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Effects of Elastane Draw Ratio of Core-spun Yarn on Air Permeability and Bursting Strength of Bi-Stretch Woven Fabrics

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Abstract

Bi-stretch woven fabrics are widely used owing to their good physical comfort properties. In this study, it is aimed to investigate the effect of elastane draw ratio in the core-spun yarn on the air permeability and bursting strength of bi-stretch woven fabrics. For this aim, 20 Tex cotton combed ring spun yarn samples were produced with four different levels of draw ratio of elastane core (3.07, 3.33, 3.63, 3.99) in the yarn. Four woven fabric samples were produced by using these sample yarns as weft with 2/1 twill weave type. Then the air permeability and bursting strength properties of the samples were tested in dry relaxed and laundered states. Analysis of variance (ANOVA) was applied to determine the effect of elastane draw ratio in the yarn and relaxation type on fabric air permeability, bursting strength and bursting height, statistically.

Keywords: Bi-stretch woven fabric; Elastane draw ratio; Air permeability; Bursting strength; Elastane core spun yar

Introduction

Elastane is used in all areas where a high degree of elasticity is required for example; in tights, sportswear, swimwear, corsetry and in woven and knitted fabrics. Elastane is a prerequisite for fashionable or functional apparel which is intended to cling the body, while at the same time remaining comfortable [1]. The elastane core spun yarns are preferred to provide a better stretch for woven fabrics. Especially, bi-stretch woven fabrics produced by using elastane core spun yarns in both warp and weft direction became more of an issue recently.

In the literature there are many studies which deal with the performance properties of woven stretch fabrics [2-8]. Apart from these studies, there are some studies which investigate the effect of elastane draw ratio in the yarn on woven fabric properties. Baghaei et al. [9] determined that the decrease in draw ratio of elastane core lead to decrease in elastic recovery of woven stretch fabrics. El-Ghezal et al. [10] examined that as the elastane's ratio in the yarn increases, the breaking elongation of stretch denim fabric decreases. Also, a consistent trend was not observed for breaking strength of the sample fabrics. In another experimental study, it is observed that increasing the elastane ratio enhanced the fabric extensibility and air permeability and reduced the tensile strength, shrinkage and permanent stretch of woven fabrics [11]. In another study, it was revealed that by increasing the draw ratio of elastane core, the fabric tensile strength and stretchability increase while the fabric tear strength and recovery after stretch decrease [12]. Previous studies examined the effects of elastane draw ratio in the yarn on fabric performance properties. But there is still lack of information on this issue. In this study, it is aimed to investigate the effects of elastane draw ratio on air permeability of woven bi-stretch fabrics considering the air permeability as a thermal comfort property. On the other hand, the bursting strength and bursting height of the samples were observed to study the effects of elastane draw ratio on durability and extensibility of woven bi-stretch fabrics.

Material and Methods

In this study it is intended to investigate the effects of elastane draw ratio and relaxation type on air permeability and bursting strength of bi-stretch woven fabrics. For this aim, 20 Tex cotton combed ring spun yarn samples were produced with four different elastane draw ratios (3.07, 3.33, 3.63, 3.99). Linear density of elastane core was 4.4 Tex. Uster HVI test device was used to determine the cotton fiber properties used in this study. Cotton fiber properties are given in Table 1.

In this study, the samples are called by elastane draw ratio. Uster Tester 5 and Uster Tensorapid 3 test devices were used to determine the yarn properties. Yarn properties are given in Table 2.

Four 2/1 twill fabric samples were woven by using the sample yarns in weft direction as weft. Warp sheet was composed of 21 Tex

Parameter	Value
Micronaire, μg/inch	4.57
Length, mm	29.95
UI, %	83.9
SFI	7.9
Strength, cN/tex	35.02
Elongation, %	5.8
SCI	160

Table 1: Cotton fiber properties.

Parameter	Samples (elastane draw ratio)			
	3.99	3.63	3.33	3.07
U, %	9.35	9.30	9.70	9.26
CVm, %	11.78	11.71	12.21	11.67
Thin places, -50%/km	0	0	0	0.6
Thick places, +50%/km	15.6	13.1	16.9	7.5
Neps,+200%/km	35.6	23.8	37.5	23.1
Hairiness	5.31	5.39	5.33	5.46
Tenacity, cN/tex	16.5	16.5	15.2	16
Breaking Elo., %	7.2	6.8	6.2	6.4

Table 2: Yarn properties.

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X 2, 65/35 % Polyester/Viscose, elastane core spun ring yarn. Linear density of elastane filament was 7.8 Tex. The fabric samples were woven by a 2.20 meter width rapier loom. The production was made in a commercial mill, with 530 rev/min loom speed. No dyeing was applied to the fabric samples. The structural properties of fabric mass, fabric density and thickness and the performance properties air permeability and bursting strength were determined after dry relaxation and home laundering. For dry relaxation, the samples were relaxed in the standard atmosphere of 20 ± 2°C and 65 ± 4% relative humidity for 24 hours. Home laundering was applied and dimensional changes were determined according to AATCC 135 [13].

Fabric mass per unit area, density and thickness properties of samples were determined according to TS EN 12127 (1999) [14], TS 250 EN 1049-2 (1996) [15] and TS 7128 EN ISO 5048 (1998) [16], respectively. The results are given in Table 3.

All fabric samples were conditioned according to TS EN ISO 139 (2008) [17] before the tests and the tests were performed in the standard atmosphere of 20 ± 2°C and 65 ± 4% relative humidity. Air permeability and bursting strength properties of samples were determined according to TS 391 EN ISO 9237 (1999) [18] and TS EN ISO 13938-2 (2003) [19], respectively. Air permeability test was done with digital air permeability test device at 100 Pa pressure drop. Bursting strength test was done with digital pneumatic bursting strength test device. Analysis of variance (ANOVA) was applied to determine the statistical significance of the effects of elastane draw ratio in the yarn and relaxation type on fabric air permeability, bursting strength and bursting height. For this aim design expert package Program was used. All test results were assessed at 95% confidence interval.

Results

Dimensional change

Figure 1 exhibits the warp and weft direction dimensional changes of the samples after domestic home laundering.

It is seen that for both warp and weft direction, shrinkage is observed for all samples. The yarn samples which have different elastane draw ratios were used in only the weft direction. Nevertheless, warp direction shrinkage values are different owing to different elastane draw ratios in weft direction. On the other hand, lower shrinkage values are observed as the elastane draw ratio decreases for both warp and weft directions. This is a probable result of lower length of elastane core in the yarn owing to higher elastane draw ratio. Since, this situation results higher contraction of the yarn and higher shrinkage of the fabric after home laundering.

Sample	Dry relaxed			
	Thickness, mm	Fabric mass, g/m²	Density, yarns/cm	
			Warp	Weft
3.99	0.73	254	30	28
3.63	0.74	263	30	28
3.33	0.78	268	30	28
3.07	0.80	278	30	28
Sample	**Laundered**			
	Thickness, mm	Fabric mass, g/m²	Density, yarns/cm	
			Warp	Weft
3.99	0.96	369	38	30
3.63	0.96	361	38	30
3.33	0.94	361	38	30
3.07	0.93	354	38	30

Table 3: Structural properties of fabric samples.'

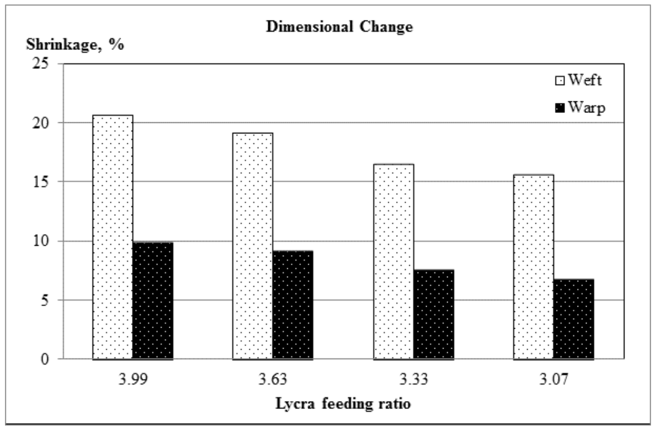

Figure 1: Dimensional changes of samples after home laundering.

Air permeability

In this study, the air permeability of the samples was assessed in accordance with thermal comfort. Air permeability values of dry relaxed and laundered samples are given in Figure 2.

It is obvious from Figure 2 that air permeability of dry relaxed samples are higher than that of laundered ones. This is a probable result of increased fabric thickness and fabric sett values of laundered samples. Higher fabric sett values of the samples cause the air gaps that the air pass through to get smaller and this makes the air passage through the fabric harder because of higher drag resistance. On the other hand increased fabric thickness cause a longer path for air passage through the fabric and air losses more kinetic energy in comparison to shorter path due to friction. Also, there is no considerable difference of air permeability among laundered samples due to elastane draw ratio. Since the fabric structure of the samples become more compact as seen from warp and weft density values given in Table 3. This compact structure compensates the effect of elastane draw ratio on air permeability. The air permeability of dry relaxed samples decreases with decreased elastane draw ratio as seen in an earlier study [11]. Consequently, fabrics with low elastane draw ratio provide a better thermal comfort with higher air permeability. Table 4 exhibits the ANOVA results for air permeability.

As seen from Table 4, the effects of elastane draw ratio ($p=0.0229<0.05$) and relaxation type ($p<0.0001<0.05$) on air permeability are found to be statistically significant in 95% confidence interval. Besides, relaxation type has a higher effect on air permeability than elastane draw ratio with a higher F value (435.27).

Bursting strength

In this study, it is intended to investigate the effects of elastane draw ratio on bursting strength and bursting height of woven bi-stretch fabrics instead of breaking or tearing strength differently from previous studies [10-12]. It is decided that it would be more convenient to study on bursting strength and bursting height of woven bi-stretch fabrics. Since this test imitates the in situ conditions more realistically than breaking and tearing strength by providing a multi-axial force application. Bursting strength and bursting height of the samples are given in Figure 3 and Tables 5 and 6, respectively.

Bursting strength values of dry relaxed samples are higher than that of laundered ones as seen from Figure 3. Additionally, laundered samples do not exhibit any difference with respect to elastane draw

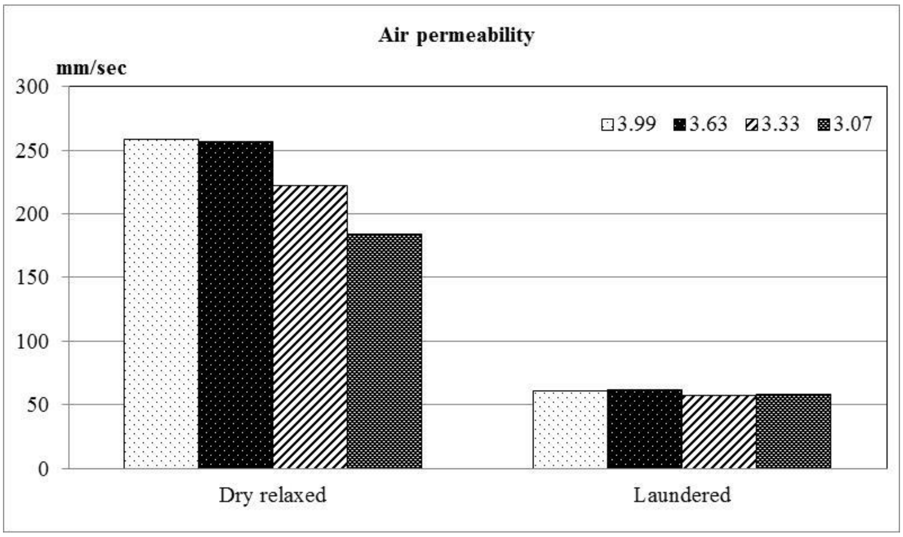

Figure 2: Air permeability of dry relaxed and laundered samples.

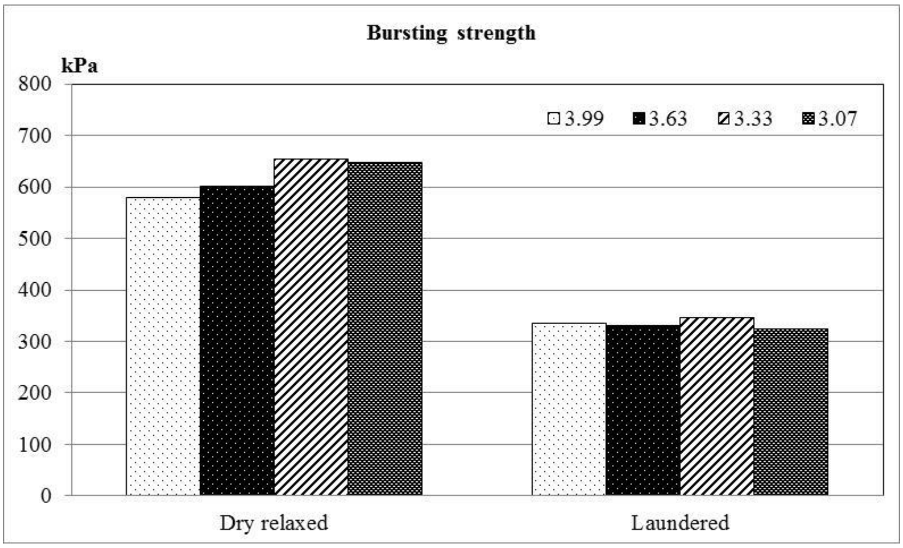

Figure 3: Bursting strength of dry relaxed and laundered samples.

Source	Sum of squares	Degrees of freedom	Mean square	F value	p-value
Model	61576.27	3	20525.42	150.41	0.0001
A - Draw ratio	1760.60	1	1760.60	12.90	0.0229
B-Relaxation type	59396.98	1	59396.98	435.27	< 0.0001
AB	1453.31	1	1453.31	10.65	0.0310
Residual	545.84	4	136.46		
Cor total	62122.11	7			

Table 4: ANOVA results for response surface 2FI model for air permeability.

Source	Sum of squares	Degrees of freedom	Mean square	F value	p-value
Model	1.680×10^5	3	55989.28	320.57	< 0.0001
A - Draw ratio	1425.08	1	1425.08	8.16	0.0461
B-Relaxation type	1.612×10^5	1	1.612 × 105	922.89	< 0.0001
AB	1919.55	1	1919.55	10.99	0.0295
Residual	698.62	4	174.65		
Cor total	1.687×10^5	7			

Table 5: ANOVA results for response surface 2FI model for bursting strength.

ratio. On the other hand, for dry relaxed samples as the elastane draw ratio decrease, the bursting strength increase. The result of our study is similar with an earlier study [11], which performed tensile strength test. Also contrary to our results an earlier study revealed that lower tensile strength was obtained with low elastane draw ratio levels [12]. Table 5 exhibits the ANOVA results for bursting strength.

As seen from Table 5 elastane draw ratio ($p=0.0461<0.05$) and relaxation type ($p<0.0001<0.05$) has a significant effect on bursting strength in 95% confidence interval. Relaxation type has a statistically higher effect on bursting strength than elastane draw ratio with a higher F value (922.89). Table 6 shows the bursting height values of dry relaxed and laundered samples.

As seen from Table 6, the bursting height values of samples rise as

Samples	Bursting height, mm	
	Dry relaxed	Laundered
3.99	11.94	48.82
3.63	12.12	48.76
3.33	12.94	49.56
3.07	13.38	49.68

Table 6: Bursting height of dry relaxed and laundered samples.

Source	Sum of squares	Degrees of freedom	Mean square	F value	p-value
Model	2682.35	2	1341.18	20948.44	< 0.0001
A - Draw ratio	1.77	1	1.77	27.61	0.0033
B-Relaxation type	2680.58	1	2680.58	41869.27	< 0.0001
Residual	0.32	5	0.064		
Cor total	2682.67	7			

Table 7: ANOVA results for response surface linear model for bursting height.

the draw ratio of elastane core in the yarn decrease for both dry relaxed and laundered samples. These results originate from higher length of elastane core in the yarn due to lower elastane draw ratio. The higher length of the elastane core in the yarn cause a higher stretch of the yarn and the fabric produced from it. According to these results, it can be concluded that the fabrics produced from the yarns with lower elastane draw ratio provide higher stretchability, thus an easier movement for the wearer. In addition, Table 6 exhibits considerably higher bursting height values of laundered samples than that of dry relaxed ones. This difference arises from the shrinkage of the samples after laundering. The contraction of the samples due to laundering causes this difference. ANOVA results for bursting height are given in Table 7.

Table 7 exhibits the statistically significant effects of elastane draw ratio ($p=0.0033<0.05$) and relaxation type ($p<0.0001<0.05$) on bursting height. It is also seen that relaxation type has a statistically higher effect on bursting strength with a higher F value (41869.27) than elastane draw ratio.

Discussion and Conclusion

In this study, it is intended to investigate the effect of elastane draw ratio on the air permeability and bursting strength of bi-stretch woven fabrics in dry relaxed and laundered states. As a result of this study, it is seen that the shrinkage values decrease as the elastane draw ratio decreases after home laundering. In the case of air permeability property, dry relaxed samples have higher air permeability than laundered ones owing to increased fabric thickness and fabric sett values of laundered samples. On the other hand, there is no considerable effect of elastane draw ratio on air permeability for laundered samples whereas the air permeability of dry relaxed samples decrease with lower elastane draw ratio. Dry relaxed samples have higher bursting strength values than laundered ones. Additionally, laundered samples do not exhibit any difference with respect to elastane draw ratio in contrary to dry relaxed samples. Dry relaxed samples have a tendency of higher bursting strength for decreasing elastane draw ratios. In regards to bursting height, for both dry relaxed and laundered samples, higher bursting height values are seen for decreased elastane draw ratio.

In addition, laundered samples exhibit considerably higher bursting height values of than dry relaxed ones. As a conclusion it is seen that laundering process has an important effect on air permeability and bursting strength. So, for further research, it is recommended to study the effects of elastane draw ratio on performance properties for dyed and finished fabrics in order to see the real end use performance.

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