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INVESTIGATION OF SOME MECHANICAL AND AIR PERMEABILITY PROPERTIES OF SHIRTING FABRICS PRODUCED FROM COMPACT YARNS MADE OF NATURAL AND SYNTHETIC FIBRES

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Abstract: Shirting fabrics are one of the most demanded product groups for textile consumers. Although cotton is the most preferred fibre as the raw material of shirting fabrics, fibres such as Polyester, Elastane, viscose and their blends with cotton may also be utilized in the shirting fabrics. For the convenience usage of shirting fabrics in apparel products, those fabrics' durability and air permeability properties should be considered in detail. Fabric constructional parameters such as weave structure, warp and weft yarn density, yarn count, fibre type are the main influential factors on shirting fabrics' mechanical and air permeability properties. This study has been performed in order to evaluate the effect of fabric construction on some mechanical properties such as tear strength, seam strength, crease recovery angle (°) as well as on air permeability of the shirting fabrics. Throughout the study, plain, dobby and satin shirting woven fabrics were produced from the compact yarns with several combinations of cotton, linen, polyamide, viscose and elastane fibre blends. Pre-treated samples were objected to tear strength test, seam strength test, crease recovery angle (°) test and finally to air permeability test. Randomized One –Way ANOVA test was performed in order to investigate the significant effect of fabric type on some mechanical and air permeability properties of shirting fabrics at significance level of 0.05. Test results were statistically evaluated and it was generally observed that there was a significant effect of fabric type on tear strength, seam strength, crease recovery angle and on air permeability features of the shirting fabrics at significant level of 0.05.

Keywords: Shirting fabrics, tear strength test, seam strength, crease recovery, air permeability

Doğal ve Sentetik Lif Esasli Kompakt İpliklerden Üretilen Gömleklik Kumaşların Bazı Mekanik ve Hava Geçirgenliği Özelliklerinin İncelenmesi

Öz: Gömleklik kumaşlar tekstil tüketicileri açısından en çok talep edilen ürün gurupları arasındadır. Bu ürünlerde hammadde olarak daha çok pamuk tercih edilse de, Poliester, elastan, viskon gibi lifler ve bu liflerin pamuk ile karışımları da gömleklik kumaşlarda kullanılabilmektedir. Gömleklik kumaşların konfeksiyon ürününde rahatlıkla kullanılabilmeleri açısından dayanıklılıkları ve hava geçirgenliği özellikleri göz önünde bulundurulmalıdır. Dokuma örgü konstrüksiyonu, çözgü ve atkı iplik sıklığı, iplik numarası, lif tipi gibi kumaş konstrüksiyon parametreleri gömleklik kumaşların mekanik ve hava geçirgenliği özelliklerini etkileyen temel parametreler arasında yerini almaktadır. Bu çalışma farklı kumaş tiplerinin, gömleklik kumaşlara ait çözgü ve atkı yönündeki yırtılma mukavemeti, dikiş mukavemeti, kat

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düzelme açısı (°) ve hava geçirgenliği özelliklerine etkisini değerlendirmek üzere yapılmıştır. Bunun için farklı oranlarda pamuk, keten, Poliamit, viskon ve elastan lifleri içeren kompakt iplikler kullanılarak bezayağı, armürlü ve saten gömleklik kumaşlar üretilmiştir. Ön terbiye işlemi yapılmış kumaşlara yırtılma mukavemeti testi, dikiş mukavemeti testi, kat düzelme açısı (°) testi ve son olarak hava geçirgenliği ölçüm testleri uygulanmıştır. Kumaş tipinin gömleklik kumaşların bazı mekanik özellikleri ve hava geçirgenliği üzerindeki etkisinin 0.05 anlamlılık düzeyinde etkisini görebilmek adına tek yönlü ANOVA testi uygulanmıştır. Test sonuçları istatiksel olarak değerlendirilmiş olup, kumaş tipinin genel olarak gömleklik kumaşlara ait yırtılma mukavemeti, dikiş mukavemeti, kat düzelme açısı ve hava geçirgenliği özellikleri üzerinde 0.05 anlamlılık düzeyinde etkili olduğu görülmüştür.

Anahtar Kelimeler: Gömleklik kumaşlar, yırtılma mukavemeti testi, dikiş mukavemeti testi, kat düzelme açısı, hava geçirgenliği

1. INTRODUCTION

Against the global competition in textile sector, shirting fabrics manufacturers should increase the product range and quality of the fabrics. New fabric designs for shirting fabrics can be provided by using colored yarns as well as with different fibre blends, by using different weaving pattern also by applying different finishing processes. Conversion of fabric to the apparel garment should also be considered especially in terms of sewing property. Garment manufacturers are advised to use high quality sewing threads in order to provide better seam performance. Seam performance of the garments may be evaluated with seam strength and seam slippage strength which are highly influenced from sewing threads and fabric mechanical properties. Gurarda (2008) emphasized that seam slippage strength is mainly influenced from fabric characteristics such as weave type, weaving yarn type, coefficient friction between yarns, fabric density and so on. Some parameters such as stitch density, thread thickness and thread extensibility, thread consumption were also mentioned to be influencing the seam slippage behaviour in woven fabrics.

Consumers' demand with respect to shirting fabric properties include the comfort properties such as air permeability, moisture management, wickability as well as their mechanical properties including abrasion, pilling, fabric tensile strength, tear strength, seam strength, crease recovery or wrinkling properties of the shirting fabrics. In a research related to determination of tactile properties of shirt fabrics; The relation between the physical properties of fabrics and the sensory analyse was evaluated. For determining the tactile properties of shirting fabrics, bending length and stiffness values of the fabrics were recorded. It was concluded that preferences of the participants with respect to color and design of the fabrics were highly correlated with the tactile test results of the shirting samples (Arık et al., 2016; Arık et al., 2018).

Cotton has been known as the most common preferred for shirting fabrics however fabrics with regenerated cellulose or synthetic fibre blends may also be utilized in shirting garments. Cotton shirting fabrics have the advantage of high durability but they are more prone to be wrinkled leading to difficulties during ironing process. Further finishing processes for improving crease recovery may be required for the cotton shirting fabrics (Ukponmwan, 1987; Okur, 1995; Chen et al.; 2000; Çoban and Cireli, 1992).

Fabric mechanical properties such as tearing strength, seam strength, crease recovery are influenced from fibre type, fabric weight, warp and weft densities, fabric weaving pattern or the finishing processes. Fabrics with different weave structure are expected to reveal different mechanical properties. For instance, satin weaves were observed to be providing higher tearing strength owing to high floats compared to plain and twill weaves in one of the study. It was emphasized that those type of weaving structures such as satin let the yarns being more free under tearing load resulting with higher tear strength (Nassif, 2012). Eltahan also emphasized that the higher number of yarn intersections per unit repeat leads to lower fabric tearing strength. Within his study among the woven samples with different weave structure, Satin woven samples were found to be having high tearing resistance compared to twill and ribs samples (Eltahan, 2018).

Crease recovery angle (°) is also influenced from the fabric construction such as fabric weight, warp and weft yarn density, yarn twist, fibre types as well as from the easy movement of yarns with respect to their weave pattern. Some researchers concluded that twill and satin weave fabrics overcame the creases better compared to plain weaves made of same yarn linear density and warp-weft density which may be attributed to easy movement of yarns in twill and satin weave pattern (Wang and Yao, 2000). In another study related to crease recovery angle of the woven fabrics ; Polyester fibres having different cross sectional shapes were utilized as the raw material and it was concluded that fabrics produced from full fibres were more satisfying about the crease recovery angles than the fabrics produced from hollow polyester Fibres (Omeroglu et al., 2010).

There are some more studies related to evaluation of physical properties of woven fabrics . Sudnik (1966) conducted a research related to effect of weave and construction on dry wrinkling of woven Poliamide 6.6 shirting fabrics. Wrinkling of fabrics in laboratory tests and in wear was compared with fabric-constructional parameters. Scelzo et al. (1994) compared the tearing strength of fabrics made of ring and rotor yarns. The authors concluded that fabrics made of rotor spun yarn fabric revealed higher tearing strength depending on the yarn linear density and tear test direction. Yick et al. (1996) conducted a study comparing the test results of FAST (fabric assurance by simple testing) with those of KES-F (Kawabata evaluation system) for two series of 22 shirting fabrics with respect to their low-stress fabric mechanical properties of bending, shear and tensile deformation. Despite to some differences between the measurement principle of two testing system, a high significant correlation between the parameters obtained from both two systems was provided. Mukhopadhyay et al. (2006) conducted a research where they investigated the tearing and tensile behaviour of military fabrics from grey to finished process. Within their study, three different types of military fabrics (3 up 1 down twill), differing in type of constituent yarns (ring/rotor) were observed to reveal less sensitive fabric tensile strength but more susceptible to the change due to the processes from grey to finished process. Ring spun yarns indicated higher tearing strength compared with rotor spun yarns. However, the difference in their strength was declared to decrease as the process approached towards the finished state. Tear strength decreased at bleaching and dying process while a sharp decrement for tensile decrement was observed at the dyeing stage. Oğulata and Kadem (2008) conducted a research related to tenacity of cotton fabrics where empirical equations were determined before production. 100% cotton woven samples with different fabric constructions were produced and pre-treated. Tensile strength of the fabrics were determined after pretreatment. A multiple regression analyse was conducted for predicting the tensile values before production. A high correlation was obtained between the tensile strength of the empirical equations and the experimental datas.

Namiranian et al. (2014) investigated seam slippage and seam strength behaviour of elastic woven fabrics under constant loading. 6 fabric samples with different elastane ratio were produced and sewn with three stitch density levels (4, 5 and 6 stitches/cm) in warp direction and one stitch level (5 stitches/cm) in weft direction. Seam strength, seam slippage strength and fabric tensile properties were evaluated in warp and weft direction. It was concluded that seam slippage and seam strength properties could be well explained in terms of fabric tensile properties. A high correlation was obtained between the tightness, crimp factor and wrinkling. Sarıoğlu and Babaarslan (2019) conducted a research related to relations between fabric air permeability, porosity properties and fabric constructional parameters. For evaluating the effect of filament fineness and yarn linear density on air permeability and total porosity, 24 woven samples with varying weft densities. Authors concluded that filament fineness and yarn linear density were influential factors on total porosity and air permeability at significance level of 0.05.

Among the woven fabrics; Demand for shirting fabrics in apparel products have been increasing in casual and official wearing. This study aims to contribute to the literature by investigating some mechanical properties including tear strength in warp and weft wise, seam strength in warp and weft wise, crease recovery angle in warp and weft wise and air permeability properties of shirting woven fabrics having different fabric construction. Those mentioned properties which give main ideas about the shirting fabrics' convenience to be used for the end-products were thought as beneficial to be considered. 7 different pre-treated fabrics with different fabric constructions such as weaving pattern, yarn linear density, warp and weft density, fibre type were compared between each other in terms of some mechanical properties and air permeability properties by means of randomized one-factor ANOVA test.

2. Material and Method

2.1. Material

7 different woven fabrics with different weaving pattern were produced on Picanol Optimax branded industrial rapier weaving machine. 100% linen, 70% cotton- 30% linen, 75% cotton - 20% Polyamide- 5% Elastane ,100 % cotton, 97 % cotton- 3% elastane and 100% viscose compact yarns with different linear yarn densities were selected to be the warp or the weft yarns of shirting fabric samples. Sizing process with PVA was applied to warp yarns. Shirting fabrics were exposed to silicon softening finish or crease resistance finishing (easy-care process with 30g/lt resin) depending to the fabric type after the pre-treatment processes. Detailed wet processing and finishing processes related to each fabric type were revealed in table 1 beside the fabric structural properties. Before the measurements, all fabric samples were conditioned for 24 hours in standard atmospheric conditions (at a temperature of 22 ± 2 °C and relative humidity of 65 ± 2%). The fabric weights were measured according to the standard test methods for mass per unit area (gr/m^2) of fabric (ASTM D3776 / D3776M-09a, 2017). The numbers of warp and weft yarns in 1 cm were determined for each fabric samples according to test standard of BS EN 1049-2 (BS EN 1049-2, 1994).

Table 1. Structural properties of woven fabrics

Fabric Codes	Weaving type	Composition	Warp yarn (Ne)	Weft yarn (Ne)	Warp density (thread/cm)	Weft density (thread /cm)	Fabric weight (g/m^2)	Pre-treatment and Finishing Processes
F1	Plain	100% linen	23/1 linen	23/1 linen	22	21	124	desizing+ scouring+ optical bleaching+ rinsing- drying+silicon finishing+ sanforization
F2	Plain	70% cotton 30% linen	24/1 cotton -linen	24/1 cotton-linen	24	21	119	desizing+ scouring+ rinsing+drying+ bleaching+ easy care finishing+optica lbleaching+ rinsing+s anforization

F3	Plain	75% cotton 20% Poliamid 5% Elastane	50/1 cotton	113/1 Poliamid-Elastane	43	35	99	rinsing+drying+ hot bleaching+rinsing+mercerization+ stenter+optical bleaching+rinsing+ silicon softening+sanforization
F4	Plain	100% cotton	60/1 cotton	50/1 cotton	37	29	79	soft washing+drying +hot bleaching+ rinsing+ mercerization+ drying+ rinsing+drying+ rinsing+ drying+optical bleaching+ rinsing+drying+ easy care finishing+ sanforization
F5	Dobby	65% cotton 35% viscose	60/1 cotton	53/1 viscose	57	34	110	rinsing+drying+ hot bleaching+ rinsing+optical bleaching+ rinsing+silicon softening+ sanforization
F6	Plain	97% cotton 3% elastan	120/2 cotton	70/1 Cotton-Elastane 22 dtex	56	36	106	soft washing+ rinsing+ mercerization+ stenter+hot bleaching+ rinsing+easy care finishing+ optical bleaching+ rinsing+drying+ sanforization
F7	4/1 Warp Satin	100% cotton	70/1 cotton	70/1 cottton	72	47	116	rinsing+stenter+ hot bleaching+ rinsing+ mercerization+ stenter+optical bleaching+ rinsing+drying+ silicon softening+ sanforization

2.2. Method

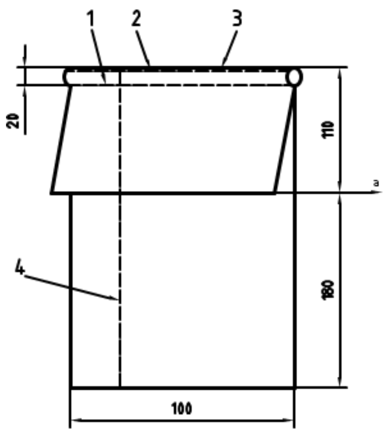
2.2.1. Tear Strength

Resistance to tearing of textiles is an important characteristic for the fabrics used in daily wear such as shirting fabrics. This parameter is a major component of fabric mechanical performance. When a static load is applied to pre-cracked samples, a tearing area called "del zone" generates which arises from stretching and sequential breakage of yarn groups along the fabric. Tearing continues as the del zone moves forward in the tearing direction with further sliding of longitudinal yarns and stretching of transverse yarns. (Krook and Fox, 1945; Teixeira et al., 1955).

In order to observe tearing strength of the shirting fabrics, dynamic tear strength (N) values were recorded. Dynamic tear strength tests for the warp and wise were performed by means of Elmendorf test device according to ISO 13937-1:2000-Textiles-Tear properties of fabrics - Part 1: Determination of tear force using ballistic pendulum method (Elmendorf) standard (ISO 13937-1, 2000). Falling pendulum method is used for the determination of the average force required to continue or propagate a single – rip type tear starting from a cut in a woven fabric by means of a falling pendulum (Elmendorf) apparatus. Part of the energy stored in the pendulum is used to produce the tearing (and any deformation of the test piece). Magnitude of this is indicated by the energy lost compared to the energy of falling pendulum without a test piece in place. Weight attached to the pendulum can be selected based on the fabric tested and standard used. An initial slit is made in the centre of the specimen (Hu, 2008).

2.2.2. Seam Strength

Failure of the seams of the garment by breaking of the sewing thread or by seam slippage affects serviceability of the shirting fabrics. Seam strength relates to the force required to break the stitching thread at the line of stitching. For seam strength tests; Rectangular specimens of 350 mm length and 100mm width were prepared. 5 specimens (350*100) with their long sides parallel to the weft of the fabric for determining warp seam strength and with their long sides parallel to the warp of the fabric for determining the weft seam strength according to ISO 13935-1: 2004 test standard by using Shimadzu tensile tester (ISO 13935-1, 2004). The values of seam strength were recorded as the required load for failure of sewing zone. Test speed was set as 100 mm/min while the jaws' width was adjusted as 150 mm. Figure 1 indicates the preparation of test specimens for seam strength measurement according to ISO 13935-1 standard.



1:seam line (20 mm from fold line)

2:cutting line (12 mm from seam line)

3:fold line

4:guide line (38 mm from edge)

+ a Cutting line direction.

Figure 1:
Preparation of test specimens for seam strength (ISO 13935-1, 2004).

2.2.3. Crease Recovery Angle (°)

Crease is an unintentional fold in the fabrics during or after processing. The resistance of the textile material for creasing during the usage is called crease resistance. Crease recovery angle of fabrics is a quantitate measurement for this parameter which should be considered especially for cellulosic based shirting fabrics. The reason of the crease or wrinkle formation on cellulosic fibres is because of the existence of free hydroxyl groups. Those groups form new hydrogen bonds with the adjacent polymer chain which leads to wrinkles and creases (Carty and Byrne, 1991; Arık et al., 2018). Crease recovery angles of fabrics were measured by utilizing SDL Atlas crease recovery tester according to AATCC 66 test method. Tests were performed in warp and weft direction with 5 replicas for each sample. Obtaining high crease recovery angle indicates better crease recovery for the fabrics (Hu, 2008; AATCC Test Method 66, 2003)

2.2.4. Air Permeability Test

Air permeability of shirting fabrics should be taken into consideration for the consumers' wear comfort where high breathability is desired. Air permeability of woven fabrics is mainly influenced from fabric structural property including fiber density, warp and weft yarn linear density, yarn type as well as from weave structure. Those mentioned properties are also related to porosity of fabrics which can be expressed as the ratio of space to the total volume of fabrics (Haylova, 2013; Mohamad, 2015; Sarıoğlu and Babaarslan, 2019). Within this study, shirting apparel fabrics were exposed to air permeability test with SDL Atlas Digital Air Permeability Tester according to EN ISO 9237 standard (EN ISO 9237, 1995). Measurements were performed by application under 100 Pa air pressure per 20 cm^2 fabric surface. Averages of measurements from 10 different areas of fabrics were calculated. Pre-selected unit of measure was dm3/s. The air permeability (mm/s) was determined as follows (equation 1) ;

$$R = \left(\frac{\bar{q}_v}{A}\right).167 \qquad (1)$$

Where: $\bar{q}_v$: an arithmetical average of the debit of air flow ,dm^3/min; A: Test area, cm^2; and 167: coefficient of conversation from dm^3/min to cm^3/s and then from cm/s to mm/s. Air permeability results of the shirting fabrics were expressed as "mm/sec".

2.2.5. Statistical Analysis

In order to understand the statistical importance of fabric type on seam strength, tear strength and crease recovery properties and air permeability properties of shirting fabrics; One way ANOVA test was performed. Student-Newman- Keuls (SNK) tests were conducted in order to compare the means of air permeability, seam strength, tear strength and crease recovery properties of the shirting fabrics. For this aim, the statistical software package SPSS 21.0 was used to interpret the experimental data. All test results were assessed at 95% confidence interval.

3. RESULTS&DISCUSSION

Tear strength test results, seam strength test results, crease recovery angle (°) test results and air permeability properties of the shirting fabrics were evaluated in this section. The results were displayed with charts. Additionally, One way ANOVA was performed in order to evaluate the effect of fabric type on tear strength, seam strength, crease recovery angle and air permeability properties of fabric samples. Table 2 indicates the randomized one-factor ANOVA test results performed for the shirting fabric samples respectively. ANOVA and SNK results were evaluated in detail in each relevant section

Table 2. One-way ANOVA tests for fabric properties

Source	Tear strength in weft wise					Tear strength in warp wise				
	ss	**df**	**ms**	**F**	**Sig.(p)**	**ss**	**df**	**ms**	**F**	**Sig.(p)**
Fabric type	663.82	6	110.63	52.96	0.00*	333.12	6	55.52	11.06	0.00*
	Seam strength in weft wise					**Seam strength in warp wise**				
	ss	**df**	**ms**	**F**	**Sig.(p)**	**ss**	**df**	**ms**	**F**	**Sig.(p)**
	85367.27	6	14227.88	15679.49	0.00*	82577.99	6	13762.99	2438.28	0.00*
	Crease recovery angle in weft wise					**Crease recovery angle in warp wise**				
	ss	**df**	**ms**	**F**	**Sig.(p)**	**ss**	**df**	**ms**	**F**	**Sig.(p)**
	1620.643	6	270.10	1.024	0.449	9758.47	6	1626.41	15.22	0.00*
	Air permeability									
	ss	**df**	**ms**	**F**	**Sig.(p)**					
	7574196.97	6	1262366.16	734.90	0.00*					

*statically significant at 0.05 level (“ss” indicates sum of square ; “ms” mean square)

3.1. Tear Strength Test Results

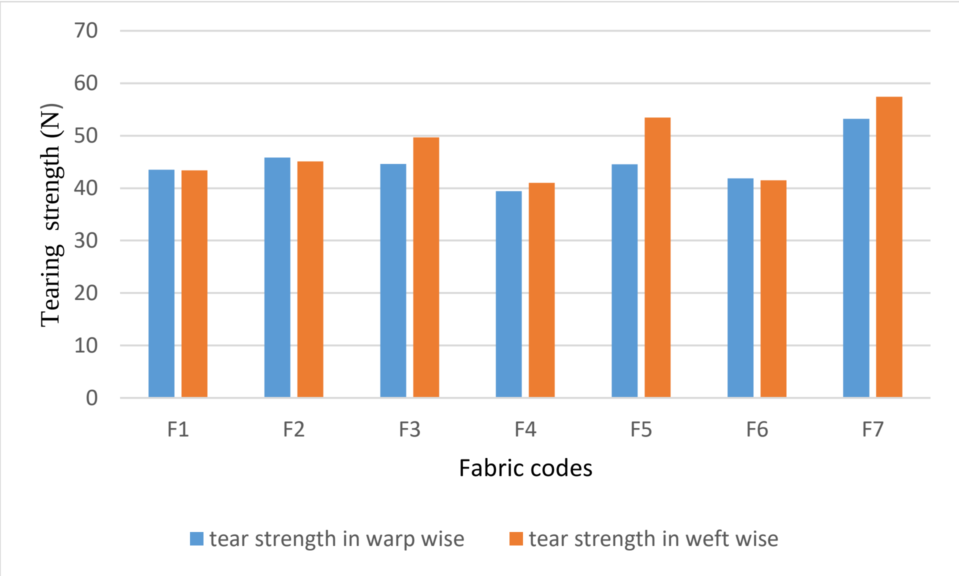


Figure 2:
Tear strength (N)

Figure 2 indicates the tear strength of different woven samples in warp and weft wise. Considering the warp wise, highest tear strength was obtained from F7 coded satin woven fabrics (100% cotton) while lowest value was obtained from F4 coded plain fabrics (100% cotton). Considering the weft wise, maximum tear strength value was obtained from F7 coded fabrics while minimum tear strength value was found among the F4 coded fabrics. There was a general trend for obtaining higher tear strength in weft wise compared to tear strength values in warp wise. This can be attributed to lower fabric density in weft wise compared to warp wise which does not restrict the yarn slippage during tearing process which refers to high tear strength (Hu, 2004). Additionally, in order to observe the significant influence of fabric codes on tear strength of the woven samples in warp and weft wise, One Way ANOVA test was performed. According to ANOVA test (table 2), fabric type was an influential factor on tearing strength in weft wise and on tearing strength in warp wise at significant level of 0.05. SNK results also revealed that different fabric types indicated different tear strength in weft wise also different tear strength in warp wise (table 3).

Table 3. SNK tests for tear strength

Parameter: Fabric type	**Tear strength - weft wise**	**Tear strength - warp wise**
F1	43.41 ab	43.52 ab
F2	45.07 b	45.81 b
F3	49.69 c	44.58 ab
F4	41.00 a	39.41 a
F5	51.81 c	44.75 ab
F6	41.52 a	41.86 ab
F7	57.41 d	53.21c

NOTE: The different letters next to the counts indicate that they are significantly different from each other at a significance level of 5 %

According to SNK results (table 3), F4 coded fabrics made of 100% cotton revealed the lowest tearing strength in weft wise as 41. 00 Newton while F7 coded fabrics made of 100 % cotton indicated the highest tearing strength in weft wise as 57.41 Newton. Tearing strength of the F4 and F6 coded fabrics in weft wise were observed under the same subset at significance level of 0.05. Moreover, tearing strength of F1 coded fabrics in weft wise was not different from tearing strength of F2 coded cotton-linen fabrics in weft wise. When considering tearing strength in warp wise ; Minimum tearing strength was obtained from F4 coded fabrics as 39.41 Newton while maximum value was obtained from F7 coded fabrics as 53.21 Newton . Additionally, F5 and F6 coded fabrics made of cotton-viscose and cotton-elastane respectively revealed the same tearing strength in warp wise at significance level of 0.05. Tearing strength for the woven samples fluctuates between 41 Newton and 57.41 Newton in weft wise while it fluctuates between 39.41 and 53.21 Newton in warp wise. As a general result it may be declared that fabrics with satin weave had more satisfying results in terms of tearing strength compared to plain and dobby woven samples**.**

3.2. Seam Strength Test Results

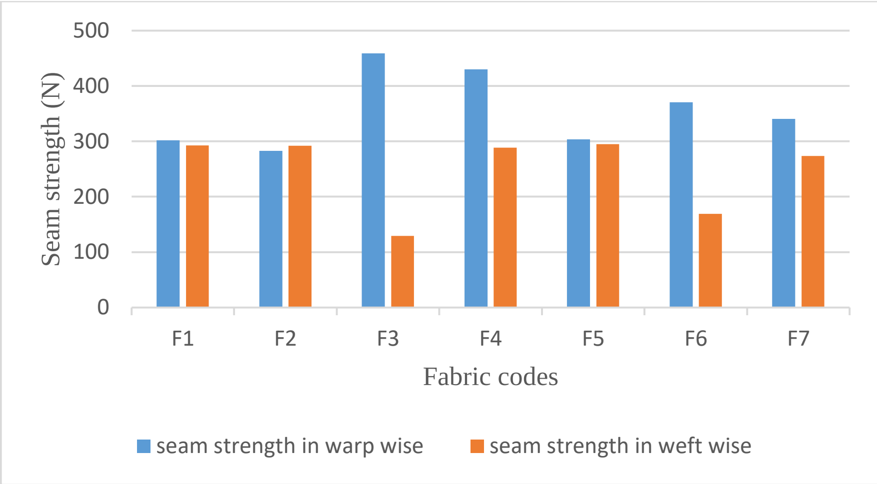


Figure 3:
Seam strength (N)

Seam strength in warp and weft wise is indicated in figure 3. Considering the warp wise; Highest seam strength was obtained from F3 coded fabrics while lowest value was obtained from F2 coded fabrics. Considering the weft wise; Except the F3 and F6 coded fabrics; all samples revealed similar seam strength values between each other. Highest seam strength was obtained from F5 coded fabrics while lowest seam strength value was found among F3 coded fabrics. The seam strength in warp wise revealed higher values compared to seam strength values in weft wise as a general trend among the samples. However, seam strength differences between the warp and weft wise were more prominent among F3 and F6 coded fabrics where elastane yarn was utilized in weft wise. Our result was supported with Namiranian et al.'s study (2014) in which the authors declared that the increase in fabric extensibility with elastane utilization led to decrement of fabrics Young' modulus. Hence there was low fabric contribution (in pure fabric zone) to sewn area against applied loads which resulted with larger amount force imposed to the seam zone.

Additionally, one-way ANOVA test was conducted in order to observe the effect of fabric type on seam strength values in warp and on seam strength values in weft wise. According to table 2, fabric type has statistically significant effect on seam strength property in weft and warp wise ($p = 0.00 < 0.05$). SNK tests were conducted (table 4) in order to compare the means of seam strength values in warp and wise direction. SNK results also revealed that different fabric types indicated different seam strength in weft wise as well as different seam strength in warp wise at significance level of 0.05.

According to SNK results in table 4; Maximum seam strength (N) in warp wise was obtained from F3 coded plain woven shirting fabrics where polyamide-elastane yarns were used as the picks and 100% cotton yarns were used as the ends. Minimum seam strength in warp wise was found among F2 coded fabrics where cotton-linen yarns were used as warp and the weft yarn. Seam strength values of F1 (%100 Linen) and F5 (35% cotton 65% viscose) coded fabrics in warp wise were found under the same subset at significance level of 0.05. Regarding the seam strength in weft wise; Maximum seam strength was obtained from F5 coded cotton-viscose fabrics as 293.92 N while minimum seam strength was found among F3 coded fabrics with elastane -polyamide weft yarns as 129.92 N. Seam strength of F1 coded fabrics and F2 coded fabrics were observed under the same subset at significance level of 0.05. This may give an idea that cellulosic based shirting fabrics indicate similar seam strength values in weft wise without depending on their fibre composition.

Table 4. SNK tests for seam strength

Parameter: Fabric type	Seam strength-weft wise	Seam strength-warp wise
F1	291.28 e	301.55 b
F2	291.68 e	282.48 a
F3	129.92a	459.83 f
F4	287.39 d	426.11 e
F5	293.92 f	301.59 b
F6	169.22 b	371.59 d
F7	273.54 c	339.61 c

NOTE: The different letters next to the counts indicate that they are significantly different from each other at a significance level of 5 %

3.3. Crease Recovery Angle (°) Test Results

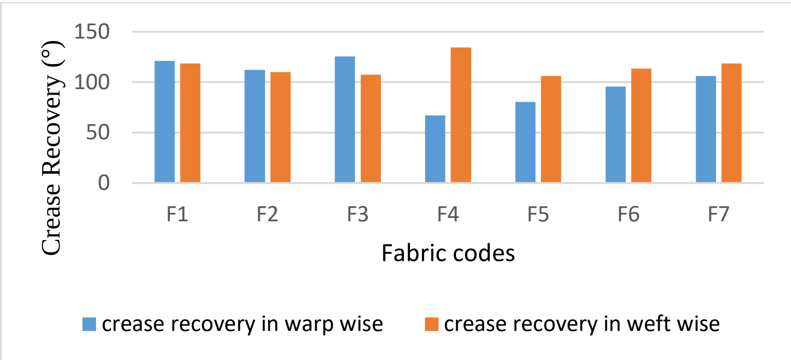


Figure 4:
Crease recovery (°)

Figure 4 indicates the crease recovery value of fabrics in warp and wise. Normally, high crease recovery values are desired for the shirting fabrics. Considering the crease recovery in warp wise, maximum crease recovery angle (°) was obtained from F3 coded fabrics while minimum value was found among F4 coded fabrics. When it comes to crease recovery angle (°) in weft wise; Highest crease recovery was obtained from F4 coded fabric while lowest value was obtained from F5 coded fabrics. Higher crease recovery angle values were obtained in the warp wise compared to weft wise among the F1, F2 and F3 coded values. However, a vice versa situation was observed among F4, F5, F6 and F7 coded samples. Within the plain fabric groups including F1, F2, F3, F4 and F6 coded fabrics; F4 coded fabric made of 100% cotton fabrics indicated the lowest crease recovery (°) in warp wise which results with more wrinkling trend while F3 coded fabric made of elastane Poliamide-cotton revealed the highest crease recovery (°) in warp wise. Moreover, in order to observe the significant effect of fabric type on crease recovery angle in weft and warp wise, One-way ANOVA test was performed (table 2). According to test results; Fabric type was an influential factor on crease recovery in warp wise however it was not a significant factor on crease recovery in weft wise ($p = 0.00 < 0.05$). SNK results also indicated that different fabric types possessed different crease recovery angles (°) in warp wise (table 5).

Table 5. SNK tests for crease recovery- warp wise

Parameter: Fabric type	Crease recovery in warp wise (°)
F1	122.66 de
F2	116.33 cde
F3	128.66 e
F4	64.66 a
F5	80.33b
F6	95.0.c
F7	101.d

NOTE: The different letters next to the counts indicate that they are significantly different from each other at a significance level of 5 %

According to SNK results (table 5), minimum crease recovery in warp wise was obtained from F4 coded plain fabrics made of 100%cotton as 64.66 (°) while maximum crease recovery was obtained from F3 coded elastane cotton-Poliamide plain samples as 128.66 (°). Additionally, crease recovery angle of F5 coded fabrics was not significantly different from crease recovery angle of F4 coded fabrics. Crease recovery of F2 coded fabric was also not different from crease recovery of F1 coded fabrics at significance level of 0.05

3.4. Air Permeability Test Results

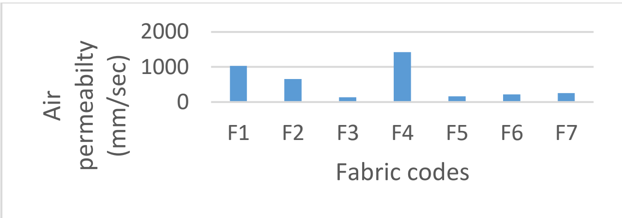


Figure 5:
Air Permeability

Figure 5 reveals the air permeability values of the woven samples. Highest air permeability was observed among the F4 coded 100% cotton samples while lowest air permeability was found among the F3 coded samples. According to figure 5, when the air permeability of F4 and F7 shirting fabrics which have the same fibre composition as 100% cotton; It is observed that those two fabrics prominently reveal different air permeability values. When the construction of F4 coded shirting fabric is evaluated (table 1), It is observed that F4 coded fabric has the lowest fabric weight (g/m^2) among all shirting samples. Moreover, linear densities of their constituent yarns and the fabric weaving pattern are different. F7 coded plain fabrics prominently indicated lower air permeability values compared to F4 coded satin fabrics. This result may require a further investigation about the fabric porosity where fabric weight, warp and weft density as well as the yarns' linear density should be considered together. In a study related to porosity and air permeability of woven fabrics made of core-spun yarns with different linear densities; It was declared that total porosity hence the air permeability of the fabrics increased as the yarns became coarse and the weft density decreased (Sarıoğlu and Babaarslan, 2019). According to ANOVA test (table 2), fabric type was an influential factor on air permeability properties of the woven samples at significance level of 0.05.

Table 6. SNK tests for air permeability

Parameter: **Fabric type**	**Air Permeability**
F1	1032.8 e
F2	661.40 d
F3	138.00 a
F4	1420.00 f
F5	167.20 ab
F6	219.60 bc
F7	254.60 c

NOTE: The different letters next to the counts indicate that they are significantly different from each other at a significance level of 5 %

SNK results (table 6) also revealed that different woven samples possessed different air permeability properties at significance level of 0.05. Among the all samples, F3 coded samples (cotton Elastane Poliamide fabrics) indicated the lowest air permeability as 138.0 mm/sec while F4 coded samples (100% cotton fabrics) revealed the highest air permeability as 1420 mm/sec. Additionally, air permeability of F5 coded fabric was observed under the same subset with air permeability of F3 coded fabrics at significance level of 0.05. F6 coded woven samples did not significantly reveal different air permeability property with F7 coded fabrics at significance level of 0.05.

4. CONCLUSIONS

This study has been focused on the influence of fabric type on tear strength, seam strength, crease recovery and air permeability properties of shirting fabrics. ANOVA tests revealed that fabric types with different construction influenced the tear strength in warp and weft wise, seam strength in warp and weft wise and crease recovery in warp wise at significance level of 0.05. Additionally, fabric type was also an influential factor on air permeability properties of the shirting samples at significance level of 0.05. Regarding to tear strength, F7 coded satin fabrics made of 100% cotton yarns revealed higher tear strength values in warp and weft wise compared to other shirting fabrics. There was a general trend for higher tear strength in weft wise compared to tear strength values in warp wise which was attributed to lower fabric density in weft wise compared to warp wise. The result can be explained with higher freedom of yarn slippage resulting with higher tear strength in weft direction of the fabrics.

The seam strength in warp wise revealed higher values compared to seam strength values in weft wise as a general trend among the samples. Considering the seam strength in weft wise, F3 and F6 coded fabrics where elastane blend was used in the weft yarns revealed lower seam strength value compared to others. This result was attributed to low fabric contribution to sewn area against applied loads. Maximum crease recovery angle in warp wise was obtained from plain F3 coded fabrics where the warp yarns were selected as the 100% cotton yarn and the weft yarns were selected as elastane-Poliamide yarns. On the other hand, minimum crease recovery in warp wise was obtained from F4 coded plain fabrics made of 100% cotton yarns. Crease recovery in weft wise of the shirting samples generally indicated similar values between each other except F4 coded fabrics which revealed slightly higher crease recovery angles (°) compared to other samples. Considering air permeability, F4 coded plain 100% cotton fabrics revealed the highest air permeability while F3 coded cotton elastane Poliamide plain fabrics revealed the lowest air permeability.

As a conclusion although cotton is the most preferred fibre type in shirting fabrics regarding to its high mechanical and well comfort properties; Linen fibre, cellulose fibre blends, synthetic fibres such as Poliamide and elastane may also be utilized as the raw material of weft or warp yarns. Those fibres' contribution to the fabrics are especially observed in seam strength in warp wise and tear strength in warp and weft wise. Further investigations related to comfort properties of shirting fabrics may be also suggested for the future studies.

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