Effect of yarn structure variables on pilling performance for blended woven fabrics

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ABSTRACT:

Pilling is undesirable dilemma that badly influences the handle and appearance of fabrics. This work aimed at studying the effects of four yarn factors (cotton materials, twist multiplier, cotton/polyester blend ratio and spinning system) on pilling propensity of cotton/polyester blend woven fabrics under five pilling cycles from 500 up to 2000 rubs. Results showed that fabrics which are woven by using the two Egyptian varieties of Giza 86 and Giza 95 reflect good pilling-resistance compared to the Greece variety of Meddling. There was negative association between twist multiplier and pilling propensity indicating that the cotton/polyester fabrics woven using the highest twist multiplier had high pilling-resistant and vice versa. It is found that the pilling propensity would be increased when the polyester proportion increased in the cotton/polyester blend fabrics. It is concluded that the fabric samples produced using combed yarns had the best pilling-resistant compared to those fabrics woven using carded yarns. This result is only being hold true when using 125 and 250 rubbing cycles. Using 500 up to 2000 pilling rubs, fabric samples produced using carded or combed yarns had convergent pilling behavior. Results of multiple linear regression model exhibited that the four yarn factors (cotton materials, twist multiplier, cotton/polyester blend ratio and spinning system) explained the majority variation of pilling behavior expressed as coefficient of determination (R^2 %) indicating that the studied yarn factors were already among the main contributors that robustly affecting the pilling phenomenon. Among these studied factors, it is appeared that the polyester proportion % of the cotton/polyester blend fabrics is the main determinant in their pilling performance.

Key words:

cotton/polyester, blend fabrics, yarn structure, pilling performance.

INTRODUCTION:

Pilling on fabrics is a well-known dilemma that occurs when fibers become entangled during washing, dry cleaning, checking, or wear, resulting in balls or pills that protrude from the fabric's surface. Fibers become intertwined during pilling, and the fibers around them join this structure, creating a greater default on the fabric surface. The unsightly nature of pilling will seriously compromise the fabric's acceptability for apparel as a result of fabric abrasion.

Doustaneh *et al* (2013) explained that Fuzz formation, entanglement, development, and wear-off are the four stages of pill formation. Pilling has become a more serious issue since the widespread use of synthetic fibers in textiles, because fibers with higher tensile strength delay wear off. However, man-made fibers, especially blends of polyester and natural fibers are now widely used due to their low cost and acceptable end-use. Therefore, the optimum choice of

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yarn and fabric factors and finishing processes should be essential steps to overcome the pilling tendency of these synthetic fibers.

From the textile industry point of view, polyester-cotton blended woven fabrics are commonly used in textile markets. Since there are many benefits, such as low cost, pressure resistance, wrinkle resistance, moisture absorption and stiffening, on the other hand, pilling not only degrades the look and feel of polyester-cotton blended woven fabrics, but also it has bad effect on their wear ability **(Wang and Xiao, 2020).**

Omeroglu and Ulku (2007) appeared that the propensity of a fabric to pill is associated with hairiness. Actually, the factors affecting pilling performance included fibers (morphology, modulus, friction coefficient, etc.), yarns (spinning method, yarn twist, yarn count, etc.) and fabrics (structure, cover factor, etc).

Abdel - Fattah and El-Katib (2007) cleared that increasing the high tenacity fibers like polyester in the polyester wool blends fabrics would increase the pilling performance. Whereas increasing weak fibers like wool (lowest tenacity) depresses the tendency of fuzz formation.

Fabric pilling evaluation is traditionally one of the most challenging tasks in textile quality measurement and control; research on the subject date back to the 1950s, and there are numerous international standards/methods for pilling evaluation. However, most of them are subjective, and mainly depend on subjective feeling and experiences of judges, so researchers attempt to develop objective evaluation methods in place of old ones **(Hassan, 2016)**.

Aung *et al* (2018) investigate the effect of anti-pilling treatment on polyester/cotton fabric by using the anti-pilling agent. They found that polyester/cotton fabrics treated with polyacrylate, salicylic acid and amino silicone softener give the pilling resistant effect. Polyacrylate is used as anti-pilling agent in order to get the anti-pilling effect, salicylic acid is used as carrier and amino silicone is used as fabric softener.

In Egypt, few studies have evaluated the respective roles of fiber, yarn and fabric factors on pilling behavior of cotton/polyester blended woven fabrics. The objective of the present paper is to investigate the effects of four yarn factors (cotton materials, twist multiplier, cotton/polyester blend ratio and spinning system) on pilling propensity for cotton/polyester blend woven fabrics under five pilling cycles from 500 up to 2000 rubs.

MATERIALS AND METHODS

The cotton materials of this work contain two Egyptian varieties of Giza 86, Giza 95 and one Greece variety being Meddling. Cotton: polyester blend woven fabrics were chosen to be used as raw materials for the current study. The fiber properties being micronaire reading, fiber length at 2.5 span length (mm), uniformity index, short fiber index, fiber strength and fiber elongation % were measured by HVI 900 (High Volume Instrument). The fiber properties for the used cotton materials are given in Table (1). Cotton samples were spun using carded and combing system. Three cotton/polyester blended ratios (50:50 & 35:65 & 20:80) and three twist multipliers (3.7, 4, and 4.3) were applied. All fiber properties were measured under the optimum process conditions at laboratories of Cotton Technology Division of the Cotton Research Institute.

All samples were made count using weft 30/1 produced by Misr Shebin El-Kom Spinning and Weaving, Co cotton using Giza 86, Giza 95 and Meddling from Egyptian and Greece yarns

respectively that with polyester produced from staple fibers, warp yarn from count 30/1 cotton combed produced by three tex. , Co.

The samples were woven in modern el-zuhoor factory Shubra El-Kheima, on weaving machine Super excel (model 1998). The machine width was 190 cm using plain weave density (89" x 82") with width Fabric 59". The samples were dyed in two stages with a white color and for finish preparation in El Hesn Textiles, co 10th Ramadan city.

Five type Rubbing Was used from 125 up to 2000 rubs, the pilling property of the experimental fabric samples were measured in El Hesn Textiles, co 10th Ramadan city using an instrument Martindale 4 Station Abrasion and Pilling Tester M235 According to ASTM D4970. After each completed cycle the samples were brought under sufficient light and compared to standard photographs and grading was done.

Table (1): Summary of six fiber technological properties measured for the used cotton materials.

Fiber properties	Cotton materials		
	Giza 86	Giza 95	Meddling
Micronaire reading, µg/inch	4.1	4.5	5.1
Fiber length, mm	33.9	30.5	27.6
Uniformity index %	87.8	84.8	80.2
Short fiber index	6.63	8.11	10.5
Fiber strength, cN/ tex	45.6	37.9	32.5
Fiber elongation %	8.4	8.2	6.5

Multiple linear regression model was automated as outlined by **Hair (2010)** to estimate the relative importance % of four yarn factors toward the pilling performance under five pilling cycles expressed as coefficient of determination R^2 and multiple correlation coefficient (R).

RESULTS AND DISCUSSION

In today`s competition market, the quality of the products becomes urgent matter for producers. Therefore, it is essential step to estimate the fabric pilling tendency particularly affecting the quality of woven fabrics in advance. Effects of four fiber factors on pilling phenomenon were studied. The results for each studied factor were individually plotted in line with marker points graph under five rubbing cycles (125, 250, 500, 1000 and 2000 rubs).

- Effect of three cotton materials on pilling phenomenon under five rubbing cycles

The effect of three cotton materials (Giza 86, Giza 95 and Meddling) on pilling behavior of cotton/polyester blended fabrics are graphically plotted in line with marker points under five rubbing cycles as depicted in Fig. (1). It can be seen from Fig. (1) that the fabrics which are woven using spun yarns from the Greek cotton variety (Meddling) exhibited the highest polling performance followed by the fabrics made by Giza 95 and at last Giza 86. Accordingly, the

current result indicated that the woven fabrics made by spun yarns from Giza 86 was more pilling-resistant followed by those textured by Giza 95 and then Meddling. **Omeroglu and Ulku (2007), Shahid *et al* (2014) and Wang and Xiao (2020**) stated that there is a considerable relationship between yarn hairiness and pilling phenomenon of woven fabrics. **Abdel Daim (2019)** found that, the Long Staple cotton materials such as Giza 86 and Giza 95 produced less hairy yarns compared to the staple cotton of Greek variety (Meddling). These results may be returned to that the Long Staple cotton materials had finer fibers, good evenness and low short fiber content as shown in Table (1). On the other hand, the pilling performance for the three cotton materials are very close starting from 500 up to 2000 rubs (Fig. 1).

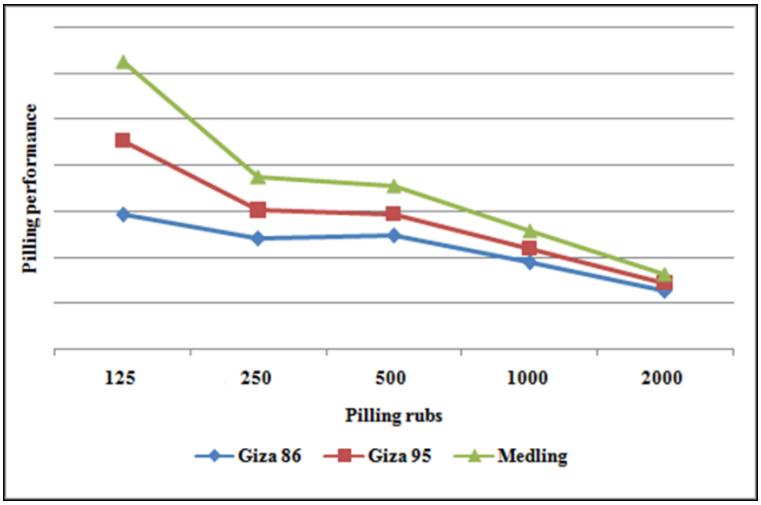

Fig. (1): The effect of three cotton materials (Giza 86, Giza 95 and Meddling) on pilling behavior of cotton/polyester blended fabrics under five rubbing cycles.

- Effect of three twist multipliers on pilling phenomenon of cotton/polyester blended fabrics under five rubbing cycles

The pilling behavior of cotton/polyester blended fabrics as affected by three twist multipliers which are graphically presented under five rubbing cycles as shown in Fig. (2). Results showed that there are negative associations between twist multiplier and pilling propensity indicating that the fabrics woven using the lowest twist multiplier (3.7) had low pilling-resistant and vice versa. Similar pilling performance was obtained for the fabrics produced using the three twist multipliers upon 500 pilling rubs up to 2000 as shown in Fig. (2). **Ruhul and Islam (2015)** and **Wang and Xiao (2020)** found that pilling performance gradually increase with the increase of yarn twist at the stage of 125 pilling rubs. After the number of pilling rubs is more than 500, pilling grades of the fabric obviously increase first and then decrease with the increase of yarn twist. They explained that when yarn twist increased from 950 T/m to 1150 T/m, the cohesion of the fibers is further tighter, which makes the rate of forming pills slower. On the other hand, the rate at which pills fall off becomes slower. The rate of falling pills is slower than forming pills. The reason may be attributed to the strong polyester fibers, which make the pills hung on the fabric surface. So the pilling grade has a decreasing trend.

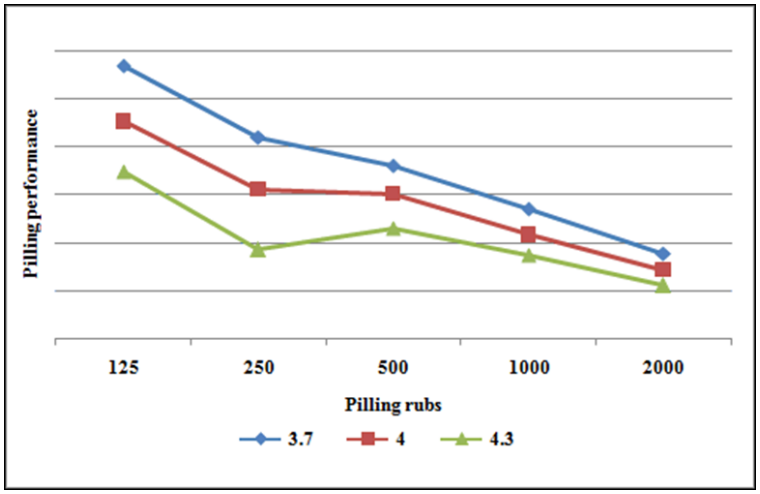

Fig. (2): The effect of three twist multipliers on pilling behavior of cotton/polyester blended fabrics under five rubbing cycles.

- Effect of three cotton/polyester blend ratios on pilling phenomenon of woven fabrics under five rubbing cycles

Figure (3) showed the pilling performance of fabrics woven using three cotton/polyester blend ratios (50:50, 35:65 and 20:80 %) under five rubbing cycles. Overall the five rubbing cycles from 125 up to 2000 rubs, it is revealed that the fabric samples woven using 50:50 % cotton/polyester blend ratio reflected the highest pilling-resistant followed by the ratio 35:65 % and at last the fabrics woven using 20:80 % cotton/polyester blend ratio. These results indicated that, as the polyester proportion increased in the fabrics woven using cotton/polyester blend, the pilling performance would be increased. **Ruhul and Islam (2015)** explained that fabrics made of synthetic fiber is more prone to severe pilling but it needs longer wear and abrasion to visualize these properties. On the contrary, **Chandrasekaran *et al* (2018)** stated that the number of pills per square inch was higher when the proportion of cotton fiber 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 fibers. For cotton fibers, the formation of pills may be due to the presence of short fibers and loosely twisted fibers in the yarn. For polyester fiber, the cut length remains uniform, hence two possible reasons for the formation of pills could be static charged generation, which causes the fibers to accumulate and form as pills, or as the formation of pills by loosely held fiber or surface fiber in the yarn or fabric.

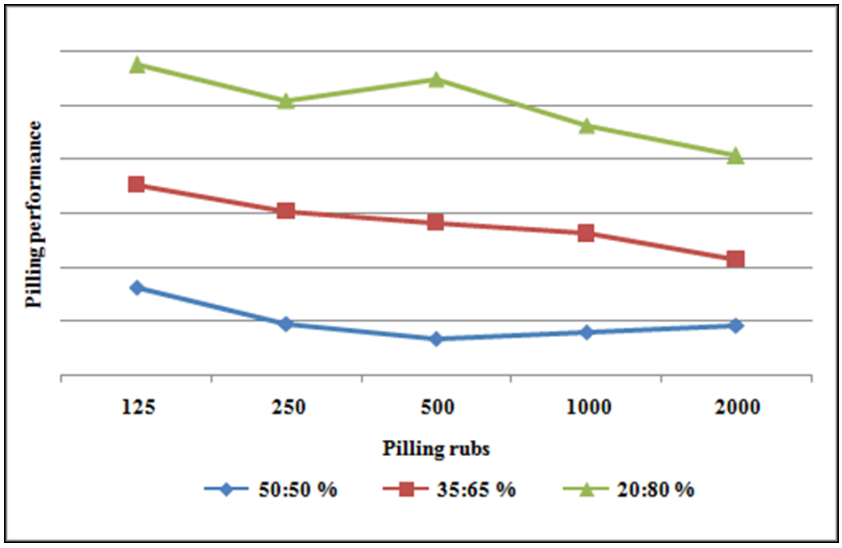

Fig. (3): The effect of three cotton/polyester blend ratios on pilling phenomenon of their woven fabrics under five rubbing cycles.

- Effect of two spinning systems on pilling phenomenon of woven fabrics under five rubbing cycles

Results of pilling behavior for cotton/polyester blended fabrics as affected by two spinning systems are diagrammatically plotted under five rubbing cycles as shown in Fig. (4). It is concluded that the fabric samples produced using combed yarns had the best pilling-resistant compared to those fabrics woven using carded yarns. This result is only being held true when using 125 and 250 rubbing cycles. Using 500 up to 2000 pilling rubs, fabric samples produced using carded or combed yarns had convergent pilling behavior as shown in Fig. (4). Many investigations studied the effect of spinning system on the pilling performance for woven fabrics. **Omeroglu and Ulku (2007)** confirmed that woven fabrics made from compact yarns were significantly more pill-resistant than those made from ring yarns. They suggested that the hairier ring spun yarns caused the fabric surfaces to pill more. They added that the visual comparison of the fabric surfaces after pilling clearly showed the advantages of the compact yarn structure in which the marginal fibers were better integrated in the body of the yarn. These findings supported the theory which indicates that the pilling properties of the fabric are highly related with the hairiness property of yarns used to construct the fabric. **Shahid *et al,* (2014)** demonstrated that pilling tendency of fabrics is affected by the yarn hairiness. They added that the compact yarns have good uniformity and extremely low hairiness. In the compact spinning system, the fibers are compacted aerodynamically just after the drafting. This enables yarn production with a reduced level of hairiness. **Abdel Daim (2019)** indicated that the lowest hairy yarns were spun by Jetring combed followed by Jetring carded and combed compact ring spinning systems with significant differences than the others.

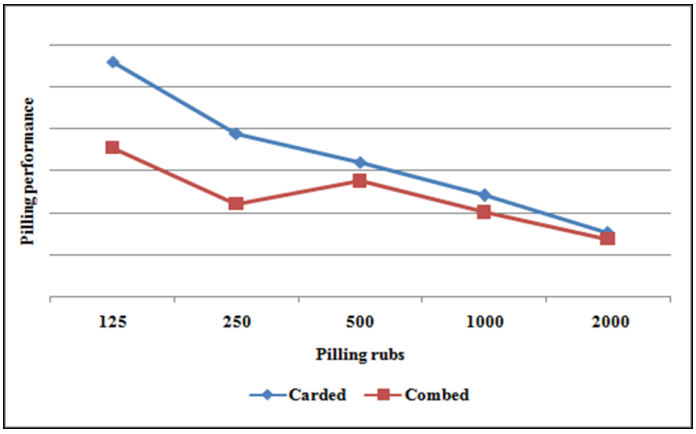

Fig. (4): The effect of two spinning systems on pilling phenomenon of woven fabrics under five rubbing cycles.

- The relative importance %, coefficient of determination (R^2) and multiple correlation coefficient (R) of four yarn factors toward the pilling performance under five pilling cycles.

Multiple linear regression models were used to account for the relative importance %, coefficient of determination R^2 and multiple correlation coefficient (R) of four yarn factors toward the pilling performance under five rubbing cycles as presented in Table (2). Results exhibited that the four yarn factors studied (cotton materials, twist multiplier, cotton/polyester blend ratio and spinning system) explained the majority variation of pilling behavior expressed as coefficient of determination (R^2 %). The coefficient of determination (R^2 %) of the four yarn factors toward pilling reading was greater than 95 % under the five pilling cycles indicating that the studied factors were already among the main contributors that robustly affecting the pilling phenomenon. Among the studied factors, it is appeared that the factor of cotton/polyester blend ratio explained the most pilling variation ranged from 79.77 to 97 % at 150 and 2000 rubs, respectively. Accordingly, the polyester proportion % of the cotton/polyester blend fabrics is the main determinant in their pilling performance. On the other hand, the multiple correlation coefficients (R) between the four yarn factors of one side and pilling performance of the other side were greater than 0.95 for all five rubbing cycles indicating strong associations between the four yarn factors parameters and pilling performance. The current results are in harmony with the findings obtained by **Ruhul and Islam (2015)** and **Wang and Xiao (2020).**

Table (2): The relative contribution %, coefficient of determination (R^2) and multiple correlation coefficient (R) of four yarn factors toward the pilling performance under five pilling cycles.

Yarn factors	Pilling cycles				
	150	250	500	1000	2000
Cotton materials	8.41	1.52	0.79	0.52	0.23
Cotton/Polyester blend	79.77	87.11	97.35	97.92	97.18
Twist multiplier	3.62	4.53	1.14	0.99	0.71
Spinning system	4.75	3.49	0.20	0.26	0.05
Coefficient of determination (R^2)	96.55	96.65	99.48	99.69	98.18
Multiple correlation coefficient (R)	0.983	0.983	0.997	0.998	0.991

CONCLUSION:

In the current investigation, the effects of four yarn factors (cotton materials, twist multiplier, cotton/polyester blend ratio and spinning system) on pilling propensity of cotton/polyester blend woven fabrics are individually studied under five rubbing cycles. Results can be summarized in the following conclusions:

1- The woven fabrics made by spun yarns from Egyptian variety "Giza 86" was more pilling-resistant followed by those woven by Egyptian variety "Giza 95" and at last the Greek variety "Meddling".

2- There was negative association between twist multiplier and pilling propensity indicating that the fabrics woven using the lowest twist multiplier (3.7) had low pilling-resistant and vice versa.

3- As the polyester proportion increased in the fabrics woven using cotton/polyester blend, the pilling propensity would be increased.

4- The fabric produced using combed spun yarns had low pilling-propensity compared to those fabrics woven using carded spun yarns.

5- The polyester proportion % of the cotton/polyester blend fabrics is the main determinant in the pilling phenomenon.

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