A Study on the Twist Loss in Weft Yarn During Air Jet Weaving

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ABSTRACT

Air jet weaving is considered to be the most advanced method of fabric production in which weft yarn is inserted with air pressure. But due to very high pressure some of yarn twist is lost during fabric production. This affects the strength of the yarn in general and quality of the fabric in particular. This study deals with the parameters affecting twist loss in weft yarn during air jet weaving. The subsequent effect of twist loss on the mechanical properties of yarn as well as fabric is also studied. A total of twenty-four different fabric samples were produced to consider the effect of yarn linear density, material, weave design and fabric width on the twist loss in picking and receiving sides of the woven fabric. The 100% cotton and polyester-cotton (PC) ring spun yarns having linear densities 37, 27 and 15 tex were used to produce fabrics in two different weaves i.e. 1/1 plain and 3/1 twill weave. In addition, two different fabric widths i.e. 121 and 100 cm were produced. The twist loss increases with increase in the fineness of yarn. In PC yarns twist loss percentage was higher as compared to cotton yarns. Twist loss in wider width was higher as compared to smaller widths of the fabric, while the effect of weave design was negligible.

Keywords: Air-jet weaving, Ring **s**pun yarn, TPI, Twist loss, Tensile strength

INTRODUCTION

A spun yarn is manufactured by twisting staple fibers or bonding them together, resulting in a fuzzy yarn with protruding fiber [1]. Weaving is a method of fabric production in which warp and weft yarns are interlaced. The twist in the yarn determines its structure and strength and when it is in fabric as a weft, its twist having impact on fabric properties like strength, drape, dye-up take etc. [2]. Most fabrics are produced using basic weaves, which are of three types: plain, twill and satin weave [3, 4]. Twist level plays an important role in the behavior of yarn by creating lateral forces which prevent the fibers in the yarn from slipping over one another. These forces bring the fibers closer, making the yarn more compact [5].

Currently, air-jet loom is the mostly used weaving machine in the textile industry because it provides good fabric quality at high production rates. Compressed air required for weft insertion is provided using the main nozzle, tandem nozzle and relay nozzles. The main and tandem nozzles provide primary acceleration to the weft yarn and relay nozzles maintain the pressure of air to keep the yarn straight while passing through the warp sheet/shed.

Twist plays a vital role in the properties of yarn as well as fabric. Twist affects the yarn strength, appearance and dye uptake. Twist loss causes irregularity of tensile properties in the different parts of the fabric. Twist loss also affects the dye take up properties of the fabric. High twist loss regions have more dye take up and vice versa. Twist loss in the weft yarn also increases the hairiness in the fabric [6]. Twist loss in the weft yarn occurs while weaving using shuttle as well as air jet looms [7]. The compressed air tends to untwist the yarn. Higher air pressure will exert higher force on the free tip of the weft yarn, so the untwisting will be rapid and easy. Thus the higher the air pressure, the higher the twist loss. Furthermore, if the yarn is subjected to compressed air for longer times, the chances of twist loss are higher [7, 8].

The over-end unwinding method is used for the withdrawal of the weft yarn from the cone before weft insertion. A certain amount of twist is added/removed from the weft yarn. In the case of air-jet looms, weft yarn is inserted using the frictional forces between yarn and air. In general, the insertion time is greater for finer yarn, as it is produced from long staple with high twist. The frictional forces between yarn and air will be less; hence the insertion time will be greater [9]. When a grooved nozzle is used, the twist loss increases significantly in the rotor spun yarn and increases in tex twist factor but decreases as the opening roller speed increases. Finer yarns exhibit considerably higher real twist loss, whereas increasing rotor speed initially decreases the twist loss followed by an upward trend [10]. The twist loss is closer to the selvedge than the middle of the fabric and twist loss has a significant effect on air permeability of the woven fabric [5].

From the literature review it can be concluded that twist loss occurs in the weft during air jet weaving and it significantly affects the global fabric properties. The greater the width of the fabric, the higher the twist loss in the weft yarn. No work can be found which analyzes the twist loss percentage in weft yarn during air jet weaving with respect to weave design, yarn linear density, material and fabric widths and determines the impact of these variables on the tensile strength of the picking and receiving sides of the fabric.

MATERIALS

In the present research ring spun cotton yarn having count of 30 tex was used as warp and six different types of ring spun yarns i.e. 37 tex cotton, 27 tex cotton, 15 tex cotton, 37 tex (Polyester/Cotton) PC, 27 tex PC and 15 tex PC yarns were used as weft. The blend ratio of PC yarns was 52:48.

METHODOLOGY

A total of twenty-four different fabric samples were prepared; 12 with cotton and 12 with PC as weft yarns, as shown in *Table I.* Threads per cm were 30 and 20 along warp and weft respectively for all the samples. Two weave designs used for this study- 1/1 plain and 3/1 twill. The woven fabric samples were produced on Toyota 600 air jet loom. Loom settings i.e. yarn tension, frame height, shed angle, etc., were constant for all the samples.

The twist per inch (TPI) and single yarn strength of weft yarns were measured before and after weaving. A digital TPI tester was used to determine the TPI according to the test method ASTM D1422 [12]. Single yarn strength was tested using Uster® Tensorapid 1 according to ASTM D2256 [11]. For yarn testing after weaving, the weft yarns were removed from both picking and receiving sides of the fabrics. Special care was taken to avoid the twist loss in yarn while removing from fabric. The twist loss % (both picking and receiving side) was determined by using TPI values of yarns before and after weaving.

TABLE I. List of samples produced for this study.

Sr. #	Weft material	Weft count (tex)	Loom width (cm)	Weave design
1	100 % Cotton	37	100	1/1 Plain
2				3/1 Twill
3			121	1/1 Plain
4				3/1 Twill
5		27	100	1/1 Plain
6				3/1 Twill
7			121	1/1 Plain
8				3/1 Twill
9		15	100	1/1 Plain
10				3/1 Twill
11			121	1/1 Plain
12				3/1 Twill
13	Polyester-cotton (52:48)	37	100	1/1 Plain
14				3/1 Twill
15			121	1/1 Plain
16				3/1 Twill
17		27	100	1/1 Plain
18				3/1 Twill
19			121	1/1 Plain
20				3/1 Twill
21		15	100	1/1 Plain
22				3/1 Twill
23			121	1/1 Plain
24				3/1 Twill

To investigate the effect of twist loss on the tensile properties, samples were cut from the fabric picking and receiving sides along weft direction. The tensile strength testing was done using a universal tensile strength tester LRX Plus according to ASTM D5034 [13]. The test was repeated five times to ensure reproducibility, and mean values were reported.

RESULTS AND DISCUSSION

Twist loss (%) of the weft yarn of the fabrics is shown in *Figure 1.* The effects of material, weave design, fabric width and yarn count are discussed below.

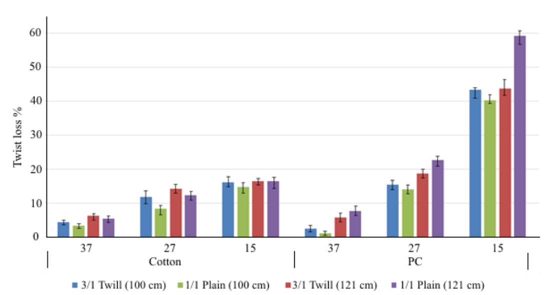


FIGURE 1. Twist loss percentage in different weft yarns.

Effect of Yarn Linear Density

It can be observed from *Figure 1* that the twist loss increases by increasing the fineness of the yarn. The maximum twist loss was observed for 15 tex yarn. In fact, more potential energy was stored in this yarn due to its higher twist per inch (TPI). During weft insertion, yarn tends to untwist because of stored potential energy. Compressed air not only untwisted the yarn itself but also expedited the process of twist loss due to potential energy.

Effect of Fabric Width

It can be noted from *Figure 1* that weft yarn twist loss in wider width is higher as compared to smaller width. The effect is more prominent in the case of PC blends, where more twist loss is observed for the 121 cm fabric width as compared to 100 cm fabric width. In case of cotton yarn, the effect is not as significant as for PC blends. The difference is more prominent for finer count i.e. 15 tex PC blend yarn. This is due to quick untwisting in fine yarn due to its high potential energy and greater air pressure per unit mass.

Effect of Fabric Weave

The present study investigated the weft twist loss in 1/1 plain and 3/1 twill woven fabrics. The hypothesis was based on the uneven separation of warp sheet in case of plain and twill weave during shedding. This can affect the compressed air distribution as yarn travels through the shed. The experimental results showed (*Figure 1*) that weave design affects the twist loss but to a very small extent, except for 15 tex PC yarn (1/1, 121 cm width). This difference may be attributed to the yarn hairiness or imperfections.

Effect of Material

In PC yarns twist loss percentage was higher than cotton yarns as shown in *Figure 1*. A higher flexural rigidity of the PC yarn is a possible reason for more twist loss. Due to higher flexural rigidity, more potential energy is stored in the polyester as compared to cotton fibers for the same amount of twist. Therefore, yarn made of polyester fibers or their blends has more tendency to untwist during insertion. Twist loss percentage of weft yarn on both picking and receiving sides for cotton is shown in *Figure 2* and that for PC yarn is shown in *Figure 3*.

Figure 2 clearly showed that twist loss in yarn was higher on the receiving side as compared to the picking side for weave design and fabric widths for all counts. This was due to the fact that yarn on the receiving side travelled a greater distance than that on the picking side resulting in higher interaction between air and yarn and higher twist loss on the receiving side. The twist loss percentage in 37 tex cotton and PC yarns on picking side was less than the 27 tex and 15 tex yarns. Similarly, the twist loss percentage in 37 tex cotton and PC yarns on receiving side was less than the 27 tex and 15 tex yarns.

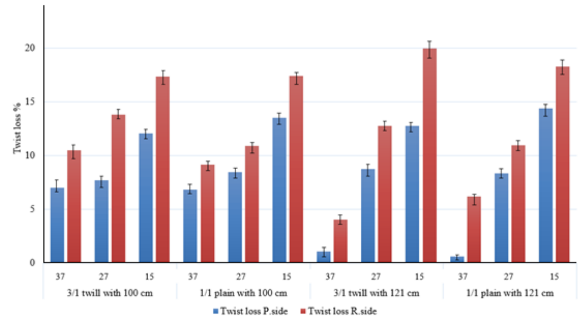


FIGURE 2. Twist lost percentage on picking and receiving side for cotton weft yarns.

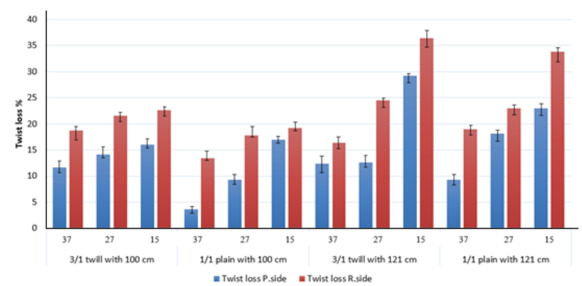
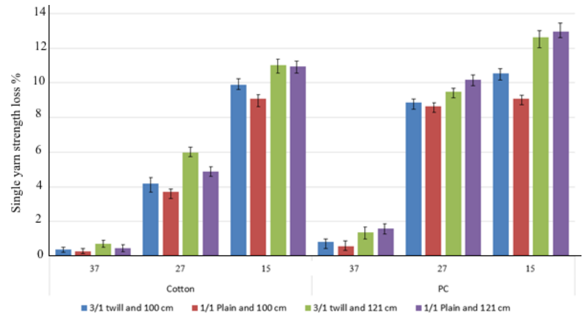


FIGURE 3. Twist lost percentage on picking and receiving side for PC weft yarns.

Figure 3 shows the twist loss percentage in PC yarns on both picking and receiving sides for different weave designs, counts and fabric widths. Similar trend of twist loss was found in PC yarns- there was more twist loss on the receiving side as compared to the picking side. In PC yarns the maximum twist loss on the picking and receiving sides occurred in the 15 tex count yarn having 3/1 twill weave with 121 cm width. This was due to the higher TPI in 15 tex PC yarn. The minimum twist loss on both the picking and receiving sides occurred in 37 tex count yarn with 1/1 plain with 100 cm fabric width of as shown in *Figure 4*. This is a result of the lower TPI in the 37 tex PC yarn.



1FIGURE 4. Single yarn strength loss percentage in different yarns.

Therefore, the twist loss on the picking side was always lower than the receiving side. The reason behind the lower twist loss on picking side in both cotton and PC yarns was that the weft was inserted from the picking side and then travels to the receiving side. The yarn on receiving side faced more air pressure which caused more untwisting. On the other hand, the picking side yarn faced less forces caused by air. Furthermore, yarn is held on the picking side during insertion while the yarn on the receiving side is free. Therefore, the yarn on picking side has less twist loss compared to the receiving side.

Six single yarn strengths were measured from fresh cones and used as reference values. Twenty four repetitions of single yarn strength from different locations in the fabric were measured. The single yarn strength loss percentage was calculated in relation to the reference values. The single yarn strength loss percentage of cotton and PC yarns, weave designs, fabric widths and yarn counts was calculated and plotted in *Figure 4.*

The single yarn strength loss percentage was lowest in 37 tex yarn count for both cotton and PC weft yarns, while the maximum single yarn strength loss percentage occurred in 15 tex yarn count for both cotton and PC materials. This was due to the lower TPI loss in 37 tex yarn count compared to the 15 tex yarn as shown in *Figure 2*. Therefore, the loss in single yarn strength is directly proportional to the loss in TPI of the yarn. In addition, the single yarn strength loss was higher in 121 cm widths compared to the 100 cm widths of fabric both in cotton and PC yarns. Thus, as fabric width increases, twist loss and single yarn strength loss of the fabric also increase.

Tensile strength on the picking and receiving sides of the fabric with cotton yarn in the weft direction with both weaves and widths was measured and is as shown in *Figure 5*. From *Figure 5*, the fabric tensile strength on picking sides of the fabrics with cotton yarns as weft was always higher than that of the receiving side. This is due to lower twist loss on the picking compared to the receiving side. Since the strength of the fabric mainly depends upon the strength of yarn, more twist in the yarn means higher yarn and fabric strength. On the picking side, there was less twist loss in the yarn so the strength loss on the picking side was lower. Similar trend of tensile strength loss was found in all counts on picking as well as receiving side, whether the weave was 1/1 plain or 3/1 twill. On both the picking and receiving sides, the tensile strength of 37 tex cotton count was higher than 27 tex and 15 tex cotton yarns. This is because in 37 tex cotton count TPI twist loss was lower than in the 27 tex and 15 tex cotton yarns. The lowest fabric tensile strength on the picking side occurred in 15 tex yarn with 100 cm width while on the receiving side, minimum fabric tensile strength occurred in 15 tex yarn woven having 121 cm width.

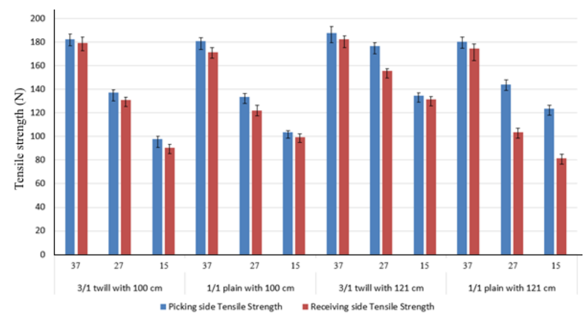
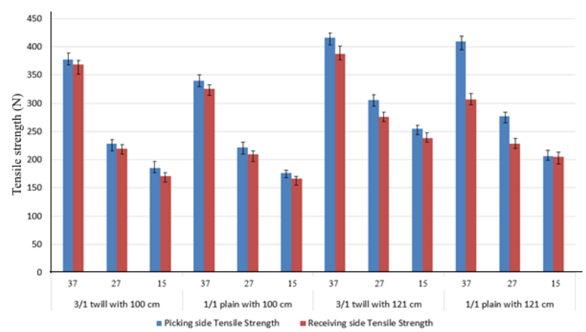


FIGURE 5. Cotton fabric weft wise tensile strength.



2FIGURE 6. PC Fabric weft wise tensile strength.

Similarly, tensile strength on the picking and receiving sides of the fabric having PC yarns in weft direction with different weave designs and fabric width was measured (*Figure 6*). It can be observed from *Figure 6* that the fabric tensile strength on the picking side of the fabric having PC yarns as weft was always higher than the receiving side. A similar trend is tensile strength loss was found in the fabric with PC yarns in weft direction. The maximum strength loss was found in the fabric having weft wise 15 tex PC yarn as compared to the fabrics having 37 tex and 27 tex PC yarns as weft. This is due to the relatively high TPI in 15 tex yarns, resulting higher losses in twist and strength. The maximum fabric tensile strength on both the picking and receiving sides occurred in the fabric woven with 37 tex count yarn with 121 cm width. The minimum fabric tensile strength on both the picking and receiving sides occurred in 15 tex yarn woven with 100 cm fabric width.

Twist loss did not have any considerable effect on the fabric tensile strength as weave changed because it primarily depends on single yarn strength. However, the tensile strength on picking side was always higher than on the receiving side since the twist loss on the picking side was lower than on the receiving side of the fabric.

CONCLUSION

The twist loss increases with increase in the fineness of the yarn or decrease in the tex number. Twist loss in the weft yarn increases as fabric strength increases. There was negligible effect of weave design on the twist loss except in the case of 15 tex PC (1/1, 121 cm width). This difference may be attributed to the yarn hairiness or imperfections. In PC yarns twist loss percentage was higher than cotton. The reason behind the higher twist loss in PC yarn is the higher stiffness of polyester fibers. Twist loss percentage was higher on receiving side yarn as compared to the picking side yarn for both weave design and fabric widths at all counts. In addition, the single yarn strength loss was directly proportional to the twist loss in the yarn. The tensile strength on picking side of the fabric was always higher than the receiving side, for both cotton and PC weft yarns. This is a result of less twist loss on the picking side compared to the receiving side. Therefore fabric strength loss was also lower on picking side. Twist loss did not have any considerable effect on the fabric tensile strength as the weave changed because it primarily depends on single yarn strength, but twist loss was significantly different on the picking and receiving sides of the fabric.

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