EFFECT OF THE SINGLE-YARN TWIST AND PLY TO SINGLE-YARN TWIST RATIO ON THE HAIRINESS AND ABRASION RESISTANCE OF COTTON TWO-PLY YARN

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Abstract

The effect of single-yarn twist and ply to single-yarn twist ratio on the evenness, hairiness and abrasion resistance of two-ply cotton yarn has been studied. The hairiness of two-ply yarn decreases as either the single-yarn or ply twist increases. The rate of reduction in hairiness with respect to twist is more for the single-yarn twist than for the ply twist, particularly for the finer two-ply yarn. Variation in hairiness decreases as the ply twist increases. Yarn-to-yarn abrasion shows a different trend as compared to yarn-to-emery abrasion at a low ply twist level. Two-ply yarn with 3/4 of the single-yarn twist shows the highest abrasion resistance in both yarn-to-yarn abrasion and yarn-to-emery abrasion. The abrasion resistance of the two-ply yarn depends on both single-yarn twist and ply twist. Single-yarn twist and ply twist have a more influential effect on the yarn-to-yarn and yarn-to-emery abrasion resistances respectively of cotton two-ply yarns.

Key words:

abrasion resistance, cotton two-ply yarn, fibre trapping, hairiness, ply twist, single-yarn twist

1. Introduction

As the staple yarn is made of fibres of finite lengths, protruding fibres on the yarn surface are inevitable. The weaving performance of warp yarn mainly depends on the protection of surface fibres in the yarn, elongation percentage, strength, and variation in strength. If the single yarn is taken as a warp for weaving, without protecting or binding the surface fibres, the protruding fibres will be easily peeled off, and may forms knops on the yarn due to the abrasion of yarn against various weaving elements, which will continue until the yarn breaks. The protruding fibres on the yarn may entangle with the protruding fibres on the adjacent yarn and cause incorrect shedding, shuttle fly and thread breakages etc. For the above reasons, the single yarn is not directly taken for weaving as warp yarn, without sizing. Hence the binding of the surface fibres of warp yarn is essential to achieve satisfactory weaving performance.

In single yarn, it is not possible to protect the surface fibres without sizing. But in the case of ply yarn, the fibres on the surface of each strand of a ply yarn can be bound to one another [5], and hence the surface fibres cannot be loosened and peeled off easily during abrasion. The hairiness and abrasion resistance of ply yarn will directly depend on the frequency of surface fibres trapping between the strands. The abrasion resistance of ply yarn also depends on cohesion between the fibres. Hence it is necessary to maximise the number of binding points per unit length of a fibre, and to optimise the cohesion between the fibres to obtain a yarn with low hairiness and highly resistant to abrasion.

Unevenness, imperfection and hairiness of two-ply yarn are lower than that of single and double-rove spun yarn [3,7]. The abrasion resistance and weavability of two-ply yarn are superior to those of single and double-rove spun yarn. Barella & Manich [1] reported that the abrasion resistance of rotor yarn increases as yarn twist increases. The effect of single-yarn and ply yarn twist factor on the characteristics of blended ring and rotor two-ply yarn has been studied [4,9]. Unevenness of polyester/cotton two-ply yarn increases as single and ply twist factors increase. Salhotra & Ghosh [6] derived equations for relating thick places, thin places and neps in single and ply yarns. However, not much work has been reported on the effect of single- to ply-yarn twist ratio and single-yarn twist on the hairiness and abrasion resistance of two-ply yarn.

In this work, the effect of ply to single-yarn twist ratio and single-yarn twist on the evenness, hairiness and abrasion resistance of cotton two-ply ring yarn is discussed.

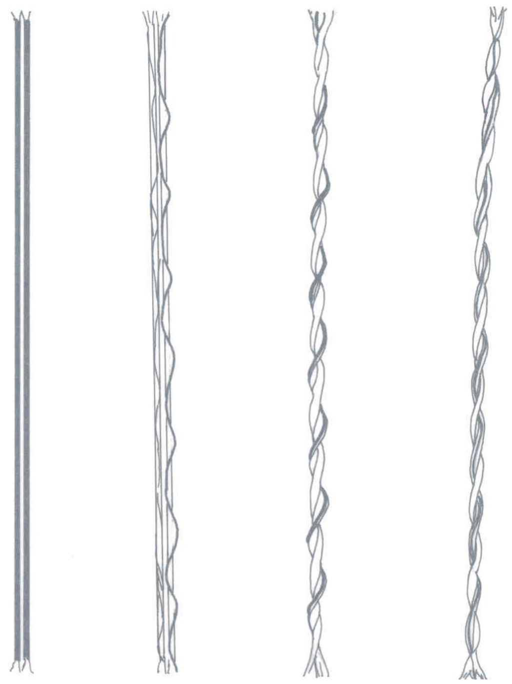
1.1. Trapping surface fibres in the ply yarn

Plate & Lappage [5] explained the mechanism of binding surface fibres in two-fold yarn by means of a model in which the two single strands are represented by long rubber cylinders (Figure 1). A line is drawn along the length of one rubber cylinder representing the surface fibre (Figure 1a). Next, the two cylinders are taken together and twisted in Z or S direction. It is interesting to note that the line drawn on one cylinder will never trap between the two cylinders (Figure 1c); the line is continuously trapped between the cylinders in case the line on one cylinder is in contact with another cylinder when the two cylinders are taken together for twisting. However if each cylinder is twisted before plying, the line drawn on one cylinder follows a helical path around the cylinder (Figure 1b). If the two cylinders are now twisted together in any direction, the line drawn on the cylinder is frequently trapped between the cylinders (Figure 1d). The higher the number of turns per unit length given to the cylinder before plying, the higher will be the frequency of line trapping between the cylinders. The frequency of surface fibre trapping between the strands does not depend on the amount and direction of the ply twist; it only depends directly on the amount of single-yarn twist before plying. The higher the single-yarn twist before plying, the lower will be the two-ply yarn hairiness, and so the higher is the abrasion resistance.

2. Materials and methods

2.1. Preparation of yarn samples

Combed cotton yarn samples of 14.8 tex and 9.8 tex were spun using a Lakshmi G 5/1 Ring frame from rovings of 369.1 tex and 246 tex respectively. The yarn samples were produced with different levels of twist (a normal twist level and 10 to 50% higher than a normal twist level). Then each of these yarn samples was ply-twisted in the opposite direction to single-yarn twist at three different ply-twist levels (1/3, 1/2 and 3/4 the single-yarn twist).



(a) (b) (c) (d)

Figure 1. Mechanism of surface fibre trapping between two strands (a) Untwisted strands (b) Twisted strands (c) Untwisted strands plied (d) Twisted strands plied

2.2. Evenness and hairiness measurements

The evenness and hairiness of the two-ply yarn was measured using a Premier IQ evenness tester by Premier Polytronics Ltd. The yarn was tested at a speed of 400 m/min for a period of one minute. Ten tests were carried out for each sample.

2.3. Yarn-to-yarn and yarn-to-emery abrasion resistance

Yarn-to-yarn and yarn-to-emery abrasion resistance were measured using a yarn abrasion tester. The method of yarn guiding in the yarn abrasion tester for yarn-to-yarn abrasion and yarn-to-emery abrasion measurements are shown in Figures 2 and 3 respectively. Zero-grade emery paper was wrapped around the guide D for yarn to emery abrasion measurement. One end of the yarn was fixed on the clamp C, the other end was threaded through the guides as shown in the figures, and finally the latter was hung with a dead weight E. A 20-g dead weight was used for yarn-to-yarn of 14.8 tex × 2 and 9.8 tex × 2 yarn, and yarn-to-emery of 14.8 tex x 2 yarn. Yarn-to-emery abrasion of 9.8 tex × 2 yarn was carried out with a dead weight of 10g. The yarn was wrapped once round around the guide D for yarn-to-yarn abrasion, in order to avoid a change of the portion of yarn being abraded during testing. Due to the up-and-down movement of the yarn guides, abrasion of the yarn takes place. The number of cycles required to break the yarn was measured. Thirty tests were carried out for each sample.

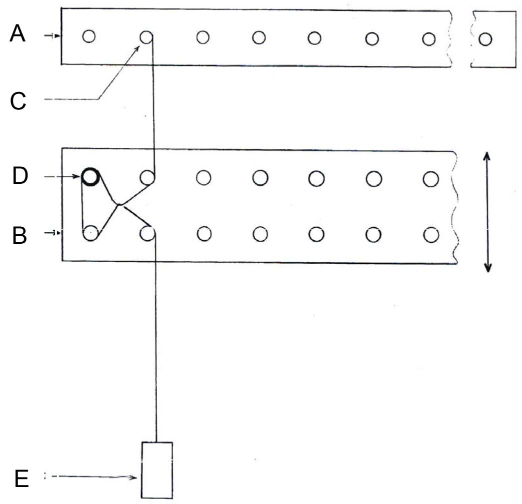


Figure 2. Method of guiding the yarn in the abrasion tester for yarn-to-yarn abrasion measurement
A – Stationary bar containing clamps, B – Traverse bar containing yarn guides,
C – Clamp D – Yarn guide, E – Dead weight

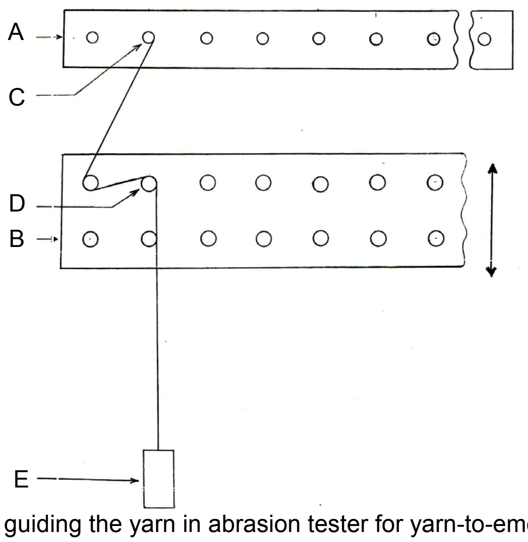


Figure 3. Method of guiding the yarn in abrasion tester for yarn-to-emery abrasion measurement;
A - Stationary bar containing clamps, B - Traverse bar containing yarn guides,
C - Clamp, D - Yarn guide, E – Dead weight

3. Results and discussion

3.1. Effect of single-yarn twist and ply to single-yarn twist ratio on evenness

Table 1 and 2 show the evenness of 14.8 tex × 2 and 9.8 tex × 2 yarns respectively. The results show that the U% and CV% of two-ply yarn are much lower than those of the single yarn as expected. Since 14.8 tex single yarn would normally be more regular than 9.8 tex yarn, the 14.8 tex × 2 yarn has a lower U% and CV% than that of 9.8 tex × 2 yarn. There is no significant difference in the U% and CV% of the two ply yarns produced with different levels of single-yarn twist and ply-yarn twist. The numbers of thick places, thin places and neps between the samples do not show any consistent trend.

3.2. Effect of single-yarn twist and ply to single-yarn twist ratio on hairiness

Table 3 and 4 shows the hairiness of 14.8 tex × 2 and 9.8 tex × 2 yarns respectively. The results show that the hairiness value decreases as the single-yarn twist increases. This is due to the increase in the frequency of surface fibre trapping between the two strands per unit length in a two-ply yarn as the single-yarn twist increases [5]. It can be further inferred from Tables 3 and 4 that hairiness also decreases as the amount of ply twist increases, even though the number of fibres trapping between the strands does not depend upon the ply twist. This finding can be explained in terms of the area of contact between the two strands. The greater is the area of contact between the strands, the lesser will be the exposure of surface to the outside. At a low ply-twist level, the compression force on each strand of the ply yarn is low, due to the lesser degree of wrapping of one strand over another; furthermore, each strand of ply yarn will have a greater amount of strand twist, which will restrict the deformation of the strand due to compression. At a high ply-twist level, the high compression force on the strands and the low twist in the strands makes the strands flatten at the point of contact between the strands. Hence the increase in ply twist reduces the hairiness. The results also show that the increase of ply twist reduces the variation in hairiness.

Table 3. Effect of single-yarn twist and ply to single-yarn twist ratio on hairiness of 14.8 tex × 2 cotton ply yarn

Single yarn twist (turns/cm)	Ply to single-yarn twist ratio	Hairiness index	Standard deviation of hairiness
9.73	1/3	5.73	1.00
	1/2	5.58	1.19
	3/4	4.88	0.88
10.72	1/3	5.74	1.17
	1/2	5.35	1.05
	3/4	5.14	0.92
11.54	1/3	5.15	1.03
	1/2	5.07	1.08
	3/4	4.72	0.92
12.71	1/3	5.08	1.05
	1/2	4.93	1.03
	3/4	4.51	0.81
13.42	1/3	4.97	1.05
	1/2	4.64	0.96
	3/4	4.53	0.86
14.44	1/3	5.03	1.02
	1/2	4.91	1.01
	3/4	4.07	0.80

Table 4. Effect of single-yarn twist and ply to single-yarn twist ratio on hairiness of 9.8 tex × 2 cotton ply yarn

Single yarn twist (turns/cm)	Ply to single-yarn twist ratio	Hairiness index	Standard deviation of hairiness
11.89	1/3	6.42	1.22
	1/2	6.28	1.23
	3/4	5.61	1.10
13.67	1/3	6.06	1.16
	1/2	5.75	1.18
	3/4	5.12	1.00
15.52	1/3	4.86	0.95
	1/2	4.68	0.90
	3/4	4.32	0.83

Tables 5 and 6 show the percentage reduction in hairiness due to the increase of one turn of single-yarn twist and ply twist respectively. The rate of reduction in hairiness with respect to twist is greater in the case of single-yarn twist than for ply twist, particularly for the finer two-ply yarn.

Table 5. Percentage reduction in hairiness per turn of single-yarn twist

Yarn linear density	Average % reduction in hairiness per turn of single-yarn twist			
	At ply twist of 1/3 the single-yarn twist	At ply twist of 1/2 the single-yarn twist	At ply twist of 3/4 the single-yarn twist	Grand average
14.8 tex × 2	1.01	0.98	1.4	1.13
9.8 tex × 2	2.82	6.0	5.4	4.74

Table 6. Percentage reduction in hairiness per turn of ply twist

Yarn linear density	Average % reduction in hairiness per turn of ply twist		
	When the ply twist is increased from 1/3 to 1/2 the single-yarn twist	When the ply twist is increased from 1/2 to 3/4 the single-yarn twist	Grand average
14.8 tex × 2	0.76	1.13	0.95
9.8 tex × 2	0.63	1.15	0.89

3.3. Effect of single-yarn twist and ply to single-yarn twist ratio on the abrasion resistance of two-ply yarn

3.3.1. Yarn-to-yarn abrasion

Figures 4 and 5 show the effect of single-yarn twist on the number of yarn-to-yarn abrasive cycles required to break 14.8 tex × 2 and 9.8 tex × 2 yarns respectively. 9.8 tex × 2 yarns show better resistance to yarn-to-yarn abrasion than 14.8 tex × 2 yarns. This fact may be mainly attributed to the longer fibres used for spinning the 9.8 tex yarn.

As the single-yarn twist increases, the abrasion resistance of the ply yarn increases at all ply twist levels. As the single-yarn twist increases, the frequency of surface fibre trapping between the two strands, the fibre-to-fibre cohesion and strand-to-strand cohesions increase, and hence abrasion resistance increases. At a ply twist of 3/4 the single-yarn twist, the percentage of improvement in abrasion resistance due to the increase of single-yarn twist is phenomenal for 14.8 tex × 2 yarn, when compared with that of 9.8 tex × 2 yarn. A 10 to 15% increase in single-yarn twist increases the abrasion resistance of 9.8 tex × 2 and 14.8 tex × 2 yarns with 3/4 the single-yarn twist by about 25% and 75% respectively.

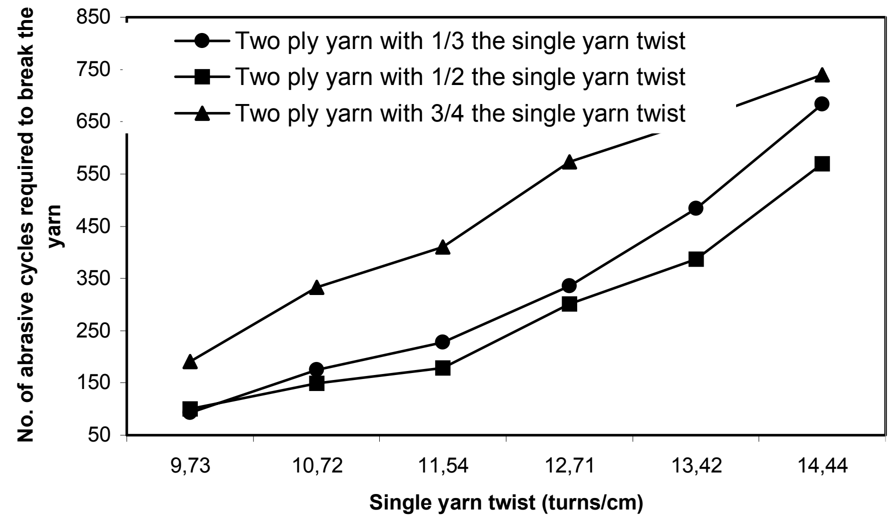


Figure 4. Effect of single-yarn twist on yarn-to-yarn abrasion resistance of 14.8 tex × 2 cotton ply yarn

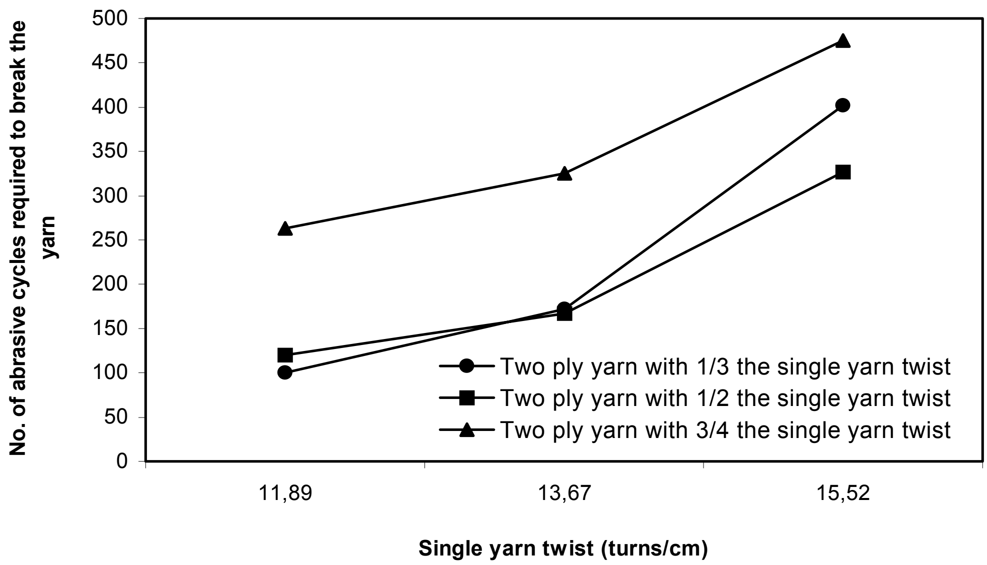


Figure 5. Effect of single-yarn twist on yarn-to-yarn abrasion resistance of 9.8 tex × 2 cotton ply yarn

The above observation is explained in terms of the longer and shorter fibres used for producing 9.8 tex × 2 and 14.8 tex × × 2 yarns respectively. The total area of contact of a fibre with other fibres and the number of times a surface fibre becomes trapped between the strands is greater for a longer fibre than for a shorter fibre in a ply yarn. Hence even with less fibre-to-fibre cohesion and strand-to-strand cohesion, the longer fibres cannot be easily pulled out during yarn-to-yarn abrasion. So, a further increase in the frequency of surface fibre trapping between the strands, fibre-to-fibre cohesion and strand-to-strand cohesion achieved by increasing the single-yarn twist would cause only a moderate improvement in the yarn-to-yarn abrasion resistance for the two-ply yarn produced from longer fibres. In the case of yarn produced from short fibres, the surface fibre can be easily pulled out during yarn-to-yarn abrasion, as the total area of contact of a fibre with other fibres and number of times the fibre trapped between the two strands is low. Hence the increase in the frequency of surface fibre trapping, fibre-to-fibre cohesion and strand-to-strand cohesion by increasing the single-yarn twist by a small amount can cause a tremendous increase in yarn-to-yarn abrasion resistance.

The two-ply yarn with 3/4 the single-yarn twist shows the highest abrasion resistance at all the single-yarn twist levels. This observation may be due to the better cohesion obtained through more wrapping of one strand over another and the better deployment of surface fibre trapping for the two-ply yarn with 3/4 the single-yarn twist.

At normal single-yarn twist level, two-ply yarn with 1/2 the single-yarn twist shows higher abrasion resistance than two-ply yarn with 1/3 the single-yarn twist. A further increase in single-yarn twist shows that the two-ply yarn with 1/3 the single-yarn twist has a higher abrasion resistance than two-ply yarn with 1/2 the single-yarn twist.

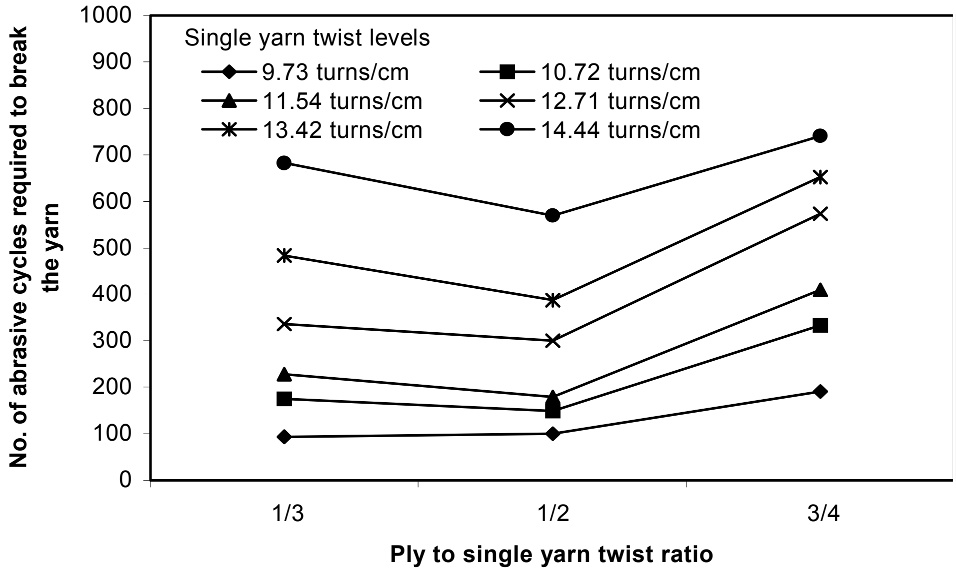


Figure 6. Effect of ply to single-yarn twist ratio on yarn-to-yarn abrasion resistance of 14.8 tex × 2 cotton ply yarn

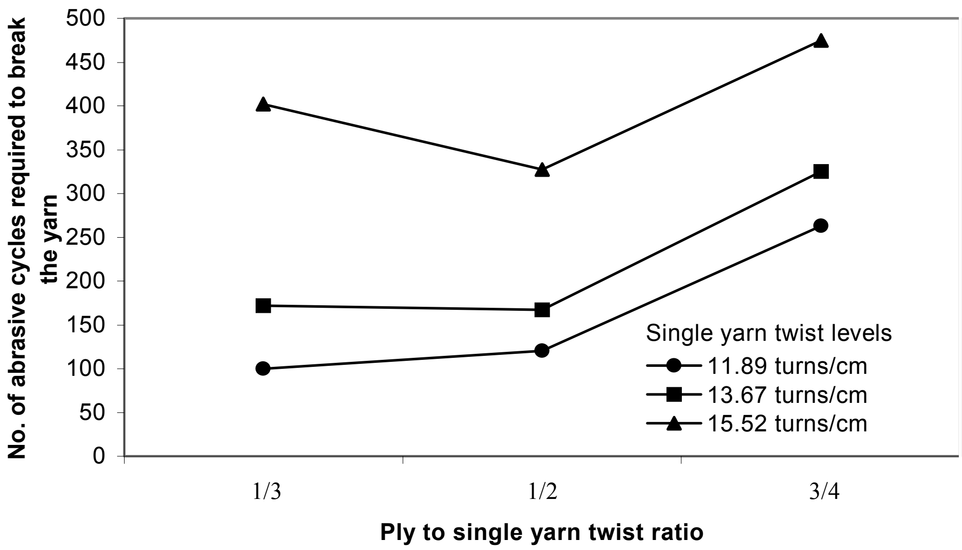


Figure 7. Effect of ply to single-yarn twist ratio on yarn-to-yarn abrasion resistance of 9.8 tex × 2 cotton ply yarn

Figures 6 and 7 show the effect of ply to single-yarn twist ratio on the yarn-to-yarn abrasion resistance of two-ply cotton yarns. A close scrutiny of the above figures reveals the following. At normal single-yarn twist level, increasing the ply twist from 1/3 to 1/2 the single-yarn twist increases the yarn-to-yarn abrasion resistance to a small extent. However, above the normal single-yarn twist level, increasing the ply twist from 1/3 to 1/2 reduces the yarn-to-yarn abrasion resistance. Increasing the ply twist from 1/2 to 3/4 the single-yarn twist improves the abrasion resistance to a very great extent at all single-yarn twist levels. Raising the single-yarn twist improves the yarn-to-yarn abrasion resistance to a greater extent at low ply-twist level than that at high ply twist level.

Tables 7 and 8 show the percentage improvement in yarn-to-yarn abrasion resistance due to the increase in one turn of single-yarn twist and ply twist respectively. These results reveal that the rate of improvement in yarn-to-yarn abrasion resistance with respect to twist is greater for the single-yarn twist than for the ply twist. The change in the single-yarn twist produces a very similar effect on both the tensile strength and yarn-to-yarn abrasion resistance, and so does the change in ply twist on both tensile strength and yarn-to-yarn abrasion resistance.

Table 7. Percentage improvement in yarn-to-yarn abrasion resistance per turn of single-yarn twist

Yarn linear density	Average % improvement in yarn-to-yarn abrasion resistance per turn of single-yarn twist			
	At ply twist of 1/3 the single-yarn twist	At ply twist of 1/2 the single-yarn twist	At ply twist of 3/4 the single-yarn twist	Grand average
14.8 tex × 2	20.2	16.8	13.3	16.8
9.8 tex × 2	22.9	14.9	7.8	15.2

Table 8. Percentage improvement in yarn-to-yarn abrasion resistance per turn of ply twist

Yarn linear density	Average % improvement in yarn-to-yarn abrasion resistance per turn of ply twist	
	When the ply twist is increased from 1/3 to 1/2 the single-yarn twist	When the ply twist is increased from 1/2 to 3/4 the single-yarn twist
14.8 tex × 2	-2.3	12.1
9.8 tex × 2	0.2	10.4

3.3.2. Yarn-to-emery abrasion

Figures 8 and 9 show the effect of single-yarn twist on the yarn-to-emery abrasion resistance of 14.8 tex × 2 and 9.8 tex × 2 yarns respectively. When the yarn-to-emery abrasion resistance values are compared with the yarn-to-yarn abrasion resistance values, there is no complete agreement in trends between the two test results. In the case of two-ply yarn with 1/2 and 3/4 the single-yarn twist, both the yarn-to-yarn and yarn-to-emery abrasion resistances follow almost the same trend with respect to single-yarn twist and ply twist. However, in the case of two-ply yarn with 1/3 the single-yarn twist, increasing the single-yarn twist increases the yarn-to-yarn abrasion resistance, whereas an increase in single-yarn twist does not significantly affect the yarn-to-emery abrasion resistance, in spite of the fact that an increase in single-yarn twist increases the frequency of surface fibre trapping between the strands, fibre-to-fibre cohesion and strand-to-strand cohesion. This conflicting trend may be due to the ply yarn with low ply-twist level behaving more like two single yarns grouped together during abrasion, which can be explained in terms of single-yarn abrasion resistance. It was observed in a separate study for single yarn that while an increase in single-yarn twist above the normal twist level does not significantly increase the yarn-to-emery abrasion resistance, the same effect causes an increase in yarn-to-yarn abrasion resistance (Tables 9 and 10).

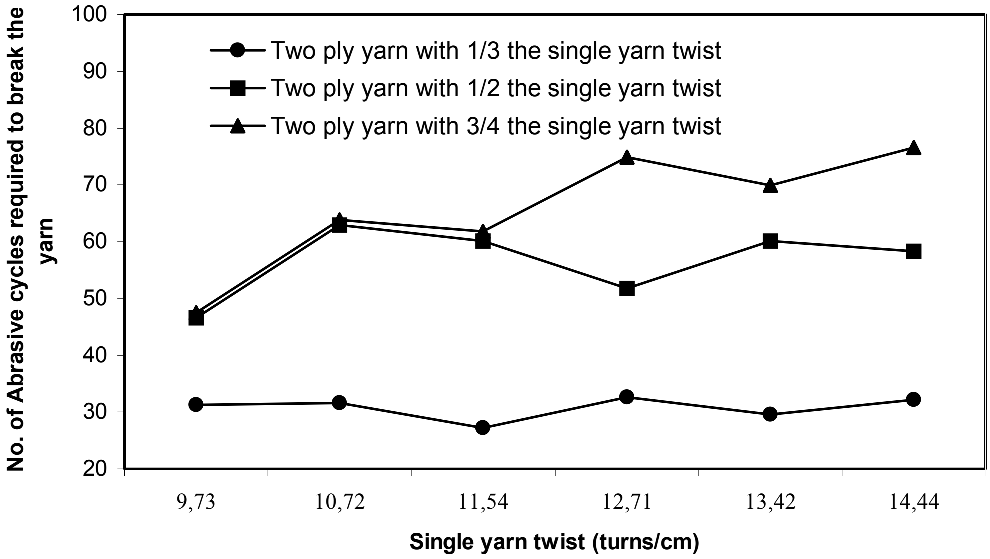


Figure 8. Effect of single-yarn twist on yarn-to-emery abrasion resistance of 14.8 tex × 2 cotton ply yarn

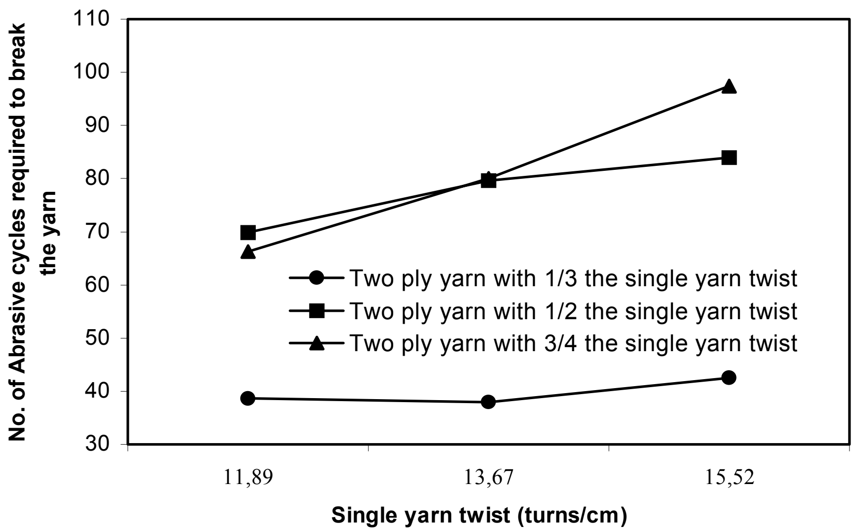


Figure 9. Effect of single-yarn twist on yarn-to-emery abrasion resistance of 9.8 tex × 2 cotton ply yarn

The difference in the behaviour of single yarn against itself and against emery can be explained by the mechanism of abrasion. The increase of single-yarn twist above the optimum level increases the cohesion between the fibres and also the stiffness of yarn. Increase of stiffness may reduce abrasion resistance as the stiffer yarn is unable to flatten or distort under pressure when being abraded [8]. Since cotton fibres are very smooth, as they contain wax, yarn-to-yarn abrasion failure would be greater because the fibres are pulled out of the yarn surface rather than being broken. Damage to the surface fibres would be more predominant when the abrasion is against emery. Hence an increase of stiffness due to an increase of twist would aid fibre damage, and further reduce abrasion resistance against emery than against yarn. So the yarn-to-yarn abrasion resistance would be improved with increased single-yarn twist; and in the case of yarn-to-emery abrasion, the improvement in abrasion resistance provided by fibre cohesion at increased single-yarn twist would be neutralised by the effect of fibre damage.

It can be inferred from the above discussion that the ply yarn abrasion resistance (both yarn-to-yarn and yarn-to-emery) depends in general on both single-yarn twist and ply twist. However, the single-yarn twist is ineffective on yarn-to-emery abrasion resistance when the ply twist is lower.

Table 9. Effect of twist on the abrasion resistance of 14.8 tex cotton single yarn

Turns/ cm	Yarn to yarn abrasion resistance (number of cycles required to break the yarn)	Yarn to emery abrasion resistance (number of cycles required to break the yarn)
9.73	166.5	13.2
10.72	227.8	14.7
11.54	304.4	13.8
12.71	386.7	12.7
13.42	501.1	13.5
14.44	547.2	14.2

Table 10. Effect of twist on abrasion resistance of 9.8 tex cotton single yarn

Turns /cm	Yarn to yarn abrasion resistance (number of cycles required to break the yarn)	Yarn to emery abrasion resistance (number of cycles required to break the yarn)
11.89	64.8	14.5
13.67	96.4	16.8
15.52	127.1	15.2

Two-ply yarn with 3/4 the single-yarn twist shows the highest yarn-to-emery abrasion resistance, followed by two-ply yarn with 1/2 and 1/3 the single-yarn twist at all single-yarn twist levels. This observation shows that the ply twist has a more predominant effect on yarn-to-emery abrasion resistance than does the single-yarn twist. This finding conforms to the results of earlier investigations done on abrasion of two-ply worsted yarn against hard steel finished with hard industrial-finish chromium plate [2]. As the single-yarn twist increases, the abrasion resistance of two-ply yarn with 1/2 the single twist first increases and then does not change significantly. However, two-ply yarn with 3/4 the single-yarn twist shows a gradual increase in the abrasion resistance of the yarn as the single-yarn twist increases. At high ply-twist level, most of the twist present in the strands is removed, and the two strands in the ply yarn are integrated into a single strand with high lateral pressure due to wrapping one strand over another. As the single-yarn twist increases, both the strand-to-strand cohesion and the frequency of surface fibres trapping between the two strands increases, which in turn increases the abrasion resistance. An increase of single-yarn twist by 10-15% increases the abrasion resistance of 14.8 tex × 2 and 9.8 tex × 2 yarns with 3/4 the single-yarn twist by about 35% and 20% respectively.

In the case of yarn-to-emery abrasion, the difference in the improvement of abrasion resistance between the coarser yarn produced with shorter fibres and the finer yarn produced with longer fibres due to an increase in single-yarn twist is lower compared to that observed during yarn-to-yarn abrasion. Even though the number of times a longer surface fibre becomes trapped between the two strands is greater for the finer two-ply yarn, the fibre breakage during yarn-to-emery abrasion would cause the single fibre to convert to many short fibres, leading to a reduction in the total number of trappings per fibre. This may be why there is less difference in improvement of abrasion resistance between finer and coarser two-ply yarns, due to the increase in single-yarn twist.

Figures 10 and 11 show the effect of ply to single-yarn twist ratio on the yarn-to-emery abrasion resistance of two-ply cotton yarn. Increasing the ply twist from 1/3 to 1/2 the single-yarn twist increases the yarn-to-emery abrasion to a great extent at all single-yarn twist levels. Increasing the ply twist from 1/2 to 3/4 the single-yarn twist does not increase the yarn-to-emery abrasion resistance up to the single-yarn twist of 120% the normal twist level. However at a high single-yarn twist level, an increase of ply twist from 1/2 to 3/4 the single-yarn twist increases the abrasion resistance of yarn against emery to a small extent.

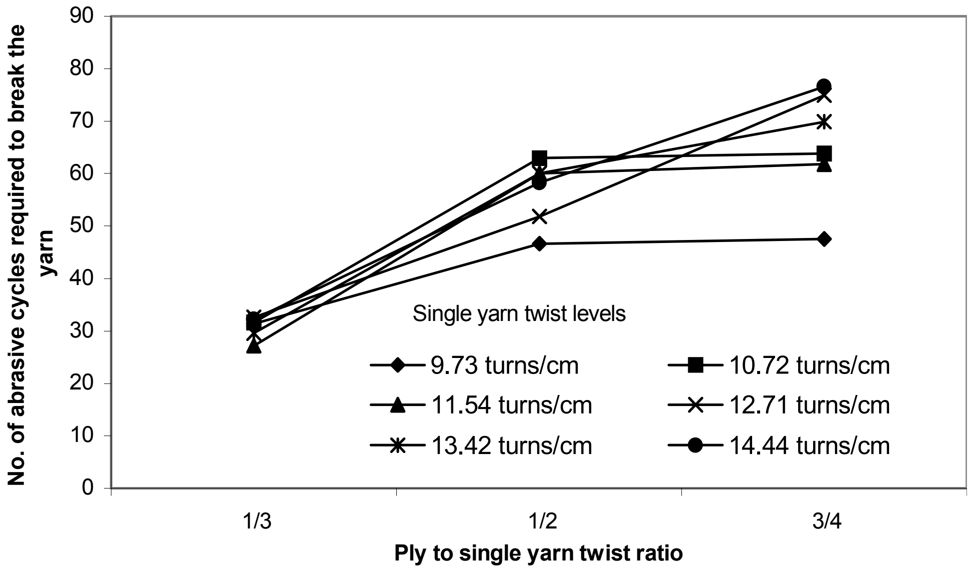


Figure 10. Effect of ply to single-yarn twist ratio on yarn-to-emery abrasion resistance of 14.8 tex × 2 cotton ply yarn

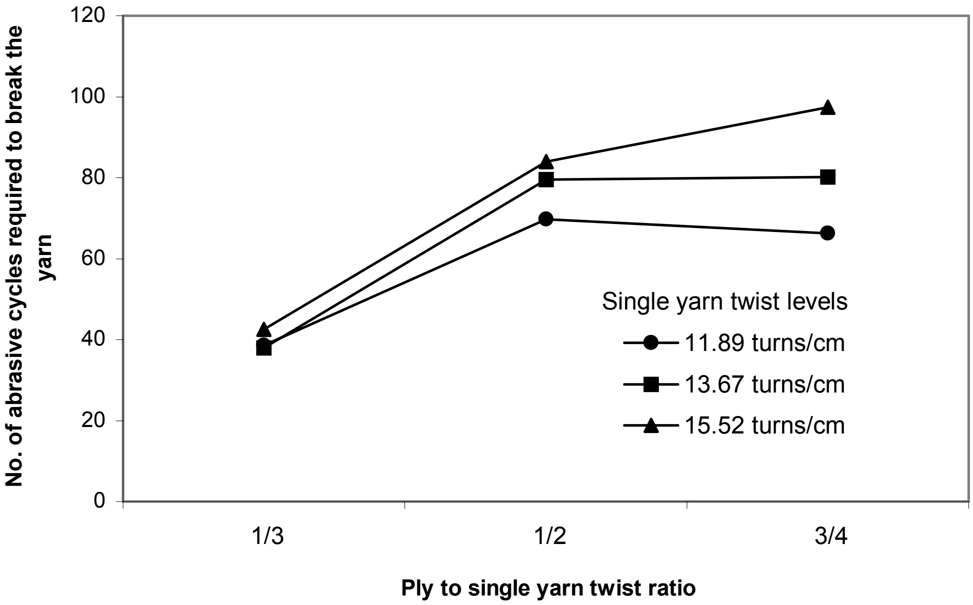


Figure 11. Effect of ply to single-yarn twist ratio on yarn-to-emery abrasion resistance of 9.8 tex × 2 cotton ply yarn

Tables 10 and 11 show the percentage improvement in yarn-to-emery abrasion resistance due to the increase of one turn of the single-yarn twist and ply twist respectively. The tables show that the ply twist has a more influential effect than the single-yarn twist on the yarn-to-emery abrasion resistance, particularly when the ply twist is increased from 1/3 to 1/2 of single-yarn twist.

Table 11. Percentage improvement in yarn-to-emery abrasion resistance per turn of single-yarn twist

Yarn linear density	Average % improvement in yarn-to-emery abrasion resistance per turn of single-yarn twist			
	At ply twist of 1/3 the single-yarn twist	At ply twist of 1/2 the single-yarn twist	At ply twist of 3/4 the single-yarn twist	Grand average
14.8 tex × 2	0.5	2.4	4.5	2.5
9.8 tex × 2	1.1	2.2	4.7	2.7

Table 12. Percentage improvement in yarn-to-emery abrasion resistance per turn of ply twist

Yarn linear density	Average % improvement in yarn-to-emery abrasion resistance per turn of ply twist	
	When the ply twist is increased from 1/3 to 1/2 the single-yarn twist	When the ply twist is increased from 1/2 to 3/4 the single-yarn twist
14.8 tex × 2	16.8	1.9
9.8 tex × 2	16.6	0.3

Conclusions

The following conclusions have been drawn from the above discussions on the results of evenness, hairiness and abrasion resistance of cotton two-ply yarns with different levels of single-yarn and ply-yarn twist.

i) The rate of reduction in hairiness with respect to twist is greater for the single-yarn twist than for the ply twist, particularly for the finer two-ply yarn.

ii) Single and ply twist levels do not affect the evenness of two-ply cotton ring yarn.

iii) The 9.8 tex × 2 cotton yarns produced with longer fibres exhibited better resistance to yarn-to-yarn abrasion than the 14.8 tex × 2 yarns produced with relatively short fibres. Hence the longer fibres seem to improve the yarn-to-yarn abrasion resistance.

iv) The yarn-to-yarn abrasion resistance of two-ply yarn depends on both single-yarn twist and ply twist. However, single-yarn twist is ineffective on yarn-to-emery abrasion when the ply twist level is lower.

v) While single-yarn twist has more influence than the ply twist on yarn-to-yarn abrasion resistance, ply twist has more influence than the single-yarn twist on yarn-to-emery abrasion of ply yarn, particularly when the ply twist is increased from 1/3 to 1/2 the single-yarn twist.

vi) Yarn-to-emery abrasion resistance and yarn-to-yarn abrasion resistance are improved tremendously when the ply twist is increased from 1/3 to , and 1/2 to 3/4 of single-yarn twist respectively, at all single-yarn twist levels.

vii) Two-ply yarn with 3/4 the single-yarn twist has low hairiness and high abrasion resistance against yarn as well as against emery, at all single-yarn twist levels.

viii) The present study has revealed that a marginal increase of single-yarn twist level causes tremendous improvement in the yarn-to-yarn abrasion resistance of shorter fibre two-ply yarns. Increasing single-yarn twist by 10% increases the abrasive resistance of two-ply yarn with 3/4 the single-yarn twist up to 75%.

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