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The Relationship between Yarn Properties and Pilling Resistance in Knitted Fabrics

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Abstract – Pilling resistance is an important subject for apparel industry. The purpose of this research was to determine whether the physical yarn properties have an effect on pilling resistance of knitted fabrics. In addition, the other aim of work was to investigate whether significant changes in these effects with different fabric compactness and pilling test turns. Twelve different knitted fabrics were obtained with two different yarn feedings by using six yarns. Fabrics were produced by using rib knit structure in flat knitting machine. Tensile strength, elongation at break, unevenness, imperfections and hairiness of yarns were measured. Pilling resistance of fabrics was tested at 2000 and 5000 turns according to Martindale method. The relationship between yarn properties and pilling were statistically evaluated through correlation analysis. This work indicated that there were significant relationship between elongation, thin places, thick places and hairiness with pilling. However, the increased fabric compactness eliminated these yarn properties on pilling resistance except yarn hairiness. These findings suggest that fabric pilling is primarily related to the fabric structure. Moreover, a clear benefit of reduction of yarn hairiness in the prevention of pilling formation could be said independently of the effect of pilling test turns and fabric compactness.

Keywords – yarn properties, yarn hairiness, yarn imperfections, knitted fabrics, pilling resistance

I. Introduction

Pilling is a critical problem in knitted fabrics. The pill formation causes an unpleasant surface and earlier fabric wear. Pilling resistance of knitted fabrics has been studied over the latest few decades because of the importance of subject for the apparel industry. Previous studies have primarily concentrated on the affecting parameters on pilling, different methods for pill formation, evaluation techniques giving pilling grade, effect of finishing processes (enzyme treatment, physical processes and chemical processing) for reducing of pilling. Numerous studies have attempted to explain the effects of parameters such as fiber, yarn, weaving, knitting, dyeing and finishing on pilling resistance [1, 2].

Literature reviews have indicated that the experimental data are rather controversial and there is no general agreement about effects on pilling. For instance, Sharma et al. (1996) point out that pilling tendency show an increase with the increase in polyester ratio [3]. Beltran et al. (2006) maintains that there was a significant difference between fiber properties and pilling [4]. Kahraman (2006) found that fabrics containing cotton have lower pilling resistance than polyester fabrics [5]. Another example, Sharma et al. (1996) and Özçelik (2006) conclude that the increasing in yarn fineness was caused to decreasing in the pilling resistance [3, 6]. However, Erdumlu et al. (2009) maintain that there was no increase of pilling associated with the increase in yarn fineness [7]. Moreover, Kahraman (2006) observed changes in the effect of the yarn fineness on pilling before and after finishing processing [5]. When findings to emerge from previous studies are taken as a whole, we can surmise that each process step may weaken the effect of the previous operation or remove it completely with right a choice.

The objectives of this paper were to determine whether the physical yarn properties have an effect on pilling resistance of knitted fabrics. In addition, the other aim of research was to examine whether significant changes in these effects with different fabric compactness and pilling test turns.

II. Materials and Method

In this study, twelve different fabrics were obtained with two different yarn feeding system by using six yarns consist of different properties. Table 1 shows the used yarn specifications. Fabrics were produced by using rib knit structure in flat knitting machine with 12E gauge. To remove paraffin, soda and oil solvents were applied on all fabrics. After this process, all fabrics were washed at 40 ºC for one hour, and dried as flat.

Table 1. Yarn Specifications

Yarn Code	Composition (%)	Yarn Number (Ne)
A	100% Cotton	Ne 16
B	100% Cotton	Ne 20
C	100% Cotton	Ne 30
D	50% Cotton / 50% Viscose	Ne 13
E	50% Cotton / 50% Viscose	Ne 20
F	50% Viscose / 50% Polyester	Ne 28

Prior to pill formation on fabrics, properties of the used yarns in the fabrics were tested. "TITAN" tensile testing device was used for tensile strength and elongation at break of the yarns according to TS 245 EN ISO 2062 standard.

Yarn unevenness were measured in ”Uster Tester 4-FX” instrument, in conformity with ISO 16549. Thus, unevenness (CVm), imperfections (IPI values) values [thin places (-40%), thick places (+35%) and neps (+200%)] values were obtained. Hairiness of yarns was tested using Zweigle G 567.

To obtain pill formation in the fabrics, Martindale method was preferred. Process was realized by using “Nu-Martindale Test Instrument” according to TS EN ISO 12945-2 [8]. Pilling was measured at 2000 and 5000 turns. Pilling degrees was evaluated by eye in compliance with ISO standards. Furthermore, EMPA Knitted standard photos were used for this assessment as supportive. All tests were made in standard atmospheric conditions after conditioning according to TS EN ISO 139.

The relationship between yarn test results and pilling grades of knitted fabrics were statistically evaluated using correlation analysis. According to the data-set, Spearman’s rho correlation analysis and Spearman’s coefficient of correlation (r) were used for the examination of the correlation. A correlation greater than 0,50 is generally described as good [9].

III. RESULTS

The results obtained from the yarn tests are shown in Table 2. Table 3 presents the fabric specifications produced from mentioned yarns and pilling test results.

Table 2. Test results of yarns

Yarn Properties	Yarn Codes					
	A	B	C	D	E	F
Tensile Strength	21,20	19,67	30,39	18,02	20,74	34,88
Elongation at Break	9,47	7,82	9,26	8,04	8,95	11,96
Unevenness	13,31	19,43	11,97	20,70	11,09	10,25
Thin Places	29,10	676,10	35,90	522,40	9,20	1,90
Thick Places	632,7	1226,7	238,9	1265,6	151,6	60,0
Neps	33,8	118,9	36,7	91,9	13,7	34,6
Hairiness	1120	4055	4785	3647	4559	2244

Table 3. Fabric specifications and pilling test results

Fabric Code	Yarn Code	Simultaneous Yarn Feeding	Pilling Grade	
			2000 turns	5000 turns
01	A	2	2/3	2
02		3	3/4	3
03	B	2	2	1/2
04		3	2/3	2
05	C	2	2	1/2
06		3	2/3	2
07	D	2	2/3	2
08		3	3/4	3
09	E	2	2/3	2
10		3	3	2
11	F	2	3	2/3
12		3	3	2/3

As can be seen from the Table 3, a clear benefit of increasing fabric compactness with the increase yarn feeding in the prevention of pilling was identified in 2000 cycles. No significant reduction in pilling was found fabrics coded as “11” and “12” containing yarn coded as “F”. In 5000 cycles, changes in pilling was not observed in fabrics coded as "9", "10",“11”and “12” containing yarn coded as "E" and “F”. A similar benefit with the increase yarn feeding in the prevention of pilling was also determined in 5000 cycles except from fabrics containing “E” and “F” coded yarns.

It is apparent from Table 3 that the increase in the pilling test turns caused a reduction in pilling resistance in all fabrics.

The correlation coefficient results obtained from the correlation analysis between physical yarn properties and pilling grade values can be compared in Table 4.

Table 4. The obtained correlation coefficient values between yarn properties and pilling results

Tests	Correlation coefficient (r) values			
	Two Yarns Feeding		Three Yarns Feeding	
	2000 turns	5000 turns	2000 turns	5000 turns
Tensile Strength	0,236	0,236	-0,318	-0,193
Elongation at Break	0,562*	0,562*	0,113	0,148
Unevenness	-0,463	-0,463	0,225	0,324
Thin Places	-0,663*	-0,663*	-0,089	0,040
Thick Places	-0,503*	-0,503*	0,148	0,241
Neps	-0,333	-0,333	-0,070	0,195
Hairiness	-0,603*	-0,603*	-0,654*	-0,777**

(*) good correlation (**) strong correlation (-) negative correlation

From the data in Table 4 for two yarns feeding, a positive good correlation was found between elongation and pilling grade in 2000 and 5000 turns. There was negative good correlation between thin places, thick places and hairiness with pilling grade in 2000 and 5000 turns. And, there were no significant relationship between tensile strength, unevenness and neps with pilling grade. As Table 4 shows for three yarns feeding, a negative good correlation was detected between yarn hairiness and pilling grade in 2000 turns. Furthermore, a negative strong correlation was found between yarn hairiness and pilling grade in 5000 turns. And, there were no significant relationship between tensile strength, elongation, unevenness, thin places, thick places and neps with pilling grade.

IV. DISCUSSION

It can be seen in reviewing the literature that so many parameters on pilling grade have been identified [1, 12]. However, the reported data are rather controversial about synergistic effect of each on pilling degree. The pills formed on the fabric surface consist of fibers. These fibers come from the yarn structure. Any combination that keeps the fibers more firmly in the yarn structure will increase pilling grade. On the contrary, any change that allows fibers to migrate to the yarn surface will decrease the pilling degree [11].

The findings from this research provide several contributions the previous studies. The increased fabric compactness by using simultaneous three yarn feedings eliminated the some yarn properties on pilling resistance according to two yarn feedings (Table 4).

Knitted fabrics have a more visible and clear loop structure in a lower fabric compactness. In this case, it can be said that friction may also occur in the gaps inter-loop in addition to the loop surface. And, the increased contact surface of the yarns cause an increase in pilling. Moreover, the effect of the yarn properties on this pilling will also increase.

When the compactness of the fabric increases with three yarn feedings, the surface of the fabric turns into a straighter structure. And, friction coefficient decreases. The contact surface of the yarns is reduced as the gaps between the loops decrease. This reduces the amount of yarn friction and prevents the movement of the fiber in the yarn and the migration to the fabric surface. A positive contribution is made to fabric pilling since fiber movements are blocked.

Only, the effect of yarn hairiness among yarn properties on pilling grade was not reduced with the increase in fabric compactness. On the other hand, negative good correlation between yarn hairiness and pilling grade in 2000 turns changed as negative strong correlation for 5000 turns.

These findings suggest that a significant decreasing in pills is possible with the removal of protruding hairs in fabric surface. Independently of the effect of pilling test turns and fabric compactness, a clear benefit of reduction of yarn hairiness in the prevention of pilling formation could be said compared to other yarn properties from observed findings in this study. This research observed findings which corroborate the results of a great deal of the previous studies in this field. For instance, diminishing of yarn hairiness can be possible with modification in conventional ring spinning process. Beltran et al. (2007) was reported reduction of approximately 46% using Solospun^{TM} apparatus and a 33% reduction using the JetWind^{TM} process in the S3 values. It was indicated by authors that the reduction of S3 value obtained from this apparatus over the conventional worsted spun yarn was provided a half grade improvement in pilling. This result suggested that a relatively large reduction in yarn hairiness was produced a moderate improvement in fabric pilling. Yarn hairiness was a key factor on fabric pilling, but the number of hairs (S3) was not the only important effect [12].

The findings of the current study also compatible with observations obtained by Erdumlu et al. (2009) in yarns containing cotton, viscose rayon and cotton-modal blends produced in different spinning systems in different yarn number. The produced fabrics from lower hairy open-end and vortex yarns showed higher pilling resistance than fabrics obtained from higher hairy ring yarns. However, researchers reported that fabrics produced from vortex yarns have better pilling grades than open-end yarns although there were no significant differences between Uster hairiness values of open-end rotor and vortex spun yarns [7]. It can be also said from their findings that the better pilling grades can be attributed to decreasing yarn hairiness up to a certain extent but it can be affected in other factors.

V. CONCLUSION

In this investigation, the aim was to assess the relationship between physical yarn properties on pilling resistance of knitted fabrics. Furthermore, this study set out to determine the change of influential yarn properties in case different fabric compactness and pilling test turns. This study has shown that there were significant relationship between elongation, thin places, thick places and hairiness with pilling grade. However, the increased fabric compactness eliminated these yarn properties on pilling resistance except yarn hairiness. These findings suggest that fabric pilling is primarily related to the fabric structure. Any combination that keeps the yarns more firmly in the fabric structure will increase pilling grade. To adjust pilling without detriment to smooth fabric appearance, the next step should be to focus on the yarn hairiness. For more excellent results, other yarn properties and the results related to fiber properties in the literature should be reviewed.

It can be said as the most important point that fiber movements should be blocked in yarn and fabric structure without harming fabric hand feeling for the more durable and better pilling performance of garments.

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