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Abrasion Behavior of Yarns at Right Angle for Ring and Rotor Spun Yarn

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Abstract
This paper investigates yarn abrasion behaviour based on the yarn structure, twist factor and fibre alignment at the rubbing contact points (twist direction at contact points). First yarns arranged at right angle (utilized with a high resolution camera) were introduced on a yarn abrasion tester and then the abrasion behaviour of the ring (R) and open-end rotor (O.E.) spun yarns were compared and analysed. Comparison of the yarns indicates that the abrasion resistance thereof is affected by the twist factor in a way that as the twist increases, the yarn on yarn abrasion cycles to failure follows the same trend as the effect of twist on the yarn strength (first an increase and then a decrease); that is, yarn on yarn abrasion resistance increases up to a certain degree (α=140 in ring spun yarn and α=156 in open-end rotor spun yarn), and then as the twist increases, the yarn on yarn abrasion resistance decreases. It also shows that the yarn abrasion cycle to failure is lower when the fibre alignments of the contact yarns are in the same direction. Close observation of the yarn rubbing also indicates that as the fibres are removed from the outer layers, the rotor spun yarn shows higher yarn on yarn abrasion resistance; that is, moving from the outer side to the interlayer of the rotor spun yarn, the relative yarn on yarn abrasion resistance (abrasion cycles to failure/yarn count) increases. This phenomenon indicates the fact that in open-end rotor spun yarn the compactness of the interlayer fibres are higher than the compactness of the outer layer fibres.

Key words: *yarn abrasion tester, rubbing, twist direction, wear resistance.*

Introduction

Abrasion in textiles could be divided into fibre, yarn and fabric categories. Most attention and efforts have focused on fabric abrasion resistance [1, 2], however yarn abrasion resistance plays a critical role in fabric process productivity [3 - 6], machine part wear and fabric resistance behaviour [7 - 9].

Undoubtedly yarn abrasion behaviour is a function of different elements such as fibre characteristics, fibre orientation, the twist factor, yarn count and finishing treatments. Any change in the above mentioned elements affects yarn abrasion resistance and, consequently, fabric processing efficiency and fabric properties [10 - 12].

There is no doubt that the existence of an accurate and realistic abrasion tester in any textile mill draws the attention of engineers towards its vital role in quality control satisfaction. In addition, in the long run, the instrument will reveal the relationship and synchronicity between yarn abrasion behaviour and other yarn properties like stress-strain behaviour. Besides this it will practically show the overall effect of any changes in the process as well as the properties of the end product.

Experimental

Materials and methods

Yarn

Two distinct yarn types in five different twist multiples (factors) were produced and evaluated. ***Table 1*** shows the yarn specification details.

The instrument

Figure 1 shows the instrument which was specially designed (by the authors) for this experimental work, built up at Waterloo University's workshop.

Description of the tester

A small electrical motor (167 r.p.m.) drives the cam pulley (A) causing the shaft (B) to rotate, and as a result the slotted cam (C) rotates (***Figure 1.a***). The basic unit for cam rotation is 1 revolution per second. Cam rotation brings the two pairs of pins into a 10 centimetre traverse; that is, each single rotation of the cam

Table 1. *Yarn specification used in this work. (100% Iranian cotton).*

Yarn count, tex	Spinning method	Twist factor, $α_m$				
30 (Nm 33)	Ring (R)	109	124	140	156	171
	Open-end (OE)	109	124	140	156	171

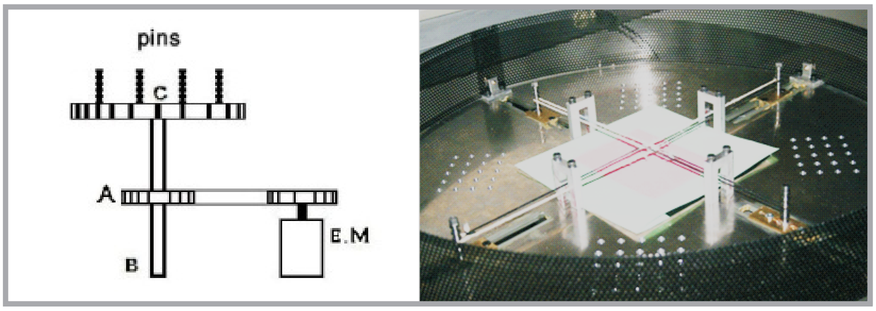

Figure 1. *Schematic of the instrument; a) Slotted cam movements. b) Pins and their locations.*

causes one complete traverse movement of the pins; the result being 20 centimetre rubbing yarn on yarn action.

The instrument contains 4 pins which are actually the holder of the samples to be tested (***Figure 1.b***). The mechanism of the pins' traverse is so that each pair moves against the other pair, that is, when a pair is traversing inward the other pair is moving outward (***Figure 2***).

Manner of yarn alignment on the tester
Yarn alignment on the tester (held by the pins) is as shown in ***Figure 2*** so that it contains two right angle contact points at two locations of the yarn sample.

Contact point a: the location where the yarns turn around each other anti-clockwise (Z type, the same direction as the yarn twist, ***Figure 3***).

Contact point b: where the yarns turn around each other clockwise (S type, against the twist direction, ***Figure 3***).

Naturally, during one cycle of the cam, the pins would have a complete traverse (inward and outward movement), and consequently the yarn sample is rubbed backwards and forwards at the two contact points for 10 cm in length, making a 20 cm rubbing action for each cycle of the cam.

Testing method
First of all, samples were conditioned for 24 hours in a standard atmosphere (relative humidity 65 ± 2% and temperature: 20 ± 2 °C). Then a two meter length of each sample yarn was aligned on the tester, based upon the above description, and put under a 50 gram tension load; thus we had a sample ready to be rubbed by itself in two directions (clockwise and anti-clockwise), and the unraveling behaviour of the outer layer fibers of the yarn (over a ten centimeter length of the yarn sample) could be observed and analysed.

Finally the unravelling behaviours of the outer layer fibres of the yarns at the contact points were captured by a Canon camera 200 which was already fixed on top of the abrasive zones and connected to a personal computer, making it possible to observe the behaviour online on a PC monitor.

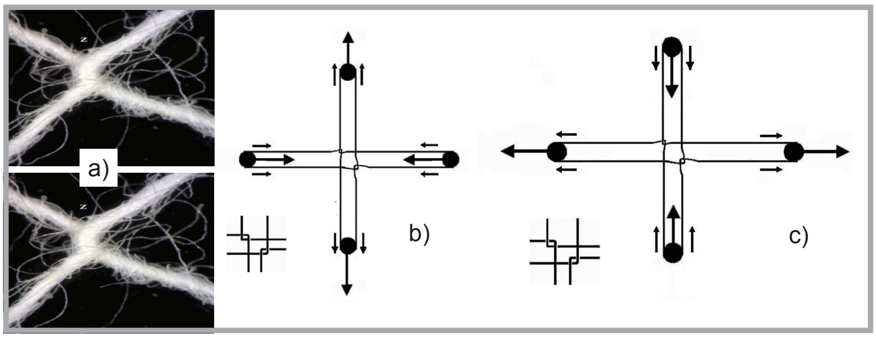

Figure 2. *Yarn layout and pins inward and outward movements. a) Yarn alignment and right angle contact points. b) Horizontal pins are moving inward whereas the vertical pins are moving outward. c) Vertical pins are moving inward whereas horizontal pins are moving outward.*

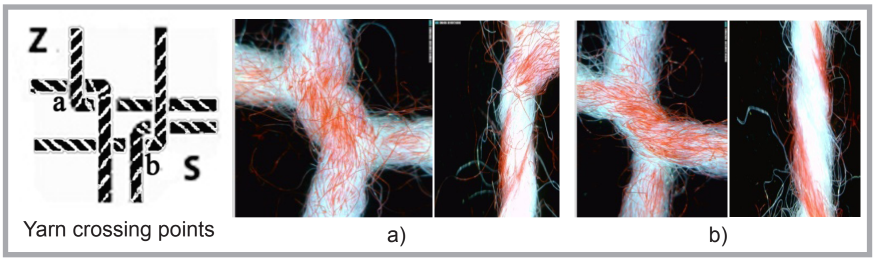

Figure 3. *Crossing points and yarn twist directions; a) Z type crossing. b) S type crossing.*

Table 2. *Rubbing cycles to failure of the yarns.*

Yarn type	Ring					Rotor				
Count, tex (Nm)	33 (30.3)					33 (30.3)				
Twist multipler	109	124	140	156	171	109	124	140	156	171
Twist, t.p.m.	625	715	805	900	985	625	715	805	900	985
Cycle to failure	1203	1250	1278	1183	1030	1061	1133	1160	1173	1061

Results and discussions

Table 2 shows the yarn abrasion results. The effect of the twist factor, fibre alignment at the contact point (yarn contact direction) and yarn structure on the yarn abrasion resistance to failure is discussed, respectively.

a) Yarn abrasion and yarn twist
Comparison of the abrasion resistance between each group of yarns (ring or rotor) indicated that as the twist factor increased, the yarn abrasion cycle to fail increased up to a certain point (α = 140) and then decreased. This was due to the fact that at first, an increase in yarn twist increases the fibre impact, as well as the surface smoothness, making the yarn act like a smooth condensed cylinder. However, an additional increase in twist increases the rubbing effect of the yarn, and as a result the cycle to failure is decreased (***Figure 4*** see page 56). This increase in the rubbing effect is due to the harshness of the yarn, which occurs when the yarns reach their maximum fibre compactness, with the yarns following a spring configuration. In this case the reversing point for ring spun yarn was at a twist factor of 140, whereas the reversing point for open-end rotor spun yarn was at a twist factor of 156, which could be due to the higher outer layer fibre compactness in ring spun yarn.

Contact direction
Observation showed that the behaviour of the yarns at the two criss-cross points were different. In general, at the point where the thread's crossing direction is parallel to that of the twist (contact point a), the abrasion was more effective, with the rubbing action pulling fibres off the yarn, which could be due to engagement between yarns at the contact area because of a convergent force existing between the two yarns. ***Figure 5.a*** (see page 56) shows that the yarn twist direction and yarn crossing line are the same (Z and Z), causing the highest engagement.

However, comparison of the case a to case b, shows that in the case a, the outer layer

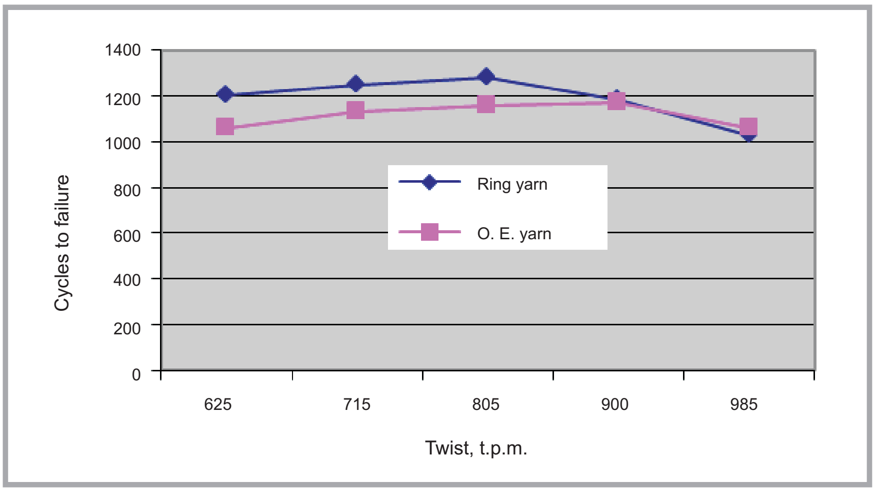

Figure 4. *Effect of twist on yarn abrasion resistance.*

fibres of both yarns are engaged so that any movement creates a force between fibres acting against them and makes the fibres rolling off the yarn whereas in the case b, the yarn movement does not inter any longitudinal friction force between the fibers (***Figure 5***).

The interesting point was that the difference in behaviour of the yarns at the two criss-cross points in the case of open-end yarn was quite low, indicating the difference in fibre alignment in open-end yarns.

b) Yarn abrasion and yarn structure

Comparison of the results for open-end rotor and ring spun yarns shows a lower value of cycle to fail for all cases of open-end rotor yarn. This could be due to the higher value of harshness for open-end rotor spun yarns as well as the easy removal of outer layer fibres in open-end rotor spun yarns.

Actually fibre alignment, especially in the outer layer of ring yarn, makes the yarn smoother and finer, hence the rubbing effect is lower, resulting in higher yarn on yarn abrasion resistance for ring spun yarns at first. In other words, the rubbing-off effect of outer layer fibres of open-end rotor spun yarns is higher than that of the outer layer fibres of ring spun yarn. In addition, the rubbing-off effect of open-end rotor spun yarn is different than for ring spun yarn. In the case of open-end rotor spun yarn the rubbing action causes some wrapped fibres to move away from the rubbing portion of the yarn without playing any role in rubbing resistance. In addition, at the early stage of the rubbing action, the amount of fibres rubbed off in open-end rotor spun yarn is higher than in ring spun yarn. In ring spun yarn, usually the part of the fibre that is off the yarn body is rolled backward, whereas the rest part of the fibre length is inside the body of the yarn, and as a result the fibres play a part in rubbing actions. Thus during the rubbing movement, the outer layer fibres in ring spun yarn last longer and make bundles (group) outside the yarn (***Figure 6***).

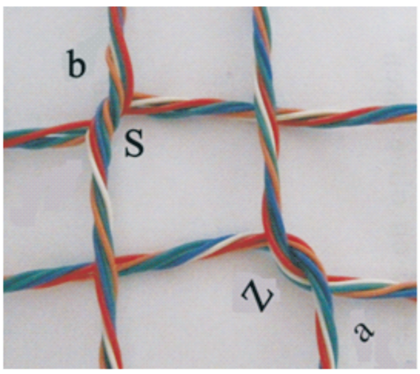

Figure 5. *Yarn engagement due to the yarn crossing direction.*

It should be emphasised that the difference in the yarn structure affects the rubbing phenomenon as well. It is a fact that ring spun yarn has higher fibre parallelisation, whereas open-end rotor spun yarn has higher fibre entanglement. In some cases of ring spun yarn (around a twist angle of 20 – 25 degrees) the parallel fibre alignment of the yarns at the contact section causes the yarns to be engaged like two ribbons. Actually at the contact point the tabular form of the yarns changes into a tape shape, and consequently as the yarns are rubbing and moving away from each other, the twist per length of the upper part of the yarn increases, whereas the lower part decreases. In other words, the crossing engagement of the ring spun yarn could cause twist-untwist ribbon behaviour in ring spun yarn. This phenomenon was observed in some cases of ring spun yarns but not for open-end rotor spun yarn, due to the entanglement among fibres inside the open-end rotor spun yarns. The tape form entanglement of yarns in ring spun yarn acts as if combing the yarns (fibres), and as a result fibre deformation, fibre movements and the rubbing off of fibres occur inside the yarn. Our observation shows that this rubbing-off action continues up to the point in which the yarn cannot stand the yarn tension any more; actually the fibres slip from each other and the yarn breaks (***Figure 7***).

Outer layer of the yarn

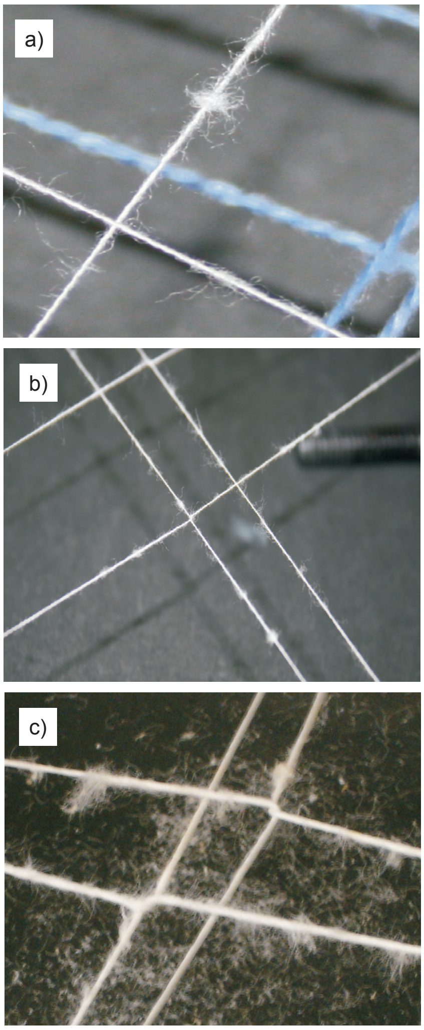

Figure 6. *Difference in rubbing-off behaviour of the outer-layer fibres in ring and open-end spun yarns. a) Wrapped fibres making bundles (top yarn in white colour). b) Groups of fibres in ring spun yarn. c) Rubbed off fibres in open-end rotor yarn abrasion.*

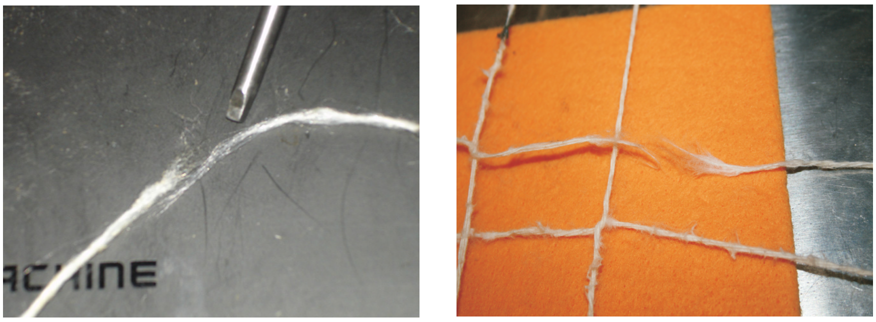

Figure 7. *Ring spun yarn breakage in yarn abrasion testing.*

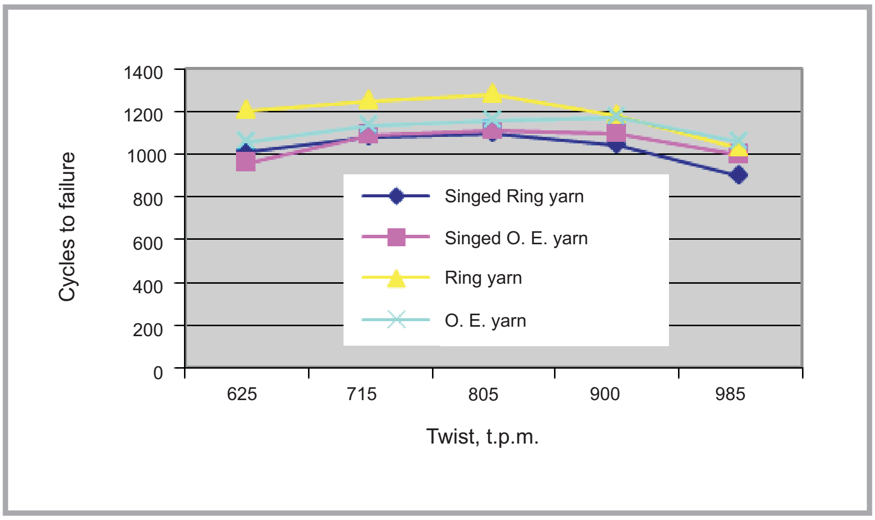

Figure 8. *Yarn on yarn abrasion resistances of ring and open-end rotor spun yarns after removing outer layer fibres.*

Close observation of the yarn rubbing indicates that as the fibres are removed from the outer layers, open-end rotor spun yarn yields higher abrasion resistance. In other words, moving from the outside to the interlayer of the open-end rotor spun yarn, the resistance to abrasion increases.

To check the observation and support the above statement, outer layer fibres for both yarns were removed by a singing machine - model GH-11, (15% of the yarn's weight was burned). The abrasion test was repeated, and the results were opposite to the first case, that is, the cycles to failure of the open-end rotor spun yarns were almost equal (and in some cases even higher) to the cycle to failure of the ring spun yarn (***Figure 8***). This is in agreement with the hypothesis that open-end rotor spun yarns may be composed of concentric structures. The inner core, which contains most of the fibres, is compact and highly twisted. The outer layers are formed by fibres wrapped around the core with a variable twist level.

Conclusions

A right angle yarn on yarn abrasion tester was introduced, which can be used as a product control tool in textile factories. The results from the experimental part of the work can be concluded as follows

1. Abrasion resistance is affected by the twist factor. The trend of the effect is similar to the curve of the twist effect on the yarn strength; that is, the abrasion cycle to failure increases up to some point and then decreases as the twist factor is increased. The return point for ring yarn is lower than that for open end yarn.
2. The abrasion behavior of ring and open end yarns is not the same. The ring yarn abrasion cycle to failure is higher than that of open end yarn.
3. The abrasion resistance of the outer layer fibres (cycle to failure) in ring yarn is higher than that of the outer layer fibre abrasion resistance (cycles to failure) of open end yarn.
4. Interlayer fibres in open-end yarn yield higher resistance to abrasion than the interlayer fibres of ring yarn. Therefore the abrasion behaviour (from the outside layer of the yarn toward the inside layer) in ring and open-end yarn is opposite to each other; that is, as the outer layer fibres remove in the ring yarn, the abrasion resistance (cycle to failure/count) decreases, whereas in the case of open-end yarn it increases.

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