = 0.000) of different yarn samples.

3.3 Fabric Elastane % and Fabric Width Contraction

The prepared fabric samples are checked for fabric elastane and widthwise contraction, calculated using Eqs (1) and (3) respectively. Table 2 shows the actual fabric elastane % found in different fabric samples and the corresponding widthwise contraction of fabric.

Figure 3 shows that as the fabric elastane % increases, the widthwise contraction decreases (R^2 value = 0.97). This may be because of the weft liveliness. The yarn with less elastane % is livelier than yarn with high elastane % because of high draw ratio kept during manufacturing. More stretched core elastane weft yarn exerts more retraction force on warp yarns. Owing to which, the fabric ends are brought together causing more fabric width contraction. Table 2 shows that as the fabric elastane % changes from 1.7 % to 3.9 %, the fabric widthwise contraction changes by 70.6 %. This also results in more serpentine path of weft, causing more fabric thickness and fabric areal density for livelier weft. Table 3 shows the values of fabric thickness and areal density and their correlation with fabric elastane %. As fabric elastane % increases, the fabric thickness and areal density decreases. The fabric elastane % has statistically significant effect on thickness and areal density.

Table 2 — Actual fabric elastane and widthwise fabric contraction

Fabric code	Actual fabric elastane, %	Fabric width contraction, %
F1	1.74	5.31
F2	2.46	3.44
F3	3.19	2.5
F4	3.92	1.56

3.4 Fabric Elastane % and Fabric Air permeability

The fabric air permeability is less for fabric with low elastane %, because stretched elastane brings the threads closer to each other, minimising the gap

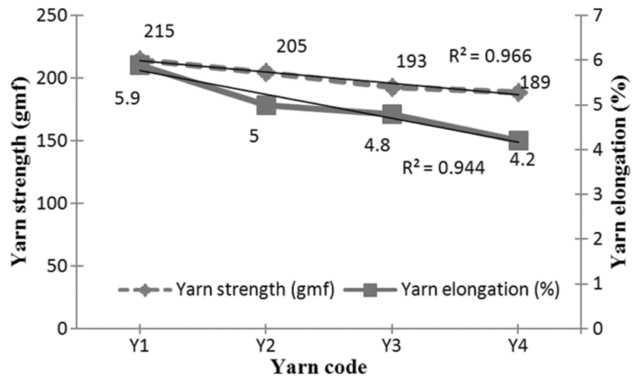

Fig. 2 — Effect of yarn elastane % on breaking strength and elongation

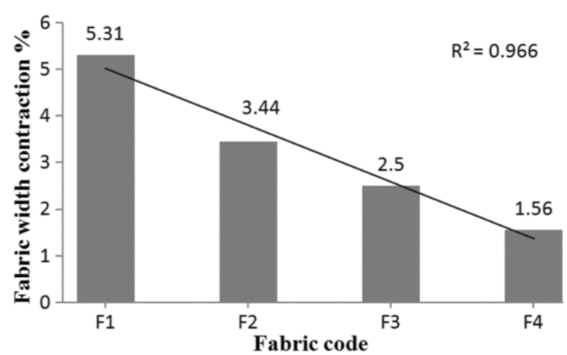

Fig. 3 — Effect of fabric elastane % on fabric width contraction

Table 3 — Fabric test results of different samples

Parameters	F1 fabric	F2 fabric	F3 fabric	F4 fabric	R^2 value	p value
Fabric thickness, mm	0.61	0.59	0.57	0.55	1	0.000
Fabric areal density, gsm	138.8	136.6	136.5	135.7	0.833	0.036
Fabric air permeability, $cm^3/cm^2/s$	27.73	28.31	30.14	30.45	0.926	0.000
Fabric breaking strength, lbf						
Warpway	52.6	51.1	47.1	46.8	0.909	0.004
Weftway	19.1	17.2	15	14.4	0.956	0.000
Fabric breaking extension, cms						
Warpway	1.95	1.8	1.74	1.63	0.974	1.7
Weftway	5.75	4.45	3.95	3.3	0.953	0.000
Fabric tearing strength, kgf						
Warpway	1.78	1.9	2.04	2.25	0.982	0.000
Weftway	1.76	1.81	1.85	1.92	0.986	0.000

between warp and weft interstices to restrict the air flow through the fabric. Table 3 shows a strong correlation between fabric elastane % and fabric air permeability, as shown by R^2 value and p value.

3.5 Fabric Elastane % and Stretch & Recovery %

Figure 4 shows values of immediate set % in warpway and weftway direction of different fabric samples. The immediate set % has been calculated using Eq (2). The results show that the fabric immediate set % is higher in weft direction than in warp direction.

As elastane % increases, the weftway immediate fabric set % increases. This may be because of the fact that the low tenacity elastane breaks during loading cycle. Due to which, fabric is unable to recover its original dimension during unloading cycle.

The negative values in warpway fabric set % show that there is no fabric growth rather elastane core weft yarn helps to prevent warpwise fabric set %, except for F1 sample. In F1 sample, the elastane % is less and elastane core is already stretched, which might have broken during loading cycle in warpway, resulting in some amount of set %.

3.6 Fabric Elastane %, Breaking Strength and Elongation

Table 3 shows that the fabric breaking strength is more in warpway than in weftway. This is because of the difference in warp and weft yarn strength. The weftway fabric breaking strength reduces as elastane % increases because of lower contribution of sheath and elastane material to the fabric strength. The warpway fabric strength also shows same trend because fabric with low elastane % has shown higher width contraction due to livelier weft which might have enhanced the effective contribution of warp yarn in fabric warpway strength. Table 3 also shows that the fabric breaking extension is more in weftway than in warpway because of elastane weft. Also fabric breaking extension decreases as fabric elastane % increases because of less interfibre friction between elastane core and cotton sheath. Owing to which, fabric having higher elastane % shows that the yarn gets easily slipped out under load.

Figure 5(a) shows that (R^2 value = 0.91/ 0.96) there is a strong correlation between fabric warpway and weftway breaking strength and elastane %. The p value in Table 3 shows that there is a significant difference in fabric warpway and weftway breaking strength as elastane % varies. Fig. 5(b) shows (R^2 value = 0.97/ 0.95) that the fabric extension has strong correlationship with fabric elastane% but results are significantly different in weftway than in warpway.

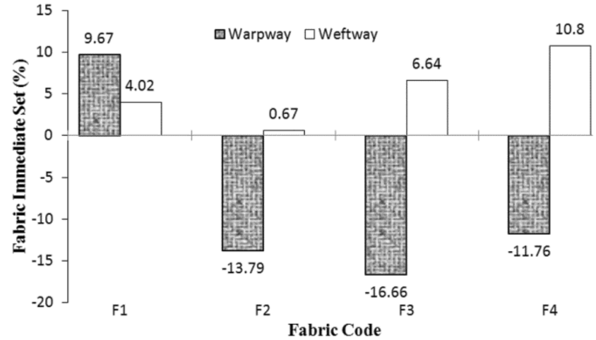

Fig. 4 — Immediate set % of different fabric samples

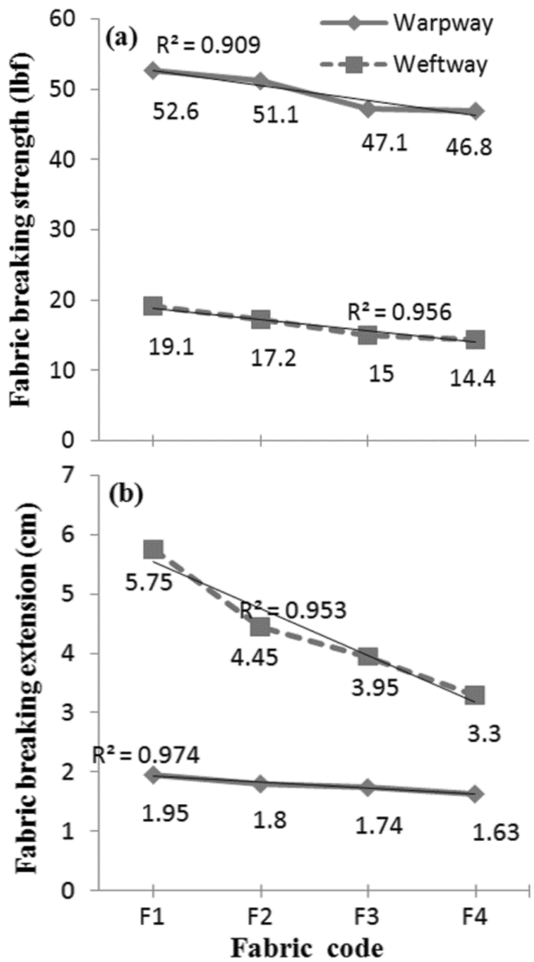

Fig. 5 — Effect of fabric elastane % on fabric (a) breaking strength and (b) breaking extension

3.7 Fabric Elastane % and Fabric Tearing Strength

Fabric tearing strength is highly dependent on easiness of yarn movement and constituent yarn's extension. Table 3 shows that fabric tearing strength increases with fabric elastane % and less lively elastane core weft. The reason for increase in warpway tearing strength may be because of the easy

Table 4 — Fabric abrasion resistance after predefined cycles

Fabric code	50 Abrasion cycles		75 Abrasion cycles		100 Abrasion cycles	
	Thickness loss, %	Weight loss, %	Thickness loss, %	Weight loss, %	Thickness loss, %	Weight loss, %
F1	5.04	10.59	10.09	16.41	14.33	21.18
F2	4.94	10.72	10.23	16.63	12.28	20.53
F3	5.12	12.33	10.07	17.7	11.66	23.60
F4	4.94	13.28	7.51	18.59	8.79	26.56

displacement of warp in fabric; having high elasatne % in less stretched condition which offers less resistance to warp during the test; whereas weftway tearing strength increases because of higher extension of weft yarn having more elastane % during the test. ANOVA analysis shows that there is statistically significant difference in warpway and weftway fabric tearing strength of different samples (p value = 0.000).

3.8 Fabric Elastane % and Fabric Abrasion Resistance

The yarn crimp, yarn core to sheath ratio, fabric areal density and fabric thickness are the main important parameters which have strong influence on fabric abrasion resistance. Table 4 shows the values of fabric thickness and weight loss (%) after certain predefined number of abrasion cycles. There is no weight and thickness loss after 25 abrasion cycles, and hence it is not mentioned.

Table 4 shows that the fabric thickness loss % increases with increase in abrasion cycles. Also the fabric thickness loss % is more for fabric with livelier elastane core as explained above. On abrasion, thicker fabric shows higher thickness loss. Also fabric weight loss % increases with increase in abrasion cycles. Also the fabric with high elastane % shows high weight loss %, because more sheath material comes out during abrasion due to less interfibre friction between sheath and core.

4 Conclusion

The study concludes that the elastane % and its liveliness have a prominent effect on yarn as well as fabric properties. The fabric elastane % and elastane liveliness govern the mechanical properties of fabric. The elastane liveliness and elastane % controls fabric width contraction thereby affecting crimp level in warp and weft and thus fabric thickness, fabric areal density and fabric air permeability. Also fabric tensile strength, tear strength and abrasion resistance are found to be significantly affected by fabric elastane % and its liveliness in the fabric.

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