IOP Conf. Series: Materials Science and Engineering **254** (2017) 082007 doi:10.1088/1757-899X/254/8/082007

An investigation on the effect of elastane draw ratio on air permeability of denim bi-stretch denim fabrics

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Abstract. Elastane is used in all areas where a high degree of elasticity is required. The elastane core spun yarns are preferred to provide a better stretch for woven fabrics. In this study, it is intended to investigate the effects of elastane draw ratio on air permeability of denim woven fabrics. For this study, 29.5 Tex cotton combed ring spun yarn samples were produced with four different elastane draw ratios (3.07, 3.33, 3.63, 3.99). 3/1 Twill and 2/2 Twill denim fabric samples were woven by using the sample yarns in weft direction with three different weft densities (21, 25, 29 wefts/cm). In doing so, 24 denim fabric samples were obtained. Then air permeability of fabric samples were measured. Analysis of variance (ANOVA) was applied to determine the statistical significance of the effects of elastane draw ratio, weft sett and weave type on fabric air permeability.

1. 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. determined that the decrease in draw ratio of elastane core lead to decrease in elastic recovery of woven stretch fabrics [9]. El-Ghezal et al. 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 [10]. In another experimental study, it is observed that increasing the elastane ratio enhanced the fabric extensibility and air permeability. Beside, the elastane ratio 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]. Kaynak investigated the effects of elastane draw ratio, load and relaxation type on stretch and recovery properties of woven bi-stretch fabrics. In this study, an optimization model was developed to determine the optimum elastane draw ratio, load applied to the fabric and relaxation type for the best stretch and permanent stretch [13]. 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, weft sett and weave type on air permeability of woven bi-stretch denim fabrics considering the air permeability as a thermal comfort property.

2. Material and Method

For this study, 29.5 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 is 7.8 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 (Table 2).

Table 1. Cotton fiber properties.

Parameter	Value
Micronaire, µg/inch	4.85
Length, mm	29.50
UI, %	84.5
SFI	7.9
Strength, cN/tex	33.6
Elongation, %	8.0
SCI	152

Table 2. Yarn properties.

Parameter	Samples (elastane draw ratio)			
	3.99	**3.63**	**3.33**	**3.07**
U, %	8.57	9.12	8.55	9.02
CVm, %	10.82	11.49	10.82	11.35
Thin places, -50%/km	0	0	0	0.0
Thick places, +50%/km	8.8	11.3	15	12.5
Neps, +200% / km	16.3	22.5	11.3	8.8
Hairiness	6.06	6.09	5.91	6.14
Tenacity, cN/tex	15.15	14.90	14.02	15.10
Breaking Elo.,%	8.3	8.0	8.0	7.9

The sample yarns were used as weft for producing the fabric samples. Three different weft sett (21, 25, 29 wefts/cm) and two different weave types (Twill 3/1 and Twill 2/2) were applied. In doing so, 24 denim fabric samples were obtained. Warp sheet was indigo dyed and composed of 37 Tex, dual core (PBT - Elastane) ring spun yarn. The fabric samples were conditioned according to TS EN ISO 139 (2008) [14] before the tests and the tests were performed in the standard atmosphere of 20±2ºC and 65±4% relative humidity. The structural properties of fabric mass, fabric density and thickness were determined according to TS EN 12127 (1999), TS 250 EN 1049-2 (1996) and TS 7128 EN ISO 5048 (1998) [15-17], respectively (Table 3).

The air permeability of the samples was determined after dry relaxation. Air permeability of samples was determined according to TS 391 EN ISO 9237 (1999) with digital air permeability test device at 100 Pa pressure drop [18].

Table 3. Structural properties of fabric samples.

Weft sett, wefts/cm	Elastane draw ratio	Twill 3/1		Twill 2/2	
		Thicknes s, mm	Fabric mass, g/m²	Thicknes s, mm	Fabric mass, g/m²
21	**3.99**	0.62	269	0.61	**273**
	3.63	0.62	270	0.60	**263**
	3.33	0.62	269	0.59	**262**
	3.07	0.64	285	0.62	**274**
25	**3.99**	0.60	289	0.58	**288**
	3.63	0.62	288	0.57	**286**
	3.33	0.61	282	0.57	**281**
	3.07	0.62	287	0.56	**275**
29	**3.99**	0.61	305	0.56	**303**
	3.63	0.60	302	0.55	**297**
	3.33	0.62	306	0.53	**293**
	3.07	0.61	301	0.54	**292**

3. Result and Discussion

Air permeability results of the 3/1 Twill and 2/1 Twill fabric samples at different weft setts are given in Figure 1 and 2 respectively. From Figure 1 and 2, it can be clearly seen that the air permeability of the samples decrease as the weft sett of the samples is increased. This situation can be attributed to the fact that when the weft sett of the fabric is increased, the pores between the warp and weft yarns get smaller. Since less open area is provided for air passage through fabric structure, the air flux will be exposed more drug resistance during the passage.

For each weft sett of 3/1 twill fabric, there are changes in air permeability performance with respect to the draw ratio changes (Figure 1). The highest performance values are obtained with 3.63, 3.07 and 3.07 draw ratios for 21, 25 and 29 wefts/cm setts respectively.

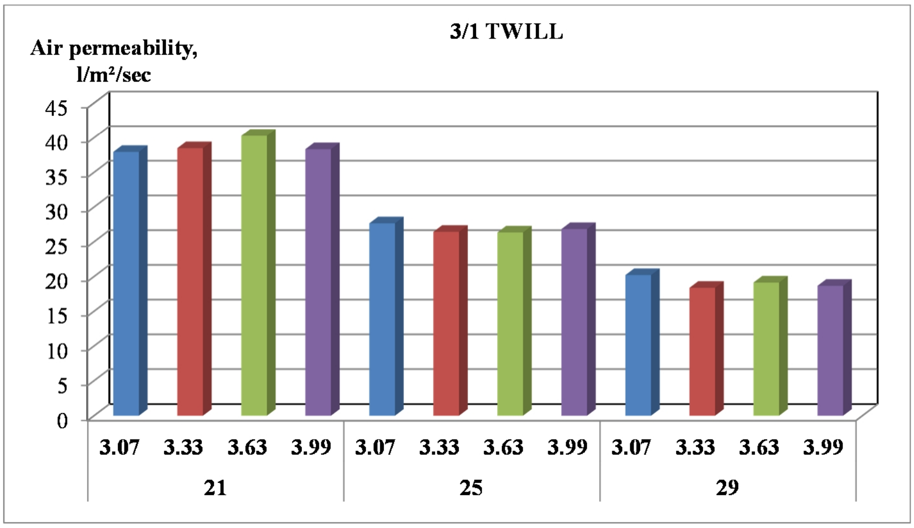

Figure 1. Air permeability results of 3/1 twill fabric samples

According to the results given in Figure 2, It can be said that the draw ratio has a diminishing effect on the air permeability performance of the 2/2 twill fabric samples. It can be observed that there is a tendency of decrease in air permeability values for all weft sett values of 2/2 twill fabrics in proportion to the increase of the elastane core draw ratio (Figure 2). The highest air permeability values are obtained with 3.07 elastane draw ratio for all weft sett values of 2/2 twill fabrics. The lowest air permeability performances are obtained with 3.99, 3.63 and 3.99 draw ratios for 21, 25 and 29 wefts/cm setts of 2/2 twill samples respectively (Figure 2).

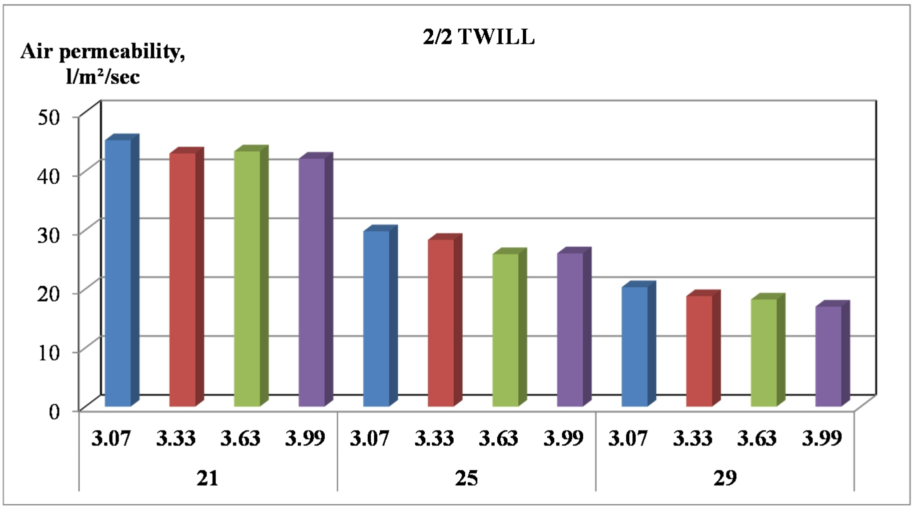

Figure 2. Air permeability results of 2/2 twill fabric samples

The air permeability performance of the fabric samples are compared with respect to their weave patterns in Figure 3. For 21 wefts/cm thread density, higher air permeability performance is obtained with 2/2 twill pattern than 3/1 twill pattern for each elastane draw ratio. The air permeability results of the 2/2 twill and 3/1 twill weave samples with 25 and 29 wefts/cm thread densities are close to each other for each elastane draw ratio. When the draw ratios of 3.07 and 3.33 are investigated for 25 wefts/cm sett, it can be said that air permeability performance of the samples with 2/2 twill pattern are higher than that of 3/1 twill samples. For both 25 and 29 weft/cm setts, the higher air permeability performance are obtained with 3/1 twill pattern at 3.63 and 3.99 elastane draw ratios than that of 2/2 twill weave samples at these draw ratios.

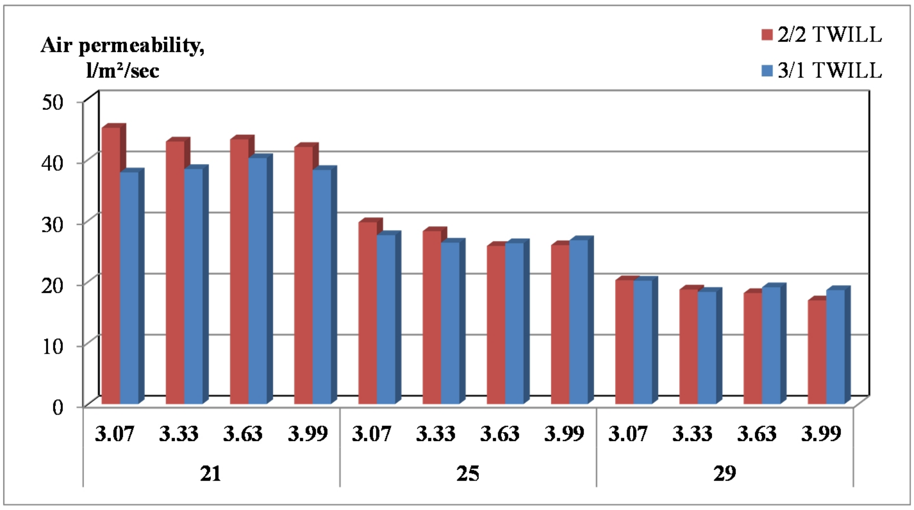

Figure 3. Air permeability results of 31/ and 2/2 twill fabric samples

Analysis of variance (ANOVA) was performed to determine the statistical significance of the effects of elastane draw ratio, weft sett and weave type on fabric air permeability. For this aim the statistical software package SPSS 21.0 was used to interpret the experimental data. All test results were assessed in 95% confidence interval.

Table 4. ANOVA for air permeability.

Source	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	20878.486[a]	23	907.760	255.783	0.000	0.965
Intercept	201828.400	1	201828.400	56869.832	0.000	0.996
Weftsett	20118.941	2	10059.471	2834.489	0.000	0.963
Drawratio	138.559	3	46.186	13.014	0.000	0.153
Weavetype	162.362	1	162.362	45.749	0.000	0.175
Weftsett * Drawratio	49.502	6	8.250	2.325	0.034	0.061
Weftsett * Weavetype	312.681	2	156.341	44.053	0.000	0.290
Drawratio * Weavetype	74.150	3	24.717	6.964	0.000	0.088
Weftsett * Drawratio * Weavetype	22.291	6	3.715	1.047	0.396	0.028
Error	766.574	216	3.549			
Total	223473.460	240				
Corrected Total	21645.060	239				

[a] R Squared = 0.965 (Adjusted R Squared = 0.961)

According to ANOVA results, weft sett, weave type and elastane draw ratio has statistically significant effects on air permeability ($p=0.000<0.05$). In addition, according to multiple comparison test results for weft sett, each weft sett value (21, 25, 29 wefts/cm) has statistically different effects on air permeability, in 95% confidence interval. On the other hand, elastane draw ratios of 3.33, 3.63 and 3.93 have statistically similar effect on air permeability, whereas 3.07 elastane draw ratio has statistically different effect on air permeability than other values (3.33, 3.63, 3.93). The 3.07 elastane draw ratio has an increasing effect on air permeability.

4. Conclusion

In this study, the effects of elastane draw ratio, weft sett and weave type on air permeability of bi-stretch denim fabrics are investigated.

In accordance with the statistical analysis results, the draw ratio, weft sett and weave pattern parameters have got significant effect on air permeability performance of the denim fabric samples. Since the higher thread density lead to less open spaces for air flux, the increase in weft sett has a decreasing effect on all samples.

For 25 wefts/sett of 3/1 twill fabric, closer air permeability results were obtained for all draw ratios. The air permeability performance of 3/1 twill fabric samples changes with respect to the draw ratio changes. The increase of the elastane draw ratio has a decreasing effect on the air permeability performance of the 2/2 twill fabric samples.

In order to investigate the effect of weave pattern on the air permeability performance of fabric samples with different elastane draw ratios, the test results are compared with regard to the pattern type. It is concluded that for all elastane draw ratios, there are significant differences between air permeability performance of 2/1 twill and 3/1 twill fabrics. For all draw ratios, the highest differences between the performances of two patterns were obtained for 21 wefts/cm sett.

Acknowledgement
The authors are grateful to Kara Holding Textile Mills for production of yarn samples and Çalık Denim for production of fabric samples.

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