(REFEREED RESEARCH)

COMPARISON OF THE PERFORMANCE AND PHYSICAL PROPERTIES OF PLAIN, PIQUE, DOUBLE-PIQUE AND FLEECED KNITTED FABRICS

DÜZ, PİKE, ÇİFT-PIKE VE İKİ İPLİK ÖRGÜ KUMAŞLARIN FİZİKSEL VE PERFORMANS ÖZELLİKLERİNİN KARŞILAŞTIRILMASI

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ABSTRACT

This paper investigates the performance and physical properties of single weft knitted fabrics. The objective of the study is to find out the impact of the raw material, count of yarn, pattern and elastomeric yarn ratio on the performance and physical properties of the plain, pique, double-pique and fleecy patterned knitted fabrics. Used raw material varies as polyester and cotton. Elastomeric yarn ratio of the samples differ between 5-10 %. To compare the performances, air permeability, bursting strength, pilling, dimensional change and skewness of the sample knitted fabrics are measured. To compare the physical properties, fabric unit weight, thickness, porosity, loop shape factor, wale per cm and course per cm are evaluated. The experimental results have been statistically evaluated with Analysis of Variance (ANOVA) method by using Design Expert 6.06 package programme.Test results show that raw material and yarn count are effective on bursting strength, yarn count is mostly effective on air permeability. Selected parameters have no decisive effect on dimensional change and skewness properties of the samples.

Keywords: Single jersey, fleecy fabric, elastomeric yarn ratio, bursting strength, dimensional change

ÖZET

Bu makalede, süprem örgü kumaşların performans ve fiziksel özellikleri araştırılmıştır. Bu çalışmada amaç, hammadde, iplik numarası, desen ve elastan iplik oranının düz, pike, çift pike ve iki iplik desenine sahip örgü kumaşların fiziksel ve performans özelliklerine etkilerini incelemektir. Hammadde olarak pamuk ve polyester kullanılmıştır. Elastan iplik oranı numuneler arasında % 5-10 arasında değişmektedir. Numune kumaşların performansını karşılaştırmak için hava geçirgenliği, patlama mukavemeti, boncuklanma, boyutsal değişim ve çarpılma testleri uygulanmıştır. Fiziksel özelliklerini karşılaştırmak için gramaj, kalınlık, gözeneklilik, ilmek şekil faktörü, ilmek sıra sayısı ve ilmek çubuk sayısı ölçülmüştür. Deneysel sonuçlar istatistiksel olarak Design Expert Analysis 6.06 paket programı kullanılarak ANOVA analiziyle değerlendirilmiştir. Sonuçlara göre patlama mukavemeti üzerinde iplik numarası ve hammadde etkiliyken, hava geçirgenliği üzerinde iplik numarasının daha etkili olduğu, buna karşın boyutsal değişim ve çarpılma üzerinde seçilen parametrenin belirleyici etkilerinin olmadığı tesbit edilmiştir.

Anahtar Kelimeler: Düz örgü, iki iplik örgü, elastan iplik oranı, patlama mukavemeti, boyutsal değişim.

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INTRODUCTION

In the daily life the using area of knitted fabrics is quite important. They are used not only as garments but also as curtain, table cloths, automotive interior and many other technical areas. Knitted structures offer several advantages. Physically, they present properties of comfort such as high stretch and elasticity, a snugness of fit to body shape, they are soft and pleasing to touch, offer a feeling of freshness and the like. These attributes make knitted fabrics the commonly preferred choice for sportswear, casual wear, and underwear. Knitted fabrics have therefore long been prefferred as fabrics in many kinds of clothing [1]. Elastane yarns, which are incorpareted into knitted fabrics in various proportion, have enabled these properties to be enhanced. Such knitted products exhibit extraordinary stretchability and elasticity, are dimensionally stable in wearing and care, and have become quite popular in the market. There are considerable differences in the behaviour of conventional knitted fabrics and knitted fabrics with elastane yarns incorpareted [2].

It is well known that the physical properties of fabrics depend on their yarn properties and fabric construction parameters. Construction parameters, such as fineness of yarns, density and the type of knitted structure. Due to the manner in which yarns and fabrics are constructed, a large proportion of the total volume occupied by a fabric is usuall airspace [3]. The distribution of this airspace influences a number of important fabric properties. The air permeability and the porosity of a knitted structure will influence its physical properties, such as the bulk density, moisture absorbency, mass transfer and thermal conductivity [4,5].

In the literature, some researches describe the relation between the knitting parameters and mechanical properties of knitwear. Parmar [6] investigated the influence of knit structure, i.e., linear density of yarns, loop length and tightness factor of the knit on garment flammability and permeability to air. Choi et al. [7] reported that the mechanical properties of weft knits for outwear as a function of knit structure and the relationships between hand, structure and density. Fatkic et al. [2] investigated the influence of selected knitting parameters and the relaxation period on the structure and mechanical properties of plain jersey weft knitted fabrics made of cotton and elastane yarns. Bivainyte and Mikucioniene [8] reported that the influence of knitting structure parameters and raw materials on the air and water vapour permeability of double layered weft knitted fabrics. Kane, Patil and Sudhakar, [9] focused on the effect of single jersey, single pique, double pique and honey comb structures and structural cell stitch length on ring and compact yarn single jersey fabric properties.

Some authors have conducted research into the relation between the rate of elastane and selected fabric properties, such as extensibility and relaxation. Cuden, Hladnik and Sluga [10] reported that the impact of material, knitted structure and relaxation process parameters on loop length. The objective was to examine the differences in loop length of single weft knitted fabrics, produced from different types of elasticized and non elasticized yarns. Marmaralı [11] investigated the air permeability of cotton/spandex single jersey fabrics within their dimensional and physical properties and compared results with fabrics knitted from cotton alone.

There are some reports in the literature about properties of knitted structures, but as far as it could be reached it is not possible to find the comparisons of plain, pique, double pique and fleeced patterned fabrics which are different each other according to yarn count, raw material and elastomeric yarn ratio. Therefore, the goal of our research is to find out the impact of the raw material, count of yarn, pattern and elastomeric yarn ratio on the performance (air permeability, bursting strength, pilling, dimensional stability and skewness) and physical properties (fabric unit weight, thickness, porosity, loop shape factor, wale per cm and course per cm) of the sample knitted fabrics (plain, pique, double pique and fleeced patterned fabrics).

Experimental

In this study ten different knitted samples were manufactured by the same 32” 28 fein Monarch circular knitting machine. The characteristics of the samples and needle diagrams of them are presented in Table 1.

As seen from the table the samples are coded according to the used raw material, pattern type and elastomeric yarn ratio. The ratio of elastomeric yarn is adjusted according to the sample weight and 40 denier elastomeric yarn is used in all types of fabrics. The strength and unevenness of the yarns inside the samples were tested by USTER Tester and the test results are illustrated in Table 2.

Manufactured sample knitted fabrics were exposured to fixation to equalize the dimensions. For dry relaxation sample knitted fabrics were conditioned at standard labarotory conditions (20 ± 2°C, 65 ± 2% relative humidity (RH)) for 24 h according to ASTM D1776-08e1[12]. The structural properties (unit weight, thickness, wpc, cpc) of sample knitted fabrics were measured according to the international standards (unit weight, thickness, wpc-cpc) and porosity was calculated in accordance with the following equation [13].

$$P = \left(1 - \frac{m}{ph}\right) 100$$

Where P is the porosity, m is the fabric weight, p is fiber density in g/cm^3 and h is fabric thickness in mm.

Bursting strength of samples were tested according to BS EN ISO 13938-2 by using Truburst tester with diaphragm correction [14]. Air permeability was measured according to ISO 9237 by using SDL Atlas M021A tester at a test pressure drop of 100 Pa (20 cm^2 test area) [15]. Dimensional stability of the sample knitted fabrics were tested according to EN ISO 6330 and EN ISO 5077, standard by home type washing machine [16,17]. During laundering the temperature was 30 ºC, the detergent was ECE non-phosphate (66 gr) and the duration was 50 minutes. Pilling resistance of the sample knitted fabrics were tested in accordance with ISO 12945-2:2014 Textiles-Determination of the fabric propensity to surface pilling, fuzzing or matting – Part 2: Modified Martindale method standard and the fabrics were evaluated by standard photographic scales with three operators.

Table 1. Specific properties and abreviations of the sample knitted fabrics

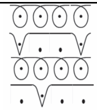
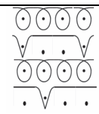
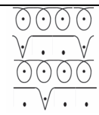
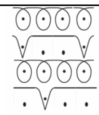
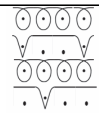
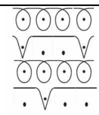
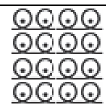
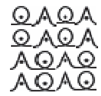
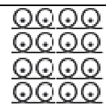
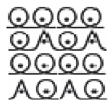
Fabric Code	Raw material of face yarn	Raw material of fleecy yarn	Elastomer yarn ratio	Pattern type	Pattern needle diagram
30FC5	Ne 30/1 Cotton (Compact ring)	Ne 30/1 Cotton (Rotor)	5 %	Fleecy	
30FC7	Ne 30/1 Cotton (Compact ring)	Ne 30/1 Cotton (Rotor)	7 %	Fleecy	
30FP5	Ne 30/1 Cotton (Compact ring)	150 Denier PES	5 %	Fleecy	
30FP7	Ne 30/1 Cotton (Compact ring)	150 Denier PES	7 %	Fleecy	
30FC10	Ne 30/1 Cotton (Compact ring)	Ne 30/1 Cotton (Rotor)	10 %	Fleecy	
20FP5	Ne 20/1 Cotton (Compact ring)	150 Denier PES	5 %	Fleecy	
50SC10	Ne 50/1 Cotton (Compact ring)	No fleecy	10 %	Single jersey	
30LC5	Ne 50/1 Cotton (Compact ring)	No fleecy	5 %	Double pique	
30SC7	Ne 30/1 Cotton (Compact ring)	No fleecy	7 %	Single jersey	
50PC10	Ne 30/1 Cotton (Compact ring)	No fleecy	10 %	Pique	

Table 2. Yarn properties

Yarn Type	CVm (%)	Breaking strength (cN)	Elongation (%)
Ne 20/1 Compact	12,13	457	5,79
Ne 30/1 Compact	12,00	359,5	5,86
Ne 50/1 Compact	11,35	294	5,92
Ne 30/1 Rotor	17,1	198,4	3,47
150 Denier PES	-------	656,4	20,16

Results and Discussion

Structural properties of the samples

The type of raw material, pattern, used yarn count and elastomeric yarn ratio influence the structural properties of knitted fabrics and also they influence the performance properties of the sample knitted fabrics. At first the structural measurements are performed and given in Table 3.

As illustrated in Table 3 the thickness, the weight and the density of fleecy fabrics are higher than the other patterned fabrics. Among these fabrics the samples produced by Ne 50/1 are lighter and thinner than those of Ne 30/1 because of the yarn count.

Statistical Analyses

Statistical analyses of the study were done by Design Expert 6.06 statistical package programme. Initially full factorial design was performed and design model is selected as linear. The experimental results have been statistically evaluated by using Analysis of Variance (ANOVA) with F values of the significance level of _=0.05, with the intention of exploring whether there is any statistically significant difference between the variations obtained. We evaluated the results based on the F ratio and the probability of the F-ratio (prob>F). The lower the probability of the F-ratio, it is the stronger the contribution of the variation and the more significant the variable. Table 4 summarizes the statistical significance analysis for all the data obtained in the study. In this ANOVA analyses, dependent factors are face yarn count, fleecy yarn raw material and elastomeric yarn ratio.

Table 3. Structural properties of sample knitted fabrics

Fabric Type	Cpc	Wpc	Thickness (mm)	Weight (gr/m²)	Fabric density (kg/m³)	Porosity (%)	Loop shape factor	Stitch density (loop/cm^2)
30FC5	20,0	16,0	0,69	207,00	300,00	80,65	1,25	320
30FC7	19,5	13,0	0,93	256,00	274,70	82,28	1,5	254
30FP5	26,0	15,0	0,66	238,00	359,50	76,81	1,73	390
30FP7	23,5	13,0	0,96	301,00	312,90	79,81	1,81	306
30FC10	26,0	15,0	1,01	330,00	325,40	79,00	1,73	390
20FP5	21,5	13,0	0,71	252,00	356,90	76,97	1,65	280
50SC10	23,5	16,0	0,53	128,00	239,70	84,54	1,47	376
50PC10	22,5	14,0	0,73	155,00	212,90	86,26	1,60	315
30SC7	20,0	14,0	0,59	170,00	288,10	81,41	1,43	280
30LC5	22,0	14,0	0,79	226,00	287,50	81,45	1,57	308

Table 4. Statistical analysis of test results

Fabric properties		Air Permeability (mm/s)	Bursting Strength (kpa)	Porosity (%)	Widthwise change (%)	Lengthwise change (%)	Skewness (%)
Yarn count	**F-value**	18,69	146,47	40,89	1,59	0,48	2,59
	P-value	0,0202	0,0010	0,0067	0,2547	0,5147	0,1534
	% Contribution	86,5	49,96	72,85	2,98	18,92	70,83
Fleecy yarn raw material	**F-value**	1,40	184,12	19,96	2,35	0,55	0,16
	P-value	0,3224	0,0009	0,0209	0,1763	0,4855	0,7046
	% Contribution	3,23	31,40	17,79	31,17	3,68	1,43
Elastomeric yarn ratio	**F-value**	0,51	39,85	2,64	0,28	5,09	2,03
	P-value	0,6437	0,0069	0,2183	0,6171	0,0650	0,9659
	% Contribution	2,37	13,59	4,70	3,40	28,79	1,73
	R^2	0,9210	0,9495	0,9534	0,3058	0,4816	0,5791
Model Significance		Significant	Significant	Significant	Not significant	Not significant	Not significant

The aim of this statistical analsis was to see the ratio of variable factors on the responses. Therefore the contributions were analysed and all the factors were selected as categorical. The initial design was full factorial and the design model was selected as 2FI automatically. The air permeability model F-value is found as 9.32 and it implies that the model is significant. There is only a 2.52% chance that a "Model F-Value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case only yarn count is significant model term on air permeability value. The bursting strength model F-value is found as 15.03 and it implies that the model is significant. There is only a 1.06% chance that a "Model F-Value" this large could occur due to noise.Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case fleecy raw material is significant model term on bursting strength value. According to the table the porosity model F-value is found as 16.36 and it implies that the model is significant. There is only a 0.91% chance that a "Model F-Value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant.

In this case is fleecy raw material significant model term on porosity value.

Air Permeability

Air permeability, being a biophysical feature of textiles, determines the ability of air to flow through the fabric. Airflow through textiles is mainly affected by the pore characteristics of the fabrics. The pore dimension and the distribution in a fabric is a function of fabric geometry [8]. During the study air permeability of all samples were measured from different ten points and the average of all tests are shown in Figure 1 as a graph.

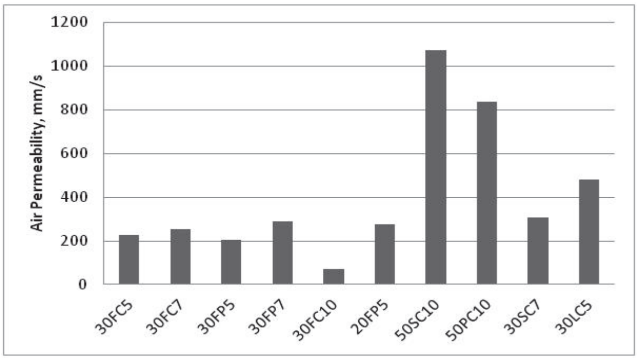


Figure 1. Air permeability test results of sample knitted fabrics

It is exhibited from the figure that generally fleecy fabric samples are not as permeable as single jersey, pique and double-pique samples because in these samples two yarns are inside the fabric and dependently the thickness of these fabrics are more. To determine the effect of yarn count/raw material on air permeability of the fabrics; only the samples which have similar characteristics are compared. The samples in the first group 30FC5, 30FC7 and 30FC10 and the other group 30FP5 and 30FP7 are manufactured by the same raw material, yarn count and pattern. However, the elastomeric yarn ratio of them is different. When the air permeability of these samples are tested, it is concluded that there is no relation between elastomeric yarn ratio and air permeability. Similarly, the difference between 30FC5 and 30FP5 is only the raw material. According to air permeability test results there is a negligible difference between these fabrics. The effect of yarn count on air permeability is evaluated by comparison of the samples 20FP5 and 30FP5. In accordance with test results the air permeability of 20FP5 is higher contrary to expectations because the stitch density of this sample is more. The results show that fabric thickness has a significant effect on the air permeability values of the plain, pique, double-pique and fleeced knitted fabrics, since air permeability tended to increase as the thickness decreased. The lower thickness and mass per square meter also facilitated the passage of air through the fabric.

The statistical analysis indicate that the yarn count has a significant influence with 86,5 % contribution on the air permeability values of sample knitted fabrics. The contributions of elastomeric yarn ratio and fleecy yarn raw material on the air permeability values of sample knitted fabrics are under 5 %.

Bursting Strength

The bursting strength of knitted fabric is extremely important in many ways. The fabric should have sufficient strength against forces acting upon it during dying, finishing and use. Bursting strength is a suitable method that measures strength in which the material is stressed in all directions. Bursting strength tests were carried out from different ten points of the fabrics by suitable inflated rate. Average of diaphragm corrected test results are presented as a graph in Figure 2.

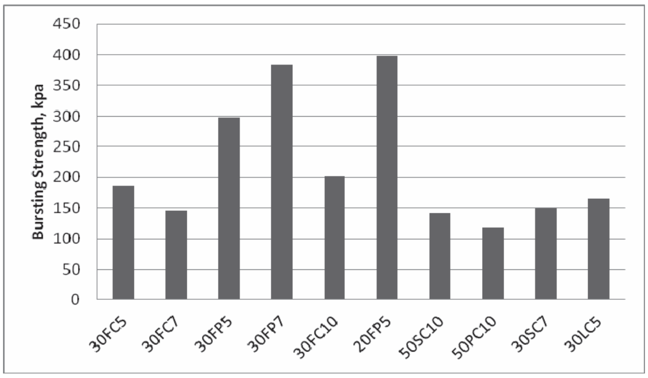


Figure 2. Bursting strength test results of sample knitted fabrics

Bursting strength properties of knitted fabrics are related with the raw material, pattern type, elastomeric yarn ratio and applied treatments. The effect of elastomeric yarn ratio on bursting strength value of samples are evaluated according to the test results of the sample group 30FC5, 30FC7 and 30FC10 or the sample group 30FP5 and 30FP7 . Results indicate that an increase in elastomeric yarn ratio causes an increase in bursting strength . However the effect of fabric density on bursting strength is more decisive than elastomeric yarn ratio. Bursting strength test results of 30FP5 and 20FP5 are realized the phenomenon that coarser and strength yarns make the fabric stronger. The samples 30FC5 and 30FP5 the are different from each other in accordance with the raw material. Results show that sample knitted fabrics with polyester yarns have higher bursting strength value. This result is related with the high breaking strength value of polyester. When the samples 50SC10 and 50PC10 are compared, the effects of pattern and stitch density on bursting strength value of sample knitted fabrics are observed. The lack of tuck stitch and the high tightness increase the resistance of fabrics to burst.

On the bursting strength of the sample knitted fabrics; yarn count has significant influence with 49,96 % contribution and fleecy yarn raw material has significant influence with 31,40 % contribution respectively. According to Table 4 on bursting strength property of sample knitted fabrics, elastomeric yarn ratio has significant influence with the contribution value of 13,59 %.

Dimensional Change

Sample knitted fabrics subjected to typical home laundering procedures to measure the dimensional change. The general procedures for preparing and marking out of samples is laid down in the ISO standards. The specimens to be tested for dimensional stability were prepared as recommended in the EN ISO 6330 and EN ISO 5077 [16,17] After measurement the samples are subjected to the required treatment and the procedure for conditioning and measurements repeated to obtain the final dimensions. The dimensional change both widthwise and lengthwise are evaluated as grow (+) or shrinkage (-). The results are illustrated as a graph in Figure 3.

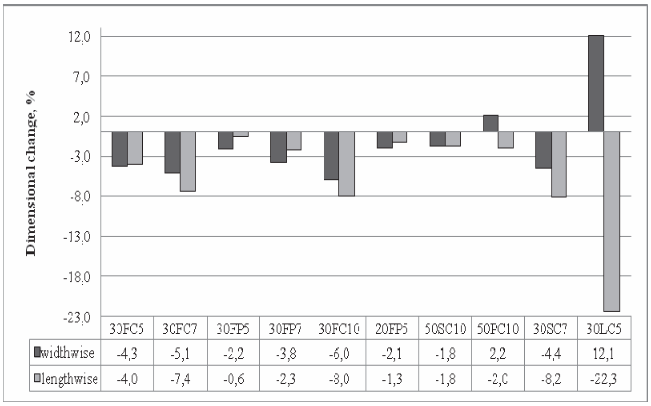


Figure 3. Dimensional change test results of sample knitted fabrics

According to the international standards dimensional change percented which are under 5 is acceptable [18]. Therefore, the samples 30FC5, 30FP5, 30FP7, 20FP5, 50SC10 and 50PL10 are quite resistant to laundering. The samples which include polyester yarns can withstand to laundering more because polyester does not like water in case water can not penetrate into the polyester yarns so the structure of polyester included fabric is not affected by water [19] In the samples 50SC10 and 50PC10 the elastomeric yarn ratio is 10% and the dimensional change of them are also quite low. The reason of it is high ratio of elastomeric yarn. The dimensional change of 30LC5 is not in the acceptable level. When the pattern of the sample is observed it is seen that there are many tuck stitches and tuck stitch causes the shrinkage of the loops inside fabrics.

Skewness Change

Skewness change test of the sample knitted fabrics were performed according to AATCC Test Method 179-2010 Skewness Change in Fabric and Garment Twist Resulting from Automatic Home Laundering. The skewness change of the samples are shown in Figure 4 as a graph.

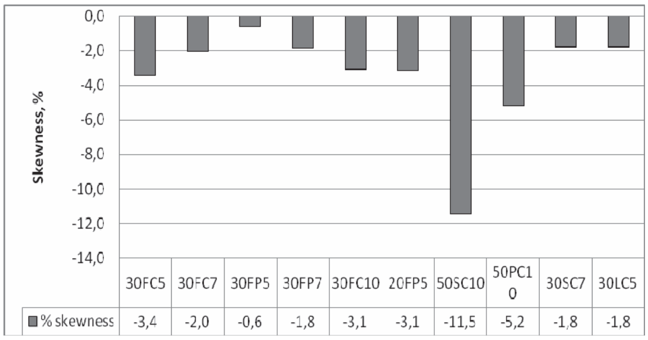


Figure 4. Skewness change test results of sample knitted fabrics

According to the international standards skewness change which are under 5 % is acceptable. Therefore except the samples 50SC10 and 50PC10 all the samples exhibit resistance to skewness. When the unit weight of 50SC10 and 50PC10 are examined, it is seen that unit weight of these samples are quite lower than the others (128 and 155 g/m^2). Hence, it is concluded that unit weight is an effective parameter on the skewness more than other properties. Owing to the fact that the unit weight of 50SC10 is the lowest, the skewness of it is the highest.

On the skewness property of the sample knitted fabrics yarn count has significant effect with the contribution value of 71 % because yarn count affects the unit weight of the fabric and with the increase in fabric weight, skewness of the fabric decreases.

Pilling Resistance

Fabric pilling is a serious problem for the apparel industry. Pilling resistance levels of the sample knitted fabrics obtained after different cycles of Martindale test device as a result of pilling resistance test are seen in Table 5. To assess the pilling resistance, the samples were tested by a Martindale Abrasion Test device. Appearance of the fabric samples after 125, 500, 1000, 2000, 5000 and 7000 cycles of testing device were assessed according to ASTM pill grade photographic views in a viewing cabinet. Photographic standards use the following scale; 1-very severe pilling, 2-severe pilling, 3-moderate pilling, 4-slight pilling and 5-no pilling.

Table 5. Pilling resistance results of samples

Cycle	Samples									
	30FC5	30FC7	30FP5	30FP7	30FC10	20FP5	50SC10	50PC10	30SC7	30LC5
125	5	5	5	5	5	5	5	5	5	5
500	5	5	5	5	5	5	5	5	5	5
1000	5	5	5	5	5	5	5	5	5	5
2000	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5
5000	4-5	4-5	4-5	4-5	4-5	4-5	4	4	4	4
7000	4-5	4-5	4-5	4-5	4-5	4-5	3-4	4	3-4	4

It is seen from the Table 5 that while plain, pique and double-pique knitted fabrics have high resistance to pilling, the resistance of fleecy fabrics are more than the other samples. They exhibited slight pilling between 125 and 7000 cycles consistently. It is emphasized from the results that fleecy knitted fabrics should be preferred for lower pilling rates. According to test results fabric pattern is quite important parameter on the pilling resistance of the knitted fabrics.

Conclusions

In this study, the dimensional, some physical and performance properties of the plain, pique, double-pique and fleeced knitted fabrics made from cotton and polyester fibers are investigated in comparison with each other. Dimensional properties are investigated by using the dimensional parameters such as wales/cm, courses/cm, stitches/cm^2, courses/wales and stitch length. As a result of the statistical and experimental study, the following conclusions can be drawn.

To determine the effect of yarn count/raw material on the air permeability of the fabrics; only the samples which have similar characteristics are compared. The results show that fabric thickness and stitch density have significant effects on the air permeability values of the plain, pique, double-pique and fleeced knitted fabrics, since air permeability tended to increase as the thickness decreased. The lower thickness and mass per square metre also facilitated the passage of air through the fabric. Among sample knitted fabrics fleeced samples have lower air permeability values because of their double layered knit structure. Air permeability of double picque patterned fabric is also low because the two consequtive tuck stitches make the structure compact. The statistical results of air permeability support the experimental results of the study. Bursting strength properties of knitted fabrics are related with the raw material, pattern type, elastomer ratio and yarn count. In fleecy patterned fabrics in the same course there are more than one yarn so the strength of these patterns are quite high among the samples. The samples produced by polyester have also higher bursting strength values because the strength of polyester yarns are higher than that of cotton yarns. Yarn count fleecy yarn raw material and elastan yarn ratio are important factors statistically. The samples which include polyester yarns can withstand to laundering more because polyester does not like water in case can penetrate into the polyester yarns so the structure of polyester included fabric is not affected by water. Fleecy patterned knited fabrics have high resistance to pilling.The statistical test results showed that only yarn count is effective parameter on air permeability while all factors have statistically significant effects on bursting strength. Porosity properties of the samples were affected by yarn raw material and count statistically. However, any factor has no statistically significant effect on widthwise change, lengthwise change and skewness properties of the knitted samples. The double layered structure of fleeced fabrics are considerably stabile so their skewness and dimensional change values are in acceptable level. The tuck stiches inside the picque and double picque patterned fabrics make the structure dense so they have low skewness values.

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