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Effect of yarn twist on tensile strength, abrasion and pilling resistance of plain-woven cotton fabric

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The effect of twist on tensile strength, abrasion resistance, and pilling resistance of plain-woven fabric has been studied. The plain-woven fabric has been produced from open-end spun cotton yarn. The weft yarn has been produced at 4 different twist levels (900, 905, 910, and 915 TPM) and the effect of twist levels is also studied. To examine the effect of twist, four different samples of plain-woven fabric are produced from these yarns. From the ANOVA results, it is found that with an increment in twist level of the yarn, there is a significant increment in tensile strength, abrasion resistance, and pilling resistance of the fabric.

Keywords: Abrasion resistance, Cotton fabric, Plain-woven fabric, Pilling resistance, Tensile strength, Yarn twist

1 Introduction

Plain-woven cloth is made by the interlacement of two sets of threads, namely warp and weft threads. It has versatile applications in the textile sector, like bed sheets, table cloth, shirting, curtain, and so on. The reason for their wide range of usage can be explained in various ways.

Firstly, it has the firmest structure of fabric when compared with other kinds of weave structures. Secondly, plain-woven fabric has a high percentage of total production. The third reason is, it can be produced on looms with two harness frames, and the production cost is relatively very low. It is also convenient for both printing and dyeing because of its smoother and regular surface when compared with other kinds of weave structures[1]. Studies by different scholars showed that the tensile strength, abrasion resistance, and pilling resistance of woven fabric are affected by fabric structure, weave type, yarn count, yarn hairiness, and weight of the fabric[2-5].

The pills on the fabric surface are formed as a result of a dynamic equilibrium between two opposing effects of wear off and pill formation as shown in Fig.1. The loose fibres are then entangled by exerted abrasion forming a pill. The anchor fibres broke eventually as the abrasion continued and the pill breaks off[6]. Various factors are affecting the pilling tendency of the fabric, such as fibre fineness, tenacity & staple length, and yarn twist direction, count, spinning process & hairiness[7].

The abrasion causes physical damage to the fabric, yarn, and fibre due to rubbing of fabric surface on other surfaces[5]. The abrasion significantly depends on the variation in fabric surface smoothness and friction, yarn diameter, fabric thickness, and the ability of the fibres to withstand mechanical forces[8]. Cleaning, wearing, washing, or use of fabric also cause abrasion which might alter the fabric structure as the fibres or yarn are pulled out or avoid fibres coming from the fabric surface[5, 9]. Abrasion results in damage of characteristics of fabrics, such as appearance and strength.

Abrasion and pilling are also affected by the hairiness of the yarn[10]. The hairiness appears on the yarn, producing bars, streaks, or other visual disturbance on the fabric. The protrude fibre on the

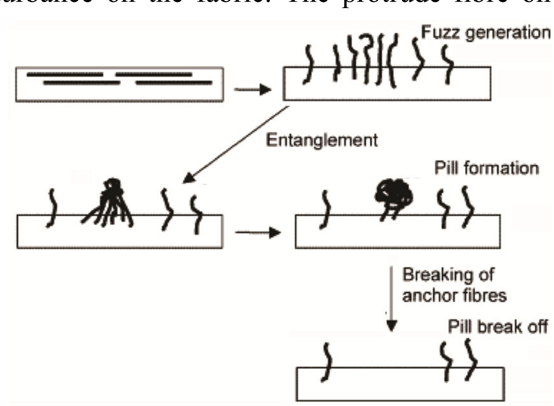

Fig. 1 — Formation of the pill on the fabric surface[7]

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yarn ends often break and drop from the hairy yarns by abrasion[11, 12]. Hairiness in yarns leads to fuzzy and hazy appearance of fabric. According to Uster, 15% of fabric defects and quality problems are due to hairiness. The pilling tendency of the fabric is higher if a hairy yarn is used in fabric manufacturing[13].

Previous studies showed that twist of fabric affects appearance, strength, and dye uptake of fabric as well as cause irregularities in properties of different parts of the fabric[14]. However, the effect of twist on pilling resistance and abrasion resistance has not been studied in depth to the best of my knowledge. The aim of this work is, therefore, to examine the effect of twist on pilling resistance, abrasion resistance, and tensile strength of 100% cotton plain-woven fabric.

2 Materials and Methods

2.1 Materials

20 Ne **w**arp yarn (twist level 910 TPM) and 20 Ne weft yarns (twist levels 900, 905, 910, and 915 TPM) were obtained from Bahir Dar Textile Share Company, Bahir Dar, Ethiopia. Both warp and weft yarns were spun using open-end spinning machine (R923).

2.2 Methodology

2.2.1 Fabric Sample Preparation

Four fabric samples were produced on Picanol air-jet weaving machine (OMNI plus 800) with the following parameters: 20 Ne warp and weft yarn count, 133.3 g/m^2 mass per unit area, 24 ends/cm, and 18 picks/cm of fabric with 500 rpm of machine speed.

2.2.2 Characterization of Fabric Property

To examine the effect of twist on abrasion resistance, pilling resistance, and tensile strength of the woven fabric, the following tests were carried out:

Abrasion Resistance Test

Abrasion resistance was carried out with a Martindale abrasion resistance tester (MARTINDALE 2568) according to ISO12947[15].

Pilling Resistance Test

Pilling resistance tests were done with a Martindale pilling tester (MARTINDALE 2568) according to ISO 12945/1[16].

Tensile Strength

Tensile strength was tested on a universal tensile strength Tester (TENSOLAB1000) according to ISO 13934/1[17].

3 Results and Discussion

3.1 Effect of Twist on Abrasion Resistance

Testing the abrasion or wear resistance of the textile fabric is very essential for clothing. Though abrasion or wear initially affects the appearance, gradually it deteriorates the entire textile product. Therefore, wear or abrasion resistance has been the focus of numerous investigations[18]. In this study, four fabric samples were prepared with weft yarn of different twist levels (900, 905, 910, and 915TPM) and then evaluated for abrasion resistance at 5000 cycles of abrasion rate. The result is analyzed by ANOVA and bar chart according to Table 1 and Fig. 2.

It is expected that the statistic "F" follows F distribution with (k − 1) = 3 and (n − k) =56 df. Thus, at 5% level of significance, that is at α = 0.05, $F_{(k-1), (n-k), \alpha} = F_{(3), (56), (0.05)} = 2.6$ according to [19]. As it is clearly shown in Table 1, F ratio =23.4 > $F_{(3), (56), (0.05)}$ =2.6 therefore, the average abrasion rates at 5000 cycles are not the same for fabric made from different twist levels. So, from the result, it can be concluded that, increasing the twist level of the yarn results in a significant increment of the abrasion resistance of the fabric.

The results in Fig. 2 also show the effect of twist on the abrasion resistance of the fabric. Increasing twist

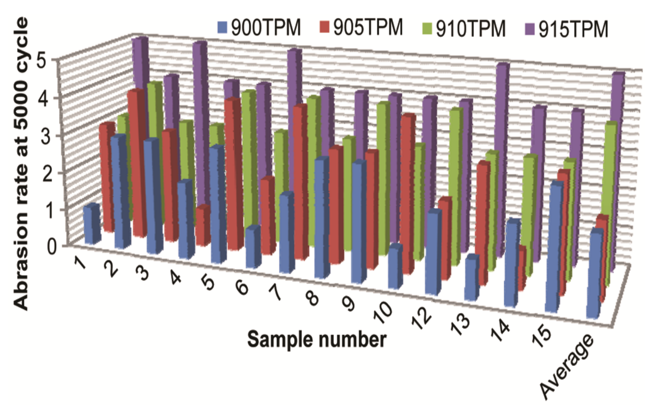

Fig. 2 — Effect of twist on abrasion resistance of fabric

Table 1 — ANOVA for abrasion resistance

Source	df (degree of freedom)	SS (sum of square)	MSS (mean of sum of square)	F ratio
Factor A (twist)	K =3	SSA = 39.3	MSSA=$\frac{SSA}{K-1} = \frac{39.3}{3} = 13.1$	F=$\frac{MSSA}{MSSE} = \frac{13.1}{0.56} = 23.4$
Error	n – k=56	SSE = 31.3	MSSE=$\frac{SSE}{n-k} = \frac{31.3}{56} = 0.56$	
	n – 1==59	TSS = 70.4		

multiplier increases the abrasion resistance of the fabric. As the weft yarn twist increases from 900TPM to 915TPM, the abrasion resistance of the fabric also increases from 2.1 to 4.3 on the greyscale. The lower the abrasion rate fabrics are more susceptible to fabric surface damage by abrasion. This propery of fabric can influence surface properties and durability.

3.2 Effect of Twist on Pilling Resistance

Little entangled fibres or pill clinging on the fabric surface is formed by wear and creates an unpleasant appearance on the garment surface. It is a problem for a user as well as fabric and garment manufacturer. Due to the pilling effect, the textile fabric quality is substantially reduced and it has also a negative effect on the user of the fabric[7]. In the present study, the test result for pilling resistance is analyzed by ANOVA (Table 2 and Fig 3).

Table 2 shows that F ratio =21.2 > $F_{(3),\ (56),\ (0.05)}$ =2.6, which implies that the average number of pilling rates is not the same for fabric made from different twist levels. As a result, the average number of pilling rates at 5000 cycles is not similar for different twist levels. From the ANOVA result, it can be deduced that as the twist of the yarn increases the pilling of fabric is significantly reduced.

Figure 3 shows that the twist of the yarn affects the pilling resistance of the fabric. Increasing the twist level of the weft yarn increases the pilling resistance of the fabric. Increasing the weft yarn twist from 900TPM to 915TPM increases the pilling resistance of the fabric substantially. The lower the pilling rate the more is the pilling on the surface of the fabric, and the higher pilling rate shows that there are insignificant entangled or balls of fibres on the surface of the fabric. This property of fabric can influence the surface properties of the fabric and also affects the properties of the fabric but does not affect the durability of the fabric.

3.3 Effect of Twist on Tensile Strength

One of the most important properties of woven fabric is its tensile strength, which makes it preferable in several applications. This is a mandatory fabric specification for the buyers, since it is an indication of both yarn and fabric quality[20]. Apparel or garment manufacturer gives the priority for fabric strength in their selection of woven fabric. Many factors are influencing the strength of the fabric such as yarn strength, twist direction, twist amount, yarn bending behaviour, yarn count, spinning system, and bending properties[3]. In this study, the effect of twist on the tensile strength property of the fabric has been examined and results are analyzed by ANOVA and bar chart, according to Table 3 and Fig. 4 respectively.

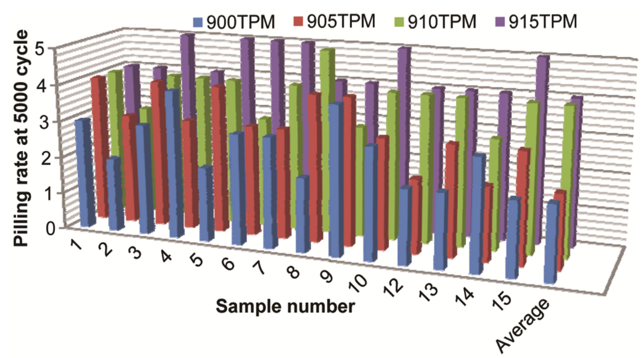

Fig. 3 — Effect of twist on pilling resistance of fabric

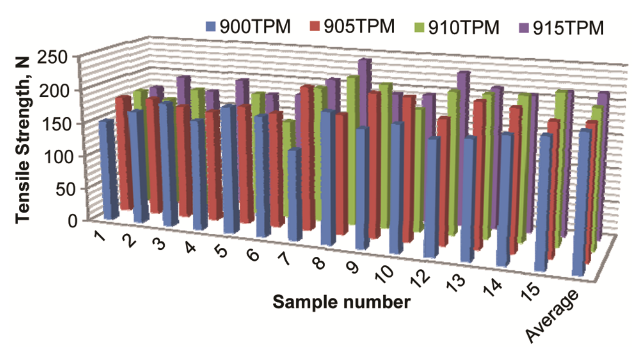

Fig. 4 — Effect of twist on tensile strength of fabric

Table 2 — ANOVA for pilling resistance

Source	df	SS	MSS	F ratio
Factor A (twist)	K – 1=3	SSA = 26	MSSA=$\frac{SSA}{K-1} = \frac{26}{3} = 8.7$	F=$\frac{MSSA}{MSSE} = \frac{8.7}{2.6} = 21.2$
Error	n – k=56	SSE = 23	MSSE=$\frac{SSE}{n-k} = \frac{23}{56} = 0.41$	
	n – 1=59	TSS = 49		

Table 3 — ANOVA for tensile strength tests

Source	df	SS	MSS	F ratio
Factor A (twist)	K =3	SSA = 5257.6	MSSA=$\frac{SSA}{K-1} = \frac{5257.6}{3} = 1719$	F=$\frac{MSSA}{MSSE} = \frac{1719}{387.5} = 4.43$
Error	n – k=56	SSE = 21,966.1	MSSE=$\frac{SSE}{n-k} = \frac{21,966.1}{56} = 387.5$	
	n – 1=59	TSS = 26,956.7		

As shown in Table 3, F ratio =4.43 > $F_{(3), (56), (0.05)}$ = 2.6, which implies that the average tensile strength of the fabric samples made from different twist levels of weft yarn is not the same. Therefore, from the result, it can be concluded that as the twist of the yarn increases the tensile strength of the fabric is also increased significantly.

Figure 4 shows that the twist of the weft yarn affects the tensile strength of the fabric. An increase of weft yarn twist increases the fabric tensile strength reasonably. As the twist level of the fabric is increased from 900TPM to 915TPM, the average tensile strength (breaking strength) of the fabric increases from 174.5N to 199.8N, which is in agreement with the findings of the previous study[14].

4 Conclusion

The ANOVA results show that an increase in the twist of the weft yarn improves the pilling resistance, abrasion resistance, and tensile strength of the fabric significantly. Increasing the twist level from 900TPM to 915TPM increases the abrasion resistance rate from 2.1 to 4.7, pilling resistance ate from 2.7 to 4.5, and tensile strength from 174.5N to199.8N. The results confirm that a substantial increase in a twist of yarn improves the performance of the fabric. Future study will entail the optimization of the twist for maximum improvement in these properties of the fabric, as it is known that an increase of twist above the limit reduces the strength of the yarn.

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