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The study of twist loss of rotor spun weft yarns in air jet loom and its effect on fabric properties

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ABSTRACT

The efficiency of air jet weaving machines and fabric properties are influenced by weft yarn twist and this greatly affects physical and mechanical properties of woven fabrics. Most studies conferred the weft yarn twist affects the physical, mechanical and comfort fabric properties but they did not consider the twist loss of rotor spun weft yarn during air jet weft insertion. Fabric samples were produced from 30tex, 37tex and 59tex rotor spun weft yarns by changing air pressure in an air jet weaving machine. Physical and mechanical properties were investigated by using different testing equipment according to ASTM standards (ASTMD 5035-95, ASTMD 1424-96, ASTMD 1777, ASTMD 1422-99 and ASTMD 737-04). The result shows that the weft yarns have significance twist loss at 95% confidence level and twist loss on the right side of the fabric is higher than the left side. The twist loss percentage of weft yarns varied with weft count and air pressure, for example, the twist loss percentage of 30 tex, 37 tex, and 59 tex yarns was 6.63 %, 5.74% and 4.44% respectively with same air pressure. The twist loss of weft yarns during air jet weft insertion significantly affects fabric thickness, tensile strength, and air permeability though other fabric property like tear strength did not show significance change.

Key words: Twist loss, weft tension, air jet loom, rotor spun yarn, woven fabric, fabric properties.

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1. INTRODUCTION

Air-jet weaving is an advanced weaving method with high efficiency and productivity. However, the weft yarn motion in air-jet weft insertion is very complicated. It is not a positively controlled process, and the air stream during the weft insertion process is turbulent and unsteady with regard to its velocity, it could be compressible. The transferred material, i.e. weft yarn, also has its complications, especially in the case of staple yarns. The weft yarn propulsion force is provided by the friction between the yarn surface and the air stream **(**Nosratya *et al* 2008).

In air jet weft insertion, the tip of the weft thread is not griped and there is freedom of the weft to untwist during insertion resulting in twist loss during weaving which affects fabric properties. This twist loss varies with weft parameters, air pressure and fabric width.

1.1 Insertion Configurations and the Movement of Weft Yarn During Insertion

The movement of the inserted yarn in the weft passage is a complex motion as it is not a positively controlled process (Szabó and Szabó 2012). During the weft insertion, two consecutive main nozzles positioned in the loom frame and sley are used to accelerate the yarn which could have an impact on fabric quality. Another group of important elements for an efficiently run weft insertion are the auxiliary or relay nozzles. The relay nozzles create air flow in the reed channel in order to compensate for loss of the air flow through reed dents and warp sheets (Brun *et al* 2008).

1.2 Influence of Weft Yarn Properties on Performance of Air Jet Weft Insertion

In air jet weft-insertion process the properties of the yarn have a great effect. The insertion time depends on the mass of the yarn, air pressure and types of yarn. Factors that essentially determine whether the yarn is suitable for pneumatic insertion are its count, structure and twist (Adanur 2001).

A further factor that influences both the resistance to the stress and the capacity to be transported are the count and twist of yarn. In particular, an increased count leads to an increase in resistance but also to a bigger difficulty in transport (Brun *et al* 2008). Different yarn counts have different linear densities, and so the velocity of a thin weft yarn is much higher than the velocity of the thick weft yarn, which also has low starting velocity as a result of the inverse relationship between velocity and mass. Since a high twist coefficient makes the yarn more compact and smoother, it reduces the yarn velocity and increases the insertion time. Increase in yarn count increases the velocity of the weft yarn led through the tube (Kayacan *et al* 2004).

Adanur and Mohamed (1988) studied the effect of weft characteristics on performance of air jet weaving machines and concluded that: high air-supply pressures increase the air velocity inside the tube, which reduces insertion time and increases yarn velocity.

1.3 Influence of Weft Yarn Twist on Fabric Properties

The properties of fabrics depend more or less on many various technical and technological parameters which should be adjusted during the design phase of a fabric (Gabrijelčič *et al* 2008). The change in the fiber packing in turn determines the cover of fabric and such other properties as warmth, crease recovery, permeability and various other related characteristics. Twist also affects the hairiness of yarns, which is a very important property in determining the pilling behavior and the economics of the singeing process (Khanum *et al* 2011).

Theoretically, the fabric thickness is equal to the sum of minor diameter of crossed yarns. Therefore, the changes in minor diameter in the fabric by the yarn twist may have an obvious effect on fabric thickness (Afrashteh *et al* 2013). The twist level of weft yarns influenced only weft tensile strength and breaking elongation measurements in case of unbalanced weave and its effect is same to the warp yarn for balanced weave (Paek and Winsor 1988).

The count of yarn has negative influence and twist level of the yarn has positive effect on fabric tensile strength woven from rotor spun yarns (M.D. Teli *et al* 2008). Bursting strength of the fabric has directly associated with twist multiplier of yarns and inversely related with yarn count. The influence of twist multiplier is also more significant for fabrics produced from rotor yarns than that of ring yarn. There is a significant effect of weft yarn twist on tear strength of woven fabric. As the weft yarn twist increases, the fabric tear strength will be increased as a result of yarn strength increments which are associated with the freedom of yarns movement (Dhamija and Chopra 2007).

As twist increase, the yarn diameter and the cover factor are decreased which increases air permeability since increasing yarn twist allows the more circular, high-density yarns to be packed closely together in a tightly woven structure with reduced air permeability (Khanum *et al* 2011).

1.4 Twist Loss of Rotor Spun Yarn During Air Jet Weft Insertion

The twist of rotor spun yarns is in principle built up from the inside to the outside (TyaGi 2010). Rotor spun yarn has the advantage of good evenness, less count variation and imperfections (Ghanmi *et al* 2015). Freedom of the weft to untwist during insertion results in twist loss during weaving which affects the strength of the fabric; its dye up takes and possibly other properties. Twist factors used in the yarns influence such fabric properties as tensile strength, tearing strength, resistance to abrasion, handle, and so on (Parekh *et al* 2011).

On an air jet loom, a significant loss of twist occurs in the weft yarn because of the presence of free leading end. This twist loss results in lower weft yarn strength simultaneously, loosening the yarn structure, which may lead to its easy flattening in the fabric thereby increasing fabric cover and the friction contact between warp and weft yarns (Dhamija and Chopra 2007).

2. Materials and Methods

2.1. Materials

Plain woven sample fabrics are produced from 30 tex, 37 tex, 59 tex 100% cotton rotor spun weft yarns and 30 tex warp yarn. All the sample fabrics were produced at a Picanol air jet weaving machine equipped with electronic pressure regulator, electronic weft tensioner and with the necessary automations by varying air pressure of nozzles and the count of weft yarns as shown in Table 1. Air jet weaving machine has main and multi-hole relay nozzles with profile reed weft insertion system. The loom runs with an average speed of 500 revolutions per minute for 190 cm fabric width during sample fabrication. The yarns and fabrics were tested in accordance to ASTM standards D1422-99 and D1422-99 (Yarns), ASTM Standards D 5035–95, D 1424, D 1777 and D 737–04 (Fabrics).

2.2. Sample Fabrics Production

Sampled fabrics were produced in Bahir Dar textile Share Company on an air jet weaving machine. The warp threads count used for all samples was 30 tex and all other weaving parameters are the same except the weft yarn count, weft density and air pressure of main and relay nozzles (see Table 1).

Table 1. Sample fabrics

			Air pressure (bar)	
Sample no	Fabric density	Weft count	Main nozzle	Relay nozzles
S2	24 ends/cm 18 picks/cm	30 tex	2	3
S5		30 tex	2	5
S8		30 tex	5	3
S10		37 tex	2	4.5
S11		37 tex	4	3
S12		37 tex	5	3
S13	24 ends/cm 15 picks/cm	59 tex	5	5
S14		59 tex	5	3
S15		59 tex	6	4

2.3. Fabric Property Testing

Different fabric properties have been tested on both the left and right sides of each sample fabrics to evaluate the effect of weft yarn twist loses mainly the twist of weft yarn before and after weaving, thickness, tensile strength and breaking elongation, tear strength, and air permeability. All tests were conducted according to ASTM standards as described in Table 2.

Table 2. Yarns and Fabrics assessment

Test	Testing machines used	Test method	Number of tests
Twist of yarn from the weft supply package	Electronic twist tester	ASTM D1422-99	25
Twist of weft yarn from fabric	Electronic twist tester	ASTM D1422-99	25
Tensile strength of fabric in weft direction	Tensolab universal strength tester	ASTM D 5035–95	10
Tear strength of fabric in weft direction	Digital Elmendorf tear strength	ASTM D 1424	5
Fabric thickness	digital fabric thickness tester	ASTM D 1777	20
Air permeability	air permeability tester	ASTM D 737–04	10

3. Results and Discussions

3.1. Twist Losses of Rotor Spun Weft Yarns in Air Jet Weaving Machine

Twist losses of weft yarns have been determined by twist difference between weft yarn from the supply package and twist of ravel weft yarns from the fabric**.**

Figure 1 shows the twist per meter for different weft counts both before and after weaving.

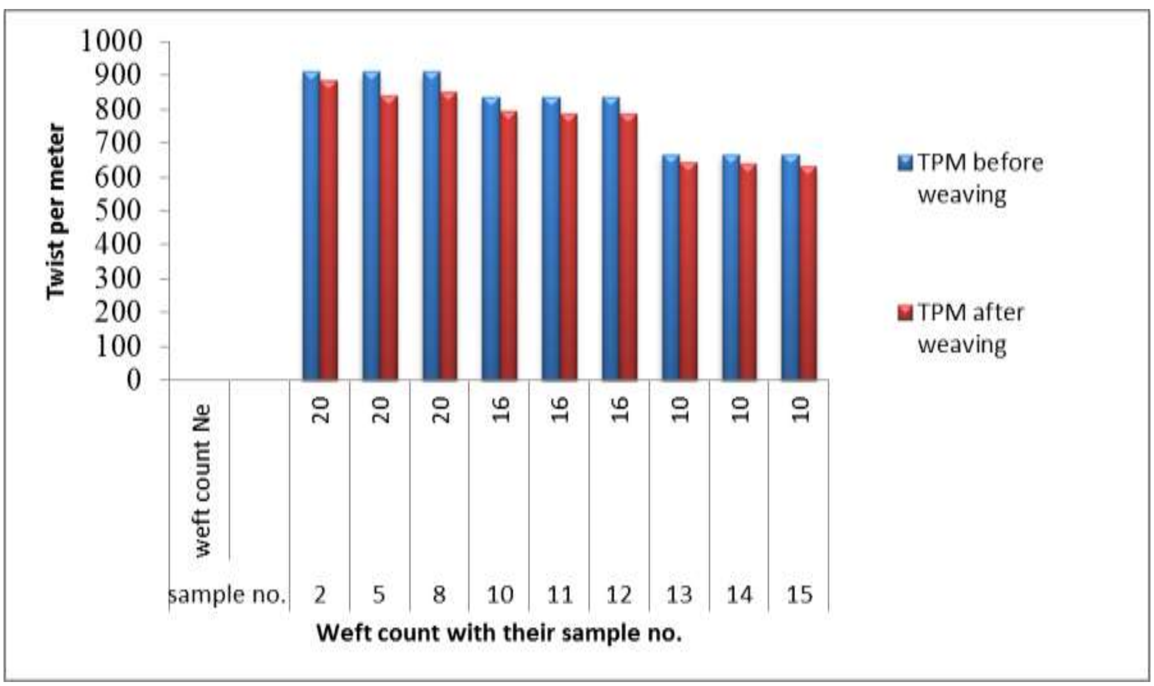

Figure 1. Twist of different weft count before and after weaving

For all samples twist of weft yarns from the weft package is higher than twist of unraveled weft yarns from each sample.

The twist comparison was done by using one sample t-test as shown in Tables 3-5. Since the p-values of all samples are less than 0.05, results in Tables 3-5 shows that the average twist of weft yarn before weaving has been found significantly different from the average twist of weft after weaving and the twist loss is statistically significant at 95% confidence level.

Table 3. Significance test of average twist loss of 20Ne weft yarn by one sample t-test

Sample no.		Test Value = 912 TPM (turns/m)					
		t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
S2	TPM	-3.619	24	.002	-26.59848	-41.9818	-11.2152
S5	TPM	-16.642	24	.000	-70.76208	-79.6618	-61.8623
S8	TPM	-13.518	24	.000	-60.49296	-69.8591	-51.1268

Table 4. Significance test of average twist loss of 16 Ne weft yarn by one sample t-test

Sample no.		Test Value = 835 TPM (turns/m)					
		t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
S10	TPM	-8.169	24	.000	-38.03425	-47.7787	-28.2898
S11	TPM	-5.843	24	.000	-45.79558	-62.1997	-29.3914
S12	TPM	-7.495	24	.000	-47.90813	-61.2876	-34.5286

Table 5. Significance test of average twist loss of 16 Ne weft yarn by one sample t-test

Sample no		Test Value = 668 turns/m					
		t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
S13	TPM	-4.671	24	.000	-22.47820	-32.5506	-12.4058
S14	TPM	-14.270	24	.000	-29.65920	-34.0094	-25.3090
S15	TPM	-20.934	24	.000	-35.38730	-38.9254	-31.8492

3.2 Effect of Air Pressure on Twist Loss of Weft Yarn

Table 6 shows the effect of air pressure on twist loss of 20 Ne weft yarn. Samples No. 2, 5 and 8 are produced from 20 Ne weft count with different air pressure of the main and relay nozzles. Twist loss increases as air pressure increases and there is significant twist loss due to the change in air pressure of weft insertion by the air jet. Twist loss of sample no. 2 is less than that of sample no. 5 and 8 and sample no. 8 has higher amount of twist as compared with sample no. 5. These three samples were produced with the same weaving parameters except air pressure of the main and relay nozzles. Therefore, the difference in twist loss of weft yarn among these samples is only due to variation of air pressure of weft insertion nozzles. As shown in table 5 the twist loss of weft yarn from sample no. 2 is significantly lower than that of sample no. 5 and 8 at 95% confidence level, but twist loss difference between sample 5 and 8 is not statistically significant at 95 % confidence level. The mean difference of TPM between sample no. 5 and 8 shows that twist loss of sample no. 5 is higher than 8 and this indicates air pressure of relay nozzles results to higher twist loss as compared with air pressure of main nozzles.

Table 6. Effect of air pressure on average twist loss of weft yarn by multiple comparisons

Dependent Variable: TPM (turns/meter)						
(I) Sample no	(J) Sample no	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
2	5	38.81400*	11.88745	.012	6.7984	70.8296
	8	35.30400*	11.88745	.026	3.2884	67.3196
5	2	-38.81400*	11.88745	.012	-70.8296	-6.7984
	8	-3.51000	11.88745	.991	-35.5256	28.5056
8	2	-35.30400*	11.88745	.026	-67.3196	-3.2884
	5	3.51000	11.88745	.991	-28.5056	35.5256

3.3 Effect of Yarn Count on Twist Loss of Weft Yarn

Twist loses percentages of weft yarns are different for different weft counts. The twist losses percentages are high for fine weft yarns and less for coarse weft yarns as shown in Figure 2. The mass per unit length differences between finer and coarser yarns resulting higher twist loses for the finer yarns since finer yarns can rotate easily during weft insertion for the same air pressure. Sample 8, 12 and 14 are produced from 30 tex, 37 tex and 59 tex weft counts respectively with air pressure of 5 bar for main nozzle and 3 bar for relay nozzles. Twist loss percentage of 30 tex, 37 tex and 59 tex weft yarns are 6.634 %, 5.738% and 4.44% respectively.

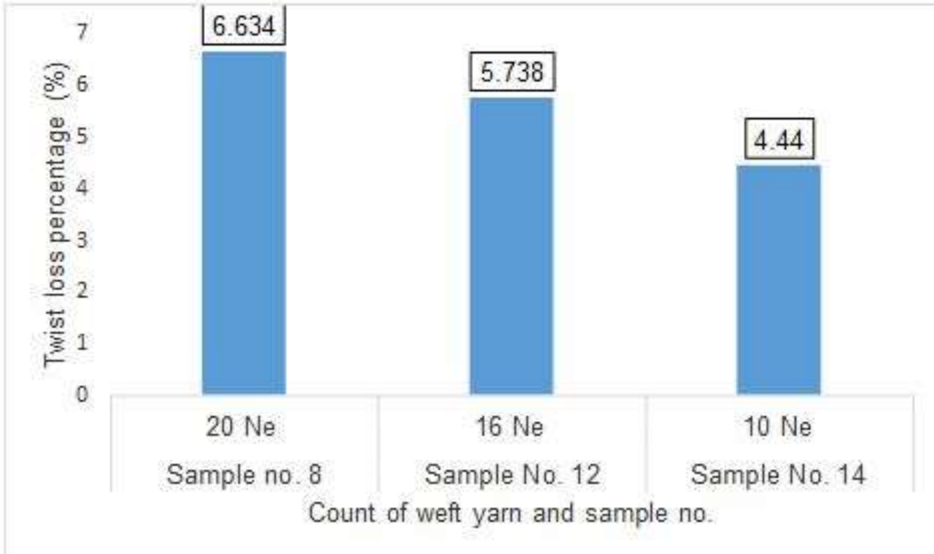

Figure 2. Percentage of weft yarn twist loss with different weft count

3.4 Twist Loss Comparison on the Left and Right Side of Fabric

The twist loss percentage of weft yarn on the left (on Weft Insertion Side) and right side (Opposite to Weft Insertion) of the fabric is different as shown in Figure 3. During weft insertion by air jet, the right side of weft yarn has more contact time with the air jet and loses more turns of twist as compared to the left side.

Table 7. Twist loss percentage on left and right side of fabric

		Sum of Squares	Df	Mean Square	F	Sig.
Twist loss percentage Vs position of specimen on the sample	Between Groups (Combined)	150.1	1	150.1	16	.000
	Within Groups	2367.1	258	9.17		
	Total	2517.3	259			

As shown in Table 7, the twist losses of weft yarn differences on the left and right side of the fabrics are statistically significant with 95 % confidence level since P-value is 0.001 which is less than 0.05. Hence, the twist loss of the weft yarn on the weft insertion side (left side of the loom) is less than on the right side of the fabrics. Figure 3 also shows twist loss percentage of weft yarns (30 tex, 37 tex and 59 tex weft yarns) both on the weft insertion side and opposite side of the fabrics.

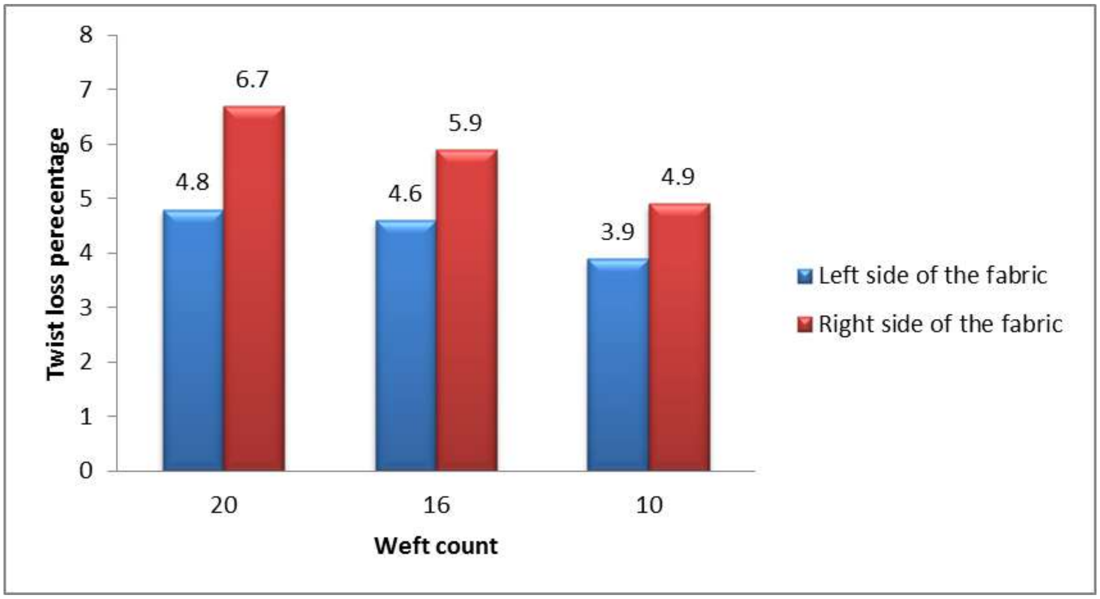

Figure 3. Twist loss at the left and right side of different samples

3.5 Effect of Twist Loss on Fabric Thickness

The thickness of fabric on the right side is 4.3 % greater than that of the left side fabric. A fabric thickness difference of 0.023 mm is the result of change in weft diameter by twist loss. When yarn twist is reduced, yarn diameter will increase and then fabric thickness also increases. Table 8 also shows the thickness of fabrics on the left and the right sides are statistical different at 95% confidence level.

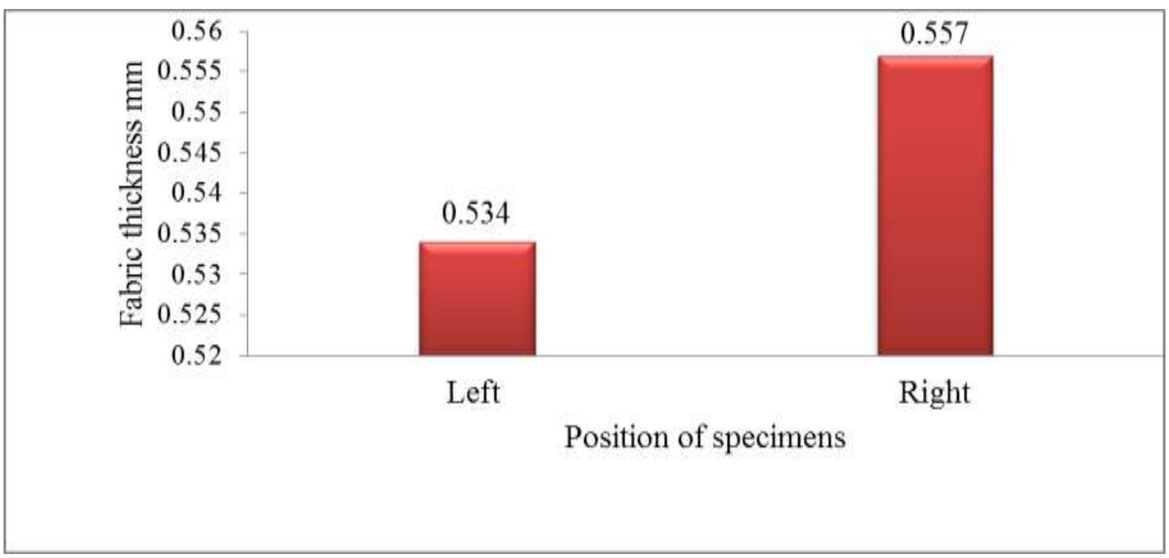

Figure 4. Average thickness on the left and right side of the fabric

Table 8. Fabric thickness on the left and right side

			Sum of Squares	df	Mean Square	F	Sig.
Thickness mm * position of specimen on the sample	Between Groups	(Combined)	.038	1	.038	21.42	.000
	Within Groups		.492	278	.002		
	Total		.530	279			

3.6 Effect of Twist Loss of Weft Yarn on Tensile Strength of Woven Fabrics

The difference between mean tensile strength at the left and right side of fabric is significant since p=0.001 which is less than 0.05 (Table 9). So, the mean breaking strength of fabric on the left side is greater than the right side because of high twist loss of weft yarn on the right side of the fabric.

Table 9. Breaking strength of fabrics on the left and right side

			Sum of Squares	df	Mean Square	F	Sig.
Tensile breaking force N * position of specimen on the sample	Between Groups	(Combined)	43262.8	1	43262	16.5	.000
	Within Groups		5330658.6	2030	2625		
	Total		5373921.5	2031			

3.7 Effect of Twist Loss of Weft Yarn on Tear Strength of Woven Fabric

Twist loss of weft yarn has insignificant effect on the tear strength of fabrics in the weft direction at 95% confidence level. As shown in Table 10 mean tear strength on left and right side of the fabric has no significant differences as p- value is greater than 0.05 (Table 10). Tear strength of fabric is mainly affected the structure, extensibility and breaking strength of the fabric. So the tear strength of fabric on the left and right side is statistically insignificant at 95% confidence level.

Table 10. Comparison of tear strength of sample fabrics on the left and right side

			Sum of Squares	Df	Mean Square	F	Sig.
Tear force N * position of specimen on the sample	Between Groups	(Combined)	.594	1	.59	.02	.91
	Within Groups		5669.6	128	44.2		
	Total		5670.2	129			

3.8 Effect of Twist Loss on Air Permeability of Woven Fabrics

Air permeability at the right side is higher than the left side of the fabric and the difference is significance at 95% confidence level for all fabric samples produced from 20 Ne weft counts. It was shown (3.4) that weft yarn twist on the left side is higher than the right side of fabrics produced by air jet loom. If weft yarn twist is higher on the left, yarn diameter becomes less and it has low hairiness this helps close the space between weft yarns by beating up forces during weft insertion therefore, air permeability of the left side is lower than the right side of the fabric (Table 11).

Table 11. Air permeability left and right side of fabrics for 20Ne weft count

Sample no				Sum of Squares	Df	Mean Square	F	Sig.
2	Air permeability * position of specimen on the sample	Between Groups	(Combined)	729.6	1	729	41.5	.000
		Within Groups		316.2	18	17.5		
		Total		1045.8	19			
5	Air permeability * position of specimen on the sample	Between Groups	(Combined)	165.8	1	165.8	6.2	.000
		Within Groups		481.0	18	26.7		
		Total		646.9	19			
8	Air permeability * position of specimen on the sample	Between Groups	(Combined)	240.1	1	240.1	7.9	.000
		Within Groups		546.4	18	30.3		
		Total		786.5	19			

4 Conclusion

The twist loss of rotor spun weft yarns and its effects on properties of plain-woven fabrics have been investigated. Twist loss of rotor spun weft yarns during air jet weft insertion is significant at 95% confidence level. The twist loss percentage of 30 tex, 37 tex and 59 tex weft yarns are 6.63 %, 5.74% and 4.44 % respectively with same air pressure (5 bar for main nozzle and 3 bar for relay nozzles). Twist loss percentage of fine yarns is higher than that of coarse yarns. Twist loss of 30 tex weft yarns is 2.92 %, 7.75 % and 6.63% with air pressure of 2 bar main with 3 bar relay nozzles, 2 bar main with 5 bar relay nozzles and 5 bar main with 3 bar relay nozzles respectively. Therefore, it can be concluded that twist loss increases as the amount of air pressure increases during air jet weft insertion and the effect is statistically significant at 95% confidence level. Twist loss percentage on the right side of the fabric was found to be higher than on the left resulting in higher fabric thickness on the right side. Results show that twist loss of weft yarns significantly affects fabric breaking strength, thickness and air permeability with 95% confidence level whereas, its effect is not statistically significant for bursting strength, tear strength and grams per square meter. The twist loss of weft yarns has positive effect on fabric thickness and air permeability but fabric breaking strength decreases as twist loss increases.

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