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Pilling Performance and Abrasion Characteristics of Plain-Weave Fabrics Made from Open – End and Ring Spun Yarns

Abstract
In this experimental study, plain fabrics made from100% cotton ring carded, ring combed and OE rotor spun yarns were produced. The weft yarn count, warp yarn count and fabric sett of the fabrics were constant. The pilling and abrasion resistance of the fabrics were investigated. After that the relationships between yarn characteristics and abrasion resistance and pilling were investigated. Finally the relationships between abrasion resistance and pilling were investigated for every group of fabrics. The results show that the arithmetic means of abrasion resistance and pilling performance have a maximum value in fabrics made from OE rotor spun yarns. The arithmetic means of abrasion resistance and pilling performance have a minimum value in fabrics made from ring carded spun yarns. Whereas standard deviations in fabric made from OE rotor spun yarns have a maximum value, standard deviations in fabric made from ring combed spun yarns have a minimum value for both fabric characteristics. The important relationships between yarn hairiness and abrasion resistance and pilling were obtained in all the fabrics. Additionally, the important relationships between abrasion resistance and pilling were obtained for all the fabrics. All correlation coefficients were found as negative. The correlation coefficient of fabrics made from ring combed spun yarns has a maximum value. The correlation coefficient of fabrics made from OE rotor spun yarns has a minimum value without taking into account the fact that it is negative or positive.

Key words: *pilling, abrasion resistance, woven fabric, yarn hairiness, plain weave, ring-spun yarn, OE yarn.*

Introduction

The range of usage of woven fabrics is quite varied. In general any woven fabric has a smooth surface, thickness, tensile strength and flexibility [1]. Mechanical characteristics are very important within fabric characteristics. The mechanical characteristics of fabrics generally affect fibre, yarn and fabric characteristics and the finishing process [2].

The resistance of fabric to friction force is known as abrasion resistance. Pilling is a fabric defect which is observed as small fibre balls or group consisting of intervened fibers that have been attached to the fabric surface by one or more fibres [3]. The pills are formed during wear and washing, which means that fabrics are affected by friction forces during usage. Friction forces results in the abrasion and pilling of fabric. Consequently there are some relationships between abrasion resistance and pilling.

Many textile scientists have studied the factors that generally affect pilling and abrasion resistance [4 - 8].

Mansour and Lord studied the abrasion resistance of plain fabrics made from Co/PES ring and OE rotor spun yarns and found that an increase in abrasion resistance, generally increases the weft sett and weft twist for both groups of fabrics [9]. Adanur et al. investigated the abrasion resistance of 3/1 cotton twill fabrics made with different warp and weft tension. They concluded that an increase in fabric abrasion resistance generally increases weft tension [10]. Candan et al. studied the abrasion resistance of knitted fabrics from OE and ring spun yarns and found that knitted fabric from ring spun yarns is slightly better than that from OE spun yarns [11].

Özdil et al. compared knitted fabrics from compact spun yarns and classic ring spun yarns and reported that knitted fabric from compact yarns demonstrated a better pilling performance [12]. Candan and Önal evaluated that the pilling performance of weft knitted fabric made from open-end and ring spun yarns. They reported that 100% cotton samples knitted from ring spun yarns tend to have lower pilling rates than those constructed from 100% cotton open-end spun yarns [13]. In addition, this study in another work by Nergis and Candan involved the pilling performance and abrasion resistance of plain knitted fabric from chenille yarns. The results showed that yarn properties (component yarn count, pile length) and laundering or dry-cleaning does not influence the pilling performance, and the abrasion resistance of dry relaxed fabrics tends to decrease in component yarns [14].

The study by Usta and Canoğlu involved the pilling performance of knitted fabrics from acrylic spun yarns. The results indicated that traveller type and weight affect the yarn hairiness and fabric pilling performance [15].

In another work, Chen and Huang evaluated fabric pilling with light-projected image analysis. They found that the method could eliminate interference with pilling information from the fabric color and pattern [16]. Göktepe observed that different pilling testers may give different pilling results for the same fabric, and it has different sensitivities for various yarn fibre and fabric parameters [17].

Material and method

The material of this study consisted of 100% cotton 30 plain weave fabric. All the fabrics were produced using the same weaving machine. These fabrics were made from ring carded, ring combed and OE rotor spun yarns with α_e of 4.20 for the warp yarn and 3.80 for the weft yarn. The count, tenacity, evenness and hairiness of the yarns were measured. ASTM D 861-99, ASTM D 1578-93, ASTM D 1425-96 and ASTM D 5647 were used, respectively. The data of the warp and weft yarns are given in Table 1.

The fabric sett, fabric weight, abrasion resistance and pilling of the fabrics,

presented in Table 2, were measured according to the relevant standards: ASTM D 3775-3a, ASTM D 3776-96, ASTM D 4966 and ASTM D 4970, respectively. The abrasion resistance was measured as a cycle quantity, up to the break off of the warp and weft yarns. The pilling was measured as a pill number a certain area after 2000 cycles. There is a possibility of pouring pills according to fibre and yarn structure after 5000 and 7000 cycles; in addition the pill formations may not be observed clearly after 125, 500 and 1000 cycles. For this reason a 2000 cycles was chosen for the pilling test. The average warp sett of the fabrics was 24 ends/cm, the average weft sett of the fabrics was 23 ends/cm, and the average fabric weight was 157 g/m^2. Only enzyme desizing was applied to the fabrics.

The arithmetic means and standard deviations of the abrasion resistance and pilling were calculated for every group of fabric. After that, Pearson's linear correlation coefficients between the yarn characteristics, abrasion resistances and pilling were calculated. Finally, a scatter diagram was drawn and Pearson's linear correlation coefficients were calculated to determine relationships between the abrasion resistances and pilling in every fabric group. The data were evaluated in SPSS software.

Results and discussion

The arithmetic means and the standard deviations of the fabric's characteristics value are given in Table 3 to compare the abrasion resistance and pilling of the fabrics tested.

A higher number for the abrasion resistance means a higher abrasion resistance, but a lower number for pilling means a higher pilling performance. Because of this, we can observe from the results that the abrasion resistance and pilling performance of the OE group of fabrics has a maximum value, on the other hand the abrasion resistance and pilling performance of the RK group of fabrics has a minimum value. It is considered that the differences between abrasion resistance and pilling may be caused by yarn differences in yarn characteristics. This is due to the fact that all the parameters that affect abrasion resistance and pilling are constant, except yarn characteristics. In this situation the yarn char-

Table 1. *Characteristics of the warp and weft yarn; [a)] RK, RP and OE group yarns ring carded yarn, ring combed yarn and OE rotor yarn respectively.*

Yarn number	Yarn codes [a]	Count, tex		Tensile tenacity, cN/tex		Evenness, %CV		Hairiness (H)	
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft
1	RK Groups	29.50	29.64	17.55	16.23	12.34	12.56	6.12	5.67
2		29.30	29.55	17.43	16.10	12.11	12.49	6.03	5.99
3		29.05	29.37	17.02	16.51	12.49	12.60	6.71	6.02
4		29.59	29.43	17.48	15.96	13.01	12.88	6.04	5.55
5		29.71	29.50	17.50	16.05	12.69	12.35	6.09	5.85
6		29.20	29.27	18.12	15.99	12.10	12.43	6.27	5.91
7		29.42	29.62	17.66	16.43	12.98	12.91	6.06	5.69
8		29.36	29.68	17.80	16.28	12.45	12.87	6.04	5.68
9		29.00	29.58	17.43	16.36	12.59	12.61	6.17	6.02
10		29.17	29.52	17.69	16.25	12.68	13.05	6.45	6.00
11	RP Groups	29.36	29.46	18.71	16.94	10.28	10.82	5.09	5.23
12		29.52	29.20	18.95	16.87	10.59	10.74	5.28	5.20
13		29.26	29.36	18.53	16.50	10.88	10.56	5.11	5.28
14		29.46	29.70	18.49	16.89	10.82	10.50	5.09	5.27
15		29.64	29.61	18.66	17.11	10.11	10.89	5.35	5.60
16		29.62	29.65	18.12	16.99	10.69	10.43	5.85	5.68
17		29.53	29.23	18.88	17.04	10.10	10.21	5.21	5.39
18		29.21	29.37	18.81	17.26	10.02	10.65	5.08	5.24
19		29.67	29.49	18.93	17.13	10.39	10.77	5.40	5.38
20		29.68	29.53	19.02	17.00	10.45	10.19	5.49	5.49
21	OE Groups	29.59	29.47	13.66	11.24	14.52	14.73	4.06	4.30
22		29.42	29.08	14.12	11.39	14.19	14.80	4.88	4.49
23		29.24	29.59	13.96	12.21	14.38	14.49	4.65	4.58
24		29.23	29.76	13.92	11.92	14.80	14.12	4.81	4.61
25		29.47	29.33	13.45	11.75	14.91	14.28	4.29	4.43
26		29.56	29.26	13.97	11.64	14.77	14.38	4.95	4.52
27		29.61	29.05	14.02	11.37	14.53	14.91	4.61	4.45
28		29.65	29.52	13.77	11.67	14.46	14.55	4.89	4.78
29		29.44	29.43	13.79	11.90	14.90	14.43	4.63	4.41
30		29.28	29.44	13.59	11.63	14.85	14.81	4.82	4.74

Table 2. *Characteristics of the fabric; [a)] RK, RP and OE groups of fabrics are made from ring carded yarn, ring combed yarn and OE rotor yarn, respectively.*

Fabric number	Fabric codes [a]	Number of threads per cm		Weight, g/m^2	Abrasion resistance, cycle	Pilling, pils/area
		Warp	Weft			
1	RK Groups	24.05	22.94	158.25	16360	85
2		23.96	22.95	157.16	16300	92
3		24.09	23.04	156.95	16220	100
4		23.90	23.00	158.03	16420	81
5		24.01	23.02	155.37	16240	83
6		24.00	22.94	156.12	16320	102
7		24.12	23.02	158.00	16460	74
8		23.91	22.97	157.13	16400	78
9		23.95	22.90	155.43	16340	99
10		23.99	23.04	159.11	16280	112
11	RP Groups	24.08	22.94	155.64	17220	74
12		24.03	23.94	156.63	17160	75
13		23.88	22.98	155.99	17240	77
14		24.09	23.00	156.32	17240	63
15		23.97	23.07	156.77	17100	95
16		23.99	22.97	155.61	17040	93
17		24.03	22.95	156.82	17250	66
18		24.00	23.04	158.74	17260	79
19		24.08	23.00	157.90	17210	80
20		23.91	23.01	156.83	17140	78
21	OE Groups	23.98	22.94	157.12	18190	60
22		23.94	22.99	156.66	18100	77
23		23.99	23.07	155.21	18120	80
24		24.07	23.01	156.84	18050	67
25		24.00	23.08	154.97	18160	65
26		24.11	22.98	156.23	18040	76
27		23.93	22.95	157.64	18100	66
28		23.95	22.99	155.93	18100	71
29		23.96	23.00	157.08	18200	59
30		23.91	22.97	156.99	18060	81

acteristics in Table 1 must be checked to see if they change between groups or not. For this purpose the difference between the count, tenacity, evenness and hairiness of RK, RP and OE yarn groups were determined using analysis of variance (ANOVA) F tests (significance level $\alpha = 0.05$). The characteristics of the warp and weft yarn in Table 1 were in the analysis of variance. The critical value is $F_{2,27,0,05} = 3,35$. The F test confirmed that there were no significant differences in the yarn count between RK, RP and OE yarn groups. However, there were significant differences in the yarn tenacity, the yarn evenness and the yarn hairiness between the groups. Thus, the Pearson's linear correlation coefficients, which were among the variables, were determined to detect statistical relationships between the yarn characteristics and the fabric characteristics. The correlation coefficients are given Tables 4, 5 and 6. All correlation coefficients were calculated between weft-warp yarn characteristics in Table 1 and fabric characteristics in Table 2.

The significance of all the correlation coefficients was checked by a t-student test. The critical value $t_{critical}$ was determined for the significance level $\alpha = 0.05$ with the number of degrees of freedom k = 8. The critical value t_{cr} is found as 2.306 [18]. As a result the correlation coefficients between yarn hairiness abrasion resistance and pilling are important by 0.05 statistical importance level. However, correlation coefficients between other yarn properties except yarn hairiness, abrasion resistance and pilling are not important. Therefore, it is considered that the differences between the abrasion resistance and pilling of RK, RP and OE fabric groups are the result of differences in yarn hairiness. As a consequence, it is indicated that an increase in yarn hairiness decreases abrasion resistance and pilling performance.

By examining Table 3, it is observed that standard deviations belonging to fabric characteristics of the OE group of fabrics has a minimum value and the standard deviations of the RK group of fabrics has maximum value. The relationships between yarn hairiness, abrasion resistance and pilling are therefore statistically important. It is observed that this situation is caused by yarn hairiness deviations of RK, RP and OE yarn groups. For this purpose the arithmetic mean and the standard deviation of yarn hairiness in Table 1 are given in Table 7.

Warp and weft yarn in the OE group of yarns, the arithmetic mean and the standard deviation of yarn hairiness has a minimum value.

The relationships between abrasion resistance and pilling

A scatter diagram was drawn for every fabric group to determine relationships between abrasion resistance and pilling. It is observed that the relationship between abrasion resistance and pilling is linear for all the fabric groups when Figure 1 (see page 84) is checked. Pearson's linear correlation coefficients were calculated to detect statistical relationships between abrasion resistance and pilling. The Pearson's linear correlation coefficients are given in Table 8 (see page 84).

The significance of all the correlation coefficients was checked by a t-Student's test. The critical value $t_{critical}$ was deter-

Table 3. *The arithmetic mean and standard deviation of the abrasion resistance and pilling.*

Fabric properties	Arithmetic mean for groups			Standard deviation for groups		
	RK	RP	OE	RK	RP	OE
Abrasion resistance, cycle	16334	17186	18112	77.7746	73.5149	56.1348
Pilling, pils/area	90.60	78.00	70.20	12.3126	10.0775	8.0111

Table 4. *The correlation coefficients between the yarn tenacity, abrasion resistance and pilling.*

Group of parameters		RK Groups		RP Groups		OE Groups	
		Warp Tenacity	Weft Tenacity	Warp Tenacity	Weft Tenacity	Warp Tenacity	Weft Tenacity
RK Groups	Abrasion resistance	0,387	-0,094				
	Pilling	-0,019	0,032				
RP Groups	Abrasion resistance			0,398	-0,147		
	Pilling			-0,340	0,231		
OE Groups	Abrasion resistance					-0,396	0,113
	Pilling					0,295	-0,025

Table 5. *The correlation coefficients between the yarn evenness, abrasion resistance and pilling.*

Group of parameters		RK Groups		RP Groups		OE Groups	
		Warp Evenness	Weft Evenness	Warp Evenness	Weft Evenness	Warp Evenness	Weft Evenness
RK Groups	Abrasion resistance	0,409	0,518				
	Pilling	-0,384	-0,057				
RP Groups	Abrasion resistance			-0,282	-0,013		
	Pilling			0,033	0,347		
OE Groups	Abrasion resistance					-0,072	-0,272
	Pilling					0,028	0,238

Table 6. *The correlation coefficients between yarn hairiness and abrasion resistance and pilling.*

Group of parameters		RK Groups		RP Groups		OE Groups	
		Warp Hairiness	Weft Hairiness	Warp Hairiness	Weft Hairiness	Warp Hairiness	Weft Hairiness
RK Groups	Abrasion resistance	-0,650	-0,646				
	Pilling	0,675	0,814				
RP Groups	Abrasion resistance			-0,878	-0,720		
	Pilling			0,653	0,668		
OE Groups	Abrasion resistance					-0,775	-0,657
	Pilling					0,632	0,642

Table 7. *Arithmetic mean and standard deviation of yarn hairiness.*

Yarn Codes [a]	Arithmetic Mean		Standard Deviation	
	Warp	Weft	Warp	Weft
RK Groups	6,183	5,846	0,2673	0,2418
RP Groups	5,295	5,377	0,2431	0,2384
OE Groups	4,679	4,531	0,2427	0,1494

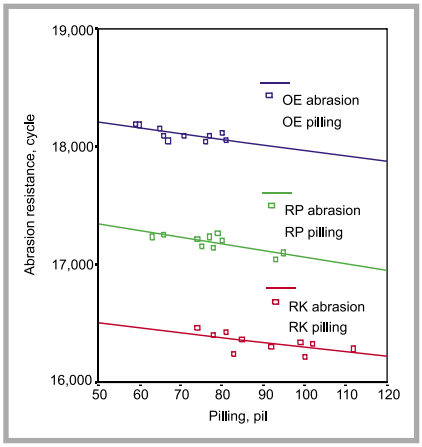

Figure 1. *A scatter diagram for abrasion resistance and pilling.*

Table 8. *The correlation coefficient between abrasion resistance and pilling.*

Fabric codes	Correlation coefficient
RK	-0,646
RP	-0,783
OE	-0,685

mined for significance levels $\alpha = 0.05$ and $\alpha = 0.01$, with the number of degrees of freedom $k = 8$. As a result, the correlation coefficients are statistically important for all the fabrics. The relationship of the RP group of fabics are important at a 0.01 importance level, however, the relationship of the OE and RK groups of fabrics are important at a 0.05 importance level. In addition, the correlation coefficient in the RP group of fabrics has a maximum value and the correlation coefficient in the RK group of fabrics has a minimum value. All the correlation coefficients are negative. Thus, an increase in abrasion resistance increases pilling performance. It is observed that the relationships between abrasion resistance and pilling are important for the 3 types of fabric.

Conclusions

In this study, the abrasion resistance and pilling of plain weave fabrics made from 100% cotton ring carded, ring combed and OE rotor spun yarns were investigated. According to the results obtained, abrasion resistance and pilling performance in fabrics made from OE rotor spun yarns has a maximum value. However, the abrasion resistance and pilling performance of fabrics made from ring carded spun yarns have a minimum value. Besides these standard deviations between the abrasion resistance and pilling in fabrics with OE rotor spun yarns, have a minimum value. On the other hand, the abrasion resistance and pilling of fabrics with carded spun yarns have a maximum value.

The yarn characteristic quantity which affects fabric abrasion resistance and pilling is yarn hairiness. Yarn tenacity and yarn evenness do not affect fabric abrasion resistance and pilling. An increase in yarn hairiness reduces fabric abrasion resistance and pilling performance. The standard deviation between abrasion resistance and pilling in different groups of fabric are variable and may be caused by the standard deviation among yarn hairiness in different groups of yarn being variable.

It is observed that the relationships between abrasion resistance and pilling are important in all fabrics. Pilling performance is high in fabrics which have high abrasion resistance in all the groups of fabric. So if the abrasion resistance or pilling of any fabric is known, pilling or abrasion resistance are able to be estimated.

High abrasion resistance and pilling performance are properties required in fabrics. Furthermore, there are so many factors of yarn hairiness that affect abrasion resistance and pilling. From OE rotor spun yarns it is possible to produce fabrics with high abrasion resistance and pilling performance.

The results declared are valid for 100% cotton plain weave fabric. Similar results cannot be achieved with different yarns, different spinning systems and different types of weave fabric.

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