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Statistical Analysis of the Pilling Behaviour of Polyester/Cotton and Polyester/Viscose Blended Woven Fabrics

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Abstract
In this work, the pilling behaviour of polyester blended fabrics was studied and analysed statistically. Two different groups of blends were selected, namely polyester/cotton (P/C) and polyester/viscose blends (P/V). All the fabrics were assessed for pilling performance using ICI pill box, and two-way ANOVA was conducted to analyse the effect of the number of revolutions and type of fibres on the pilling behaviour of the fabrics. The analysis was further narrowed down by conducting a series of ANOVA, by segregating the number of revolutions into two stages and blend proportions into three stages for group I fabrics. Similarly for group II fabrics, both the, number of revolutions and blend proportions were segregated into two stages each. It was found that the type of component fibre used to produce the fabric loses its significance as the number of revolutions increases.

Key words: *pilling, polyester, viscose, cotton, blend, statistical analysis.*

Introduction

Pills are the entangled mass of fibres formed on the surface of fabric by short or loosely twisted fibres present in the yarn. Pills are formed during rubbing action, like the resting of body parts on a table, chair or any other surface, or during washing. As a result, it degrades the appearance of clothing. Since pills are the fibres already protruded from the body of the fabric, they have very poor strength to hold along with the fabric and hence they will rub of during regular use. But this process happens over a period of time or a number of rubbing or washing cycles. The whole pilling process can be explained in three stages, namely fuzz formation, *i.e.*, the stage prior to actual pilling starting; secondly the pilling process, and lastly the removal of the formed pills, which is the predominant process [1].

Many researchers have studied the pilling properties of different types of fibres and fabrics under different conditions. Sivakumar and Pillay [2] analysed various parameters such as the effect of weave, blend composition, denier, etc. on the pilling behaviour of different types of polyester blended fabrics. However, the effect of the number of revolutions on pilling performance has not been detailed. Sharma *et al.* studied the pilling behaviour of polyester/wool blended fabrics at three different numbers of revolutions, namely 10.000, 18.000 and 26.000 revolutions [3]. It has to be noted that the researchers did not study lower numbers of revolutions than 10.000. Long and Wei [4] studied the pilling performance of polyester/wool fabrics with modified polyester fibre. Abdel – Fattah and El-Katib [5] studied the pilling behaviour of six different types of polyester/wool blended fabrics using the ICI pill box method. But they only categorised the pilling of fabrics into three categories: I, II and III, which indicate no pilling, slight pilling and severe pilling, respectively, which is more subjective in nature. Similarly El-Shakankery [6] studied the pilling behaviour of polyester/wool blended fabrics. It was reported that the increase in polyester fibre content increases the pilling tendency. Details of the number of revolutions of the pill box test is not mentioned clearly. Omeroglu and Ulku [7] compared the pilling properties of fabrics produced from ring and compact spun cotton yarn using two different techniques of pilling, namely a Martindale abrasion and pilling tester and a ICI pill box. It was observed that the researchers compared the samples for their pilling behaviour after 14.000 cycles in the ICI pill box; but there was no report on the pilling behaviour before 14.000 cycles. They also graded the samples from 1 to 5, and the number of pills and amount of weight loss in the fabric were not observed.

The pilling properties of solid and hollow polyester fibres were compared by Khoddami *et al*. [1] They observed the same trend for fabrics produced from 100% wool and hollow polyester/wool blended fabrics. It was reported that the pilling tendency of polyester fabrics is clear after 5,000 rubs of pilling. Jerkovic

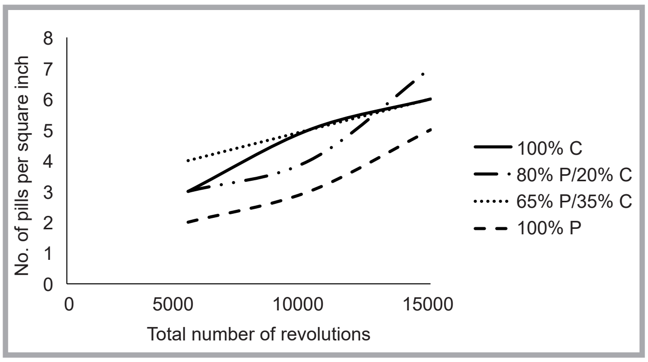

Figure 1. Pilling behaviour of group I fabrics.

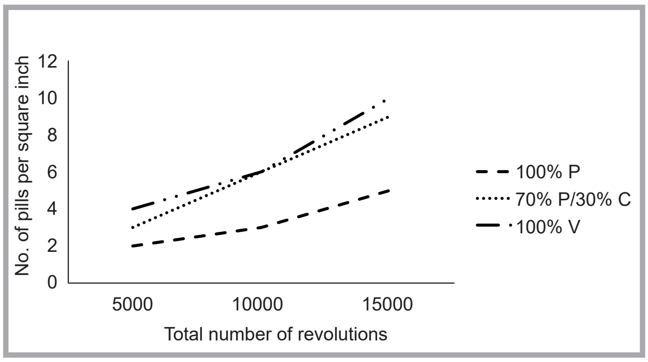

Figure 2. Pilling behaviour of group II fabrics.

et al. [8] attempted to analyse different types of fabrics used for automobile seats with four different types of abrasive testers. [8] Busilienė *et al*. [9] investigated the effect of fibrous composition on the pilling behaviour of fabrics with different types of fibres: cotton, bamboo, viscose, polyester, polyamide, etc. It was observed that the fabric produced from viscose fibre showed lesser resistance to pilling, and those produced from polyester and polyamide exhibited higher resistance to pilling [9]. Few researchers have attempted to model the pilling behaviour of textile fabrics [10, 11], and few have also evaluated the pilling behaviour of fabrics objectively using different methods [12-16].

From the literature, it was observed that many researchers analysed polyester blended fabrics for their pilling behavior. Variations in the number of cycles were observed for polyester fabrics from 5.000 onwards. Among the various researches conducted, a few did not report the number of revolutions for pill formation nor the number of pills formed on the fabric. Statistical analysis of the pilling behaviour of fabrics produced from blends of polyester fibre is scarcely available. In this study, two different blends, namely polyester/cotton and polyester/viscose were analysed for their pilling behaviour from 5.000 to 15.000 revolutions. Detailed statistical analysis of both groups of fabrics was conducted by ANOVA, and the effect of the number of revolutions and that of the blends were studied.

Materials and methods

Materials

Six types of plain woven blended fabrics were selected to analyse their pilling behaviour. Constructional properties of the fabrics are shown in ***Table 1***. Based on blending, these fabrics were categorised into two different groups, namely group I and II. Details of the grouping are shown in ***Table 2***.

Evaluation of pilling

A pilling test of the textile fabrics selected was carried out in an ICI pill box. Four fabric samples of 125 mm × 125 mm each were cut and stitched, which were then firmly mounted on round moulded polyurethane tubes and rotated in cork lined boxes for a preset number of revolutions. An analysis was carried out to understand the pill formation behaviour of different blends of fabrics at different numbers of revolutions, *i.e.*, 5.000, 10.000 and 15.000. The extent of pilling was assessed by counting the number of pills per square inch.

Statistical analysis

To find the effect of blends and the number of rotations, two way ANOVA was conducted and 'F' values calculated for both groups of fabrics. To find the significance of these parameters, the calculated and tabulated 'F' values were compared at a 95% confidence interval.

Results and discussion

The pilling behaviour of different blends of fabrics in terms of the number of pills

Table 1. *Constructional properties of fabrics.*

Blend proportion	100% cotton	100% viscose	100% polyester	80%/20% P/C	70%/30% P/V	65%/35% P/C
End per inch	132	116	116	128	124	126
Picks per inch	92	88	92	88	88	82
Warp count, tex	9.5	9.8	9.2	8.0	9.2	9.5
Weft count, tex	10.2	10.2	9.5	9.8	10.9	10.5

Table 2. *Details of grouping of fabrics.*

Blend code	Group I	Blend code	Group II
B1	100% Cotton	B5	100% Polyester
B2	80%/20% Polyester/Cotton	B6	70%/30% Polyester/Viscose
B3	65%/35% Polyester/Cotton	B7	100% Viscose
B4	100% Polyester		

Table 3. *Pilling behaviour of different fabrics (number of pills per square inch).*

Type of fabrics	Number of revolutions		
	5000	10000	15000
100 % Cotton	3	5	6
100% Viscose	4	6	10
100% Polyester	2	3	5
80% Polyester/20% Cotton	3	4	7
65% Polyester/35% Cotton	4	5	6
70% Viscose/30% Cotton	3	6	9

Table 4. ANOVA of group I fabrics.

Source of Variation	Sum of squares	Degree of freedom	Mean squares	F value
Among numbers of revolutions	18.1	2	9.08	29.7
Among types of fabrics	4.9	3	1.64	5.3
Residual error	1.8	6	0.31	
Total	24.9	11		

Table 5. Details of series of two-way ANOVA conducted for group I fabrics.

Analysis code	Parameters considered for ANOVA	Parameters considered common for ANOVA
A1	5.000 and 10.000	B1, B2, B3 and B4
A2	10.000 and 15.000	
A3	B1 and B2	5.000, 10.000 and 15.000 revolutions
A4	B1 and B3	
A5	B1, B2 and B3	

Table 6. ANOVA of group I fabrics.

Analysis code	$F_{Calculated}$ value		$F_{Tabulated}$ value	
	A mong revolutions	Among blends	Among revolutions	Among blends
A1	25.00	11.67	$F_{(0.05, 1, 3)}$ = 10.128	$F_{(0.05, 3, 3)}$ = 9.2766
A2	13.36	2.45		
A3	12.33	0.00	$F_{(0.05, 2, 2)}$ = 19	$F_{(0.05, 1, 2)}$ = 18.51
A4	19.00	1.00		
A5	15.25	0.25	$F_{(0.05, 2, 4)}$ = 6.9443	

per square inch is shown in ***Table 3***, from which and ***Figures 1*** and ***2***, two observations can be made as far as group 1 and 2 fabrics are concerned. Firstly, if the number of revolutions of the pill box increases from 5.000 to 15.000, the number of pills per unit area increases. Secondly the pilling behaviour differs with respect to the type of component fibres present in their blend. To analyse the effect and significance of both parameters, namely the number of revolutions and type of component fibres, two way ANOVA was conducted and 'F' values calculated, shown in ***Table 4***.

For both groups of fabrics, the 'F' values calculated were compared with the tabulated 'F' values at a 95% confidence interval. The values of F_{table} (0.05, 2, 6) and F_{table} (0.05, 3, 6) are 5.1433 and 4.7571, respectively. From ***Table 4***, it can be noted that the values of 'F' calculated for the number of revolutions and type of fabric are higher than the tabulated 'F' values (29.7 > 5.1433 and 5.3 > 4.7571). Hence it can be said that the number of revolutions and type of fabric significantly affects the pilling behaviour of polyester/cotton and polyester/viscose blended fabrics.

Analysis of group I fabrics

Certain parameters of fabrics gain or lose their importance during usage in real time. To analyse the significance, a series of ANOVA was conducted by narrowing down the number of revolutions and types of fibres. To analyse the effect of the number of revolutions, the process was divided into two stages *i.e.,* 5.000 & 10.000 revolutions and 10.000 & 15.000 revolutions. Two different two-way ANOVA were conducted to analyse the effect of both parameters at different stages of usage. Similarly to identify the significance of the types of fibres, two different two-way ANOVA were conducted including any one blend proportion of cotton (*i.e.,* either a 20% polyester or 35% polyester blend) and comparing with 100% cotton fibre. A separate ANOVA was conducted excluding 100% polyester fibre alone (*i.e.*, for all the remaining blends).

Results of all the ANOVA were studied by analysing the significance of the number of revolutions and type of fabric. From this statistical analysis, the effect of selected parameters in the short and long run *i.e.,* the pilling behaviour at different time periods of usage of a particular product, was analysed. The analysis code and details of the series of ANOVA conducted are shown in ***Table 5***. The results of the series of ANOVA are shown in ***Table 6***.

From ***Figure 1***, it can be observed that the number of pills per square inch was higher when the proportion of cotton fibre is higher in the blends. The number of pills was lower for 100% polyester fabrics. The following could be the reason for the formation of pills but may differ for both the types of fibres. For cotton fibres, the formation of pills may be due to the presence of short fibres and loosely twisted fibres in the yarn. For polyester fibre, the cut length remains uniform, hence two possible reasons for the formation of pills could be static charge generation, which causes the fibres to accumulate and from as pills, or the formation of pills by loosely held fibre or surface fibre in the yarn or fabric. As the number of revolutions increases from 5.000 to 10.000, short fibres and loosely twisted fibres form pills. With a further increase in the number of revolutions from 10.000 to 15.000, the different types of fibre decrease, and the reason for the formation of pills may be common for all the fabrics i.e., only due to natural frictional force, which causes that the weakly held fibres in the yarn or fabric may accumulate and form as pills. The results of the series of ANOVA conducted, which are shown in ***Table 6***, also give affirmation to those interpreted from ***Figure 1***. In analysis A1, for a lower number of revolutions, *i.e.*, when the number of revolutions are 5,000 and 10,000, the 'F' value calculated (25 and 11.67) is greater than the tabulated 'F' value (10.128 and 9.276) for the number of revolutions and type of fibre, respectively. Therefore both the number of revolutions and type of fibre play a significant role in the pilling behaviour of fabrics. But when the number of revolutions increases from 10.000 to 15.000 in analysis A2, the 'F' value calculated (13.36) is higher than the tabulated 'F' value (10.128) only for the number of revolutions parameter. For the type of fibre, the 'F' value calculated is lower than the tabulated 'F' value (2.45 < 9.276). From this interpretation, it can be said that the number of revolutions increases; in other words, in real time along with the usage of fabrics, where the type of fibre does not play a significant role in the pilling behaviour of fabrics.

In analysis of A3 and A4 for two different blends *i.e.*, 100% cotton and 80% Polyester/20% cotton and 100% cotton and

65% Polyester/35% cotton, respectively, the ‘F’ values calculated are lower than the tabulated ‘F’ values at a 95% confidence interval (***Table 6***). This analysis reveals that even the number of revolutions gains significance when the polyester fibre component is lower in the blend proportion. While for 100% cotton and 80/20 polyester/cotton in ANOVA, no significant variation was observed. In the case of polyester fibre, the majority of the formation of pills may only be due to static electricity generated during continuous abrading action, while in the case of cotton, the formation of pills is due to the presence of short fibres, which is visible with the comparison of 100% cotton and 65/35 polyester/cotton blends. The calculated and tabulated ‘F’ value are almost equal, from which it can be said that the number of revolutions has higher significance than the type of blend present in the component fibre. For the type of fibres, the ‘F’ value calculated is much smaller than the tabulated ‘F’ value for both types of blends i.e., 1 and 0 for 100% cotton with 80/20 P/C and 100% cotton with 65/35 P/C, respectively, which again confirms that the type of fibre in the blends does not play a significant role in the formation of pills. In the case of all the three blends, excluding 100% polyester, which were considered for ANOVA, the number of revolutions were observed to be significant, and the type of blend component did not show any significance. It confirms that during the usage of fabrics over a period of time, the type of fibre used in the blend loses its significance for the pilling behaviour of fabrics.

Analysis of group II fabrics

Table 3 and ***Figure 2*** show the pilling behaviour of fabrics produced from polyester and viscose blends. From the table and figure, it can be noted that 100% viscose and blends of viscose produce a slightly higher number of pills compared to 100% polyester fibre fabrics. Moreover in this set of fabrics, as the number of pill box rotations increases, the number of pills per unit area rises, which is obvious. From ANOVA (***Table 7***), it can be concluded that the ‘F’ values calculated for the numbers of revolutions and types of fibres (22.8 and 11.2, respectively) are both higher than the tabulated ‘F’ value, which is 6.9443.

Thus it is clear that both parameters have a significant effect on the pilling behaviour of the fabrics produced. For further analysis, similar to that for P/C blended fabrics and P/V blended fabrics , a series of ANOVA were conducted, the particulars and results of which are shown in ***Table 8*** and ***9***. From ***Table 9***, it can be observed that the ‘F’ values calculated are lower than the tabulated ‘F’ value for A6. For A7, the ‘F’ value calculated is higher than the tabulated ‘F’ value for among revolutions, whereas it is neither higher nor lower for among blends. In the analysis of A6 and A7, it can be said that both the number of revolutions and type of fibre show no significant difference at a lower number of revolutions (between 5000 and 10000) *i.e.*, when the usage of the fabric is at the initial stage. However, as the number of revolutions increases in the range of 10000 to 15000, the number of revolutions *i.e.*, usage of the garment a higher number of times, plays a significant role in the formation of pills, whereas the type of fibre shows a marginal effect on the pilling behaviour of fabrics. Similarly in the analysis of A8 and A9, for A8 the ‘F’ values calculated are lower than the tabulated ‘F’ values, and for A9 the ‘F’ value calculated is higher than tabulated ‘F’ value for among revolutions and lower for among blends. It shows that when the polyester fibre content is decreased from 100% to 70% (A8), there is no significant difference in the formation of pills in the fabric. However, when it is further decreased from 70% to 0% (A9), a significant different was observed as far as the number of revolutions is concerned, *i.e.*, during the usage of fabrics, whereas the type of fibre has no significant effect on the pilling behaviour of fabrics.

Table 7. *ANOVA of group II fabrics.*

Source of variation	Sum of squares	Degree of freedom	Mean squares	F value
Among number of revolutions	38.0	2	19.00	22.8
Among types of fabrics	18.6	2	9.33	11.2
Residual error	3.3	4	0.83	
Total	60.0	8		

Table 8. *Details of series of two-way ANOVA conducted for group II fabrics.*

Analysis code	Parameters considered for ANOVA	Parameters considered common for ANOVA
A6	5000 and 10000	B5, B6 and B7
A7	10000 and 15000	
A8	B5 and B6	5000, 10000 and 15000 revolutions
A9	B6 and B7	

Table 9. *ANOVA of group II fabrics.*

Analysis code	$F_{Calculated}$ value		$F_{Tabulated}$ value	
	Among revolutions	Among blends	Among revolutions	Among blends
A6	12.00	7.00	$F_{(0.05, 1, 3)}$ = 18.51	$F_{(0.05, 3, 3)}$ = 19.00
A7	27.00	19.00		
A8	8.71	9.14	$F_{(0.05, 2, 2)}$ = 19.00	$F_{(0.05, 1, 2)}$ = 18.51
A9	109.00	4.00		

Conslusions

In this research, a study on the pilling behaviour of polyester and its blends in fabrics at different pill box rotations was conducted, which enabled simulate the usage of fabric for different durations of time. It was noticed that the number of revolutions of the pill box and type of fibre used in the blend contribute significantly to the pilling behaviour of fabrics. In order to critically analyse the effect of these two parameters, a series of ANOVA was conducted and ‘F’ values calculated. From the analysis, it can be concluded that the type of fibre used in the blend may slightly influence the formation of pills in the polyester/cotton or polyester/viscose blends, if we analyse superficially. But as the number of number of revolutions increases beyond a certain extent, the type of fibre used to produce the fabric diminishes the effect of pilling, whereas with an increase in the number of revolutions of the pill box or in the actual usage of the fabric, increases the formation of pills in the fabric rather than the type of fibres used, irrespective of the type of fibre blend.

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