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Twisting Characteristics of Rotor-Spun Composite Yarns

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Abstract
At two filament over-feed ratios, different kinds of rotor-spun composite yarns were produced by combining staple fibres with filament yarns under varying twisting factors. The yarn tensions were measured, and the effects of twist factors on the characteristics of composite yarns were investigated. The polyester filament in the composite yarn is twisted with the cotton strand and follows a helical path. When the filament tension increases with increasing yarn twist factors and filament over-feed ratio, the filament yarn tends to lie near the inner layer of the composite yarn, and the properties of composite yarns will change accordingly. Compared with the normal rotor-spun yarn, the appearance of composite yarns is clearer, the structure is much tighter, and the properties are improved.

Key words: *twisting characteristic, rotor-spun composite yarn, twist factor, filament over-feed ratio, tension.*

Introduction

Compared with conventional staple fibre yarns, composite yarns made of staple fibres and filaments have higher tenacity and improved irregularity, and they possess the properties of both filament yarns and staple fibre yarns [1]. Composite yarns can be produced by many kinds of machines and processes, such as ring, friction, and air-jet spinning, in which the ring spinning process is more commonly used [2, 3]. Rotor spinning has been adopted worldwide at present. Its main advantages over ring spinning are high yarn output rates, reduced production costs, increased bulkiness and improved evenness of the yarns. However, the relatively low breaking strength and wrapper fibres of yarn surface are still matters of concern [4 - 6]. These disadvantages may be improved by combining staple fibres with a continuous filament yarn in the rotor spinning process.

Some researchers have studied the spinning conditions and characteristics of rotor-spun composite yarns. Nield [7] described a mechanism for producing open-end-spun core-spun yarns. Cheng [8] reported a method for making cover-spun yarns on an open-end rotor spinning frame. Pouresfandiari and Matsumoto [9, 10] reported their progress in producing different kinds of novel hybrid yarns on an experimental open-end spinning frame.

In this paper, a composite yarn spinning system that produces different kinds of composite yarns on a modified open-end rotor spinning frame was developed. At two filament over-feed ratios, different kinds of rotor-spun composite yarns were produced under varying twisting factors. The yarn tensions were measured, and the effects of twist factors on the structure and properties of composite yarns were investigated.

Experimental

Preparation of yarn samples

We used a cotton sliver (25.4 mm mean fibre length, 1.5 dtex fibre linear density, 3.43 fibre Micronaire value and 4.32 g/m sliver size) as the staple fibre, and a polyester filament (33.3 dtex, 30 d/15 f) as the filament yarn fed into the rotor.

The schematic diagram of open-end rotor spinning process modified is shown in Figure 1. The filament yarn was fed from a supply bobbin by means of a tension device and suitable guides to the filament feed rollers, then passed straight through the filament guide tube and drawn into the rotor freely by suction, in which the filament yarn was combined with the staple fibre strand to form the composite yarn. Then, the composite yarn was drawn through the doffing tube and finally on to the take-up roller. The filament guide tube was positioned along the axis of rotation of the hollow rotor shaft, which rotated freely about it.

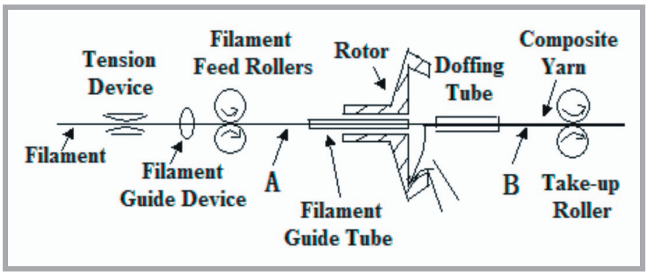

Figure 1. *Schematic diagram of rotor-spun composite yarns spinning process.*

The Rothschild R046 tension meter was used to measure both the tensions of the filament and composite yarns respectively. During the spinning process, the filament tension was measured between the filament feed rollers and the filament guide tube (A in Figure 1), and the composite yarn tension was measured between the doffing tube and the take-up roller (B in Figure 1).

Some of the spinning parameters for composite yarns were as follows: 58 tex yarn linear density, 7000 rpm opening roller speed, 45,000 rpm rotor speed (50 mm rotor diameter). The filament over-feed ratios were 0.97 and 1.06 respectively. The filament over-feed ratio (OFR) was given by OFR = (filament feed speed) / (composite yarn take-up speed). The other spinning parameters are listed in Table 1. For comparison, we produced

Table 1. *Spinning parameters for composite yarns and normal rotor-spun yarns.*

Composite yarns	OFR=0.97	N11	N12	N13	N14	N15
	OFR=1.06	N21	N22	N23	N24	N25
Normal rotor-spun yarns		C1	C2	C3	C4	C5
Twist factor		530	500	470	450	430
Machine twist, tpm		696	657	617	591	565
Take-up speed, m/min		64.7	68.5	72.9	76.1	79.6
Cotton feed speed, m/min		0.80	0.85	0.90	0.94	0.99

normal rotor-spun yarns under the same spinning conditions respectively.

Testing yarn structure and properties

The yarn longitudinal view was observed with a Questar Hi-scope video microscope system. Twist was measured with the pretension of 29 cN by the detwist-retwist method on a Y331 yarn twist tester. Breaking strength and elongation were determined with a test length of 500 mm, extension rate of 500 mm/min and pretension of 29 cN on an XL-1 tensile tester. Irregularity CV% was measured with the yarn speed of 400 m/min and a testing time of 1 minute on YG135G irregularity tester. Hairiness was tested with the testing speed of 30m/min and a test length of 100 m on a YG172 hair tester, and hairs above 2 mm per meter was measured. All the tests were performed under a standard atmosphere of 20±2 ºC and 65±2% RH.

Results and discussion

Yarn tension under varying twist factors

The relationship between the twist factors and the yarn tensions is shown in Figure 2. While the yarn twist factors increase, both the tensions of the filament and composite yarns have a tendency to increase, and the composite yarn tension is higher than the filament tension. The tension of normal rotor-spun yarns increases with increasing twist factors also, and is less than the composite yarn tension. The spinning tension of the composite yarn is composed of the filament tension, staple fibre strand tension and some other factors, so the composite yarn tension is higher compared with the tension of normal rotor-spun yarns.

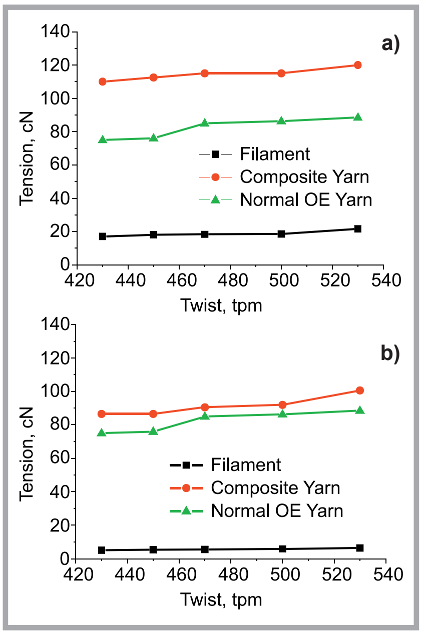

Figure 2. *Effects of twist factors on yarn tensions; a) OFR=0.97, b) OFR=1.06.*

Comparing Figure (a) with (b) in Figure 2, both the tensions of the filament and composite yarns at the filament over-feed ratio of 0.97 are higher than that at the filament over-feed ratio of 1.06. The filament over-feed ratio decreases, i.e. the filament feed speed decreases gradually under the constant take-up speed, so the filament tension increases. The composite yarn tension will increase with increasing filament tension.

Effects of twist factor on yarn morphology and structure

The magnified longitudinal photographs of composite yarns and normal rotor-spun yarns are shown in Figure 3. While the yarn twist factors increase (from sample N15 to N11 and from sample N25 to N21 respectively), the helical angle of the polyester filament in the composite yarns increases, the thread pitch decreases, and the filaments have a tendency to lie near the inner layer of the composite yarn. The polyester filament in the composite yarn is twisted with the cotton strand and follows a helical path. According to idealised helical yarn geometry [11], when a composite yarn is made from two components, it is necessary to have different component lengths in the yarn. If one component is a filament yarn, the length can be easily controlled by the tension. When the filament tension increases with increasing twist factors, the filament yarn tends to lie near the inner layer of the composite yarn. The influence of twist factor on the wrapper fibres near the surface of composite yarns is relatively complex. The morphology of wrapper fibres shows no obvious change under varying twist factors.

The filament over-feed ratio has a great influence on the appearance and structure of composite yarns as shown in Figures 3a and 3b. When the filament tension increases with the decrease of filament over-feed ratio, the filament yarn tends to lie along the axis of the composite yarn near the centre as a core, and can be covered by the staple fibre strand. In the case of OFR=0.97, the polyester filament tends to be located near the centre of the composite yarn.

Compared with the normal rotor-spun yarn, the appearance of composite yarns is clearer and more regular. Rotor-spun yarn is known to have a skin-core structure, consisting of a central core that resembles ring-spun yarn, and an outer sheath containing a random disarray of fibres and wrappers [12, 13]. The morphology of wrapper fibres lying near the surface of rotor-spun yarns is relatively loose. Because of the insertion and wrapping of the filament, the morphology of wrapper fibres on the cotton strand surface becomes tighter and clearer than that of normal rotor-spun yarns.

Effects of twist factor on yarn properties

The effects of twist factor on yarn breaking strength and elongation are shown in Figure 4 and 5 respectively. When the filament over-feed ratio is different, the change of yarn breaking strength with varying twist factors is different too. In the case of OFR=1.06, the filament tension is relatively low, so the filament yarn wraps over the staple fibre strand and follows a helical path. As the filament tension increases with increasing twist factors, the wrapping action of the filament yarn is greater and the yarn structure becomes tighter and more uniform, so the inter-fibre cohesive forces increase and the breaking strength of composite yarns tends to increase also. In the case of OFR=0.97, the filament yarn also follows a helical path and tends to lie in the inner layer of composite yarns. The filament is stretched effectively and the tensile characteristic of the filament

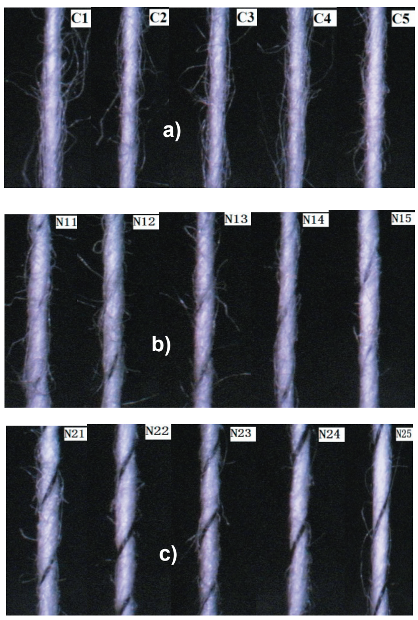

Figure 3. *Yarn morphology and struc-ture under varying twist factors; a) Normal rotor-spun yarns, b) Composite yarns (OFR=0.97), c) Composite yarns (OFR=1.06).*

itself is changed. While the twist factor increases, the breaking strength of composite yarns increases substantially up to around twist factors of 470, and decline thereafter to 530. The breaking strength of composite yarn (OFR=0.97) is less than that of composite yarn (OFR=1.06).

With increasing twist factors, the breaking elongations of composite yarns tend to increase at two filament over-feed ratios. The breaking elongation of composite yarn (OFR=0.97) is higher than that of composite yarn (OFR=1.06).

The composite yarns show a marked increase in the breaking strength and elongation compared with the normal rotor-spun yarn. The morphology of wrapper fibres on the surface of the rotor-spun yarn is relatively loose, and they make little contribution to the yarn strength. During the formation of composite yarns, owing to the insertion and wrapping of the filament, the morphology of wrapper fibres becomes much tighter and the transverse pressure and cohesive forces among fibres will be increased; the breaking strength and elongation of the composite yarn will thus also be increased.

The effects of yarn twist factor on yarn irregularity and hairiness are shown in Figures 6 and 7 respectively. As the twist factor increases, the CV% of composite yarn has a tendency to increase and the change of hairiness is not significant. At the same twist factor, the CV% of the composite yarn (OFR=0.97) is less than that of composite yarn (OFR=1.06).

Compared with the normal rotor-spun yarn, both the CV% and hairiness of composite yarns are less. The evenness of the composite yarn is better and its surface is clearer, which is consistent with the results obtained from the yarn longitudinal photographs (as shown in Figure 3). The improvement of hairiness on the surface of the composite yarn is great. This phenomenon can be explained by the wrapping of the spandex filament on the cotton fibre strand.

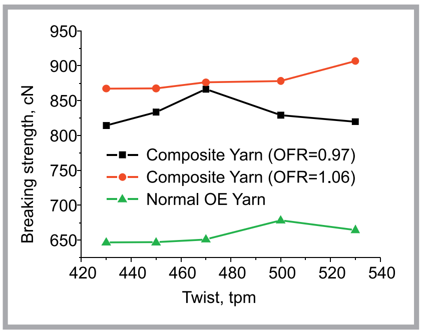

Figure 4. *Effects of twist factor on yarn breaking strength.*

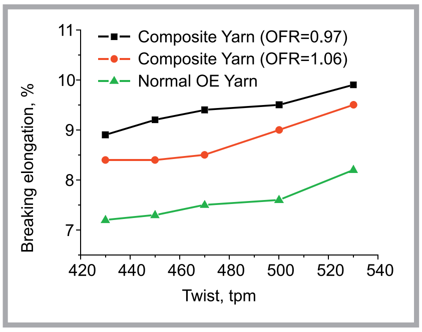

Figure 5. *Effects of twist factor on yarn breaking elongation.*

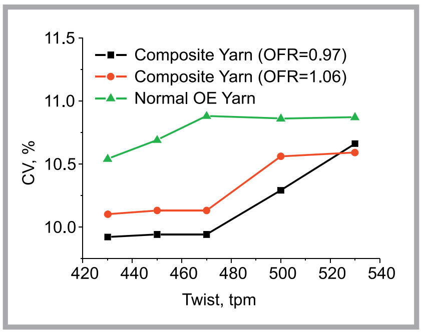

Figure 6. *Effects of twist factor on yarn irregularity.*

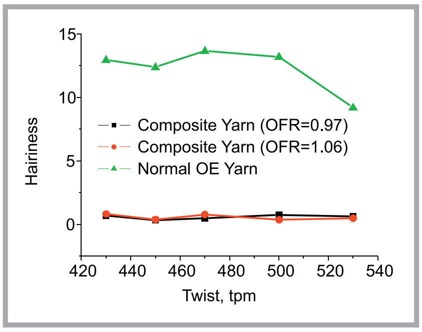

Figure 7. *Effects of twist factor on yarn hairiness.*

Conclusions

At two filament over-feed ratios, different kinds of rotor-spun composite yarns were produced under varying twisting factors. The yarn tensions were measured, and the effects of twist factors on the characteristics of composite yarns were investigated. The following conclusions can be drawn:

The polyester filament in the composite yarn is twisted with the cotton strand and follows a helical path. While the yarn twist factors increase, both the tensions of the filament and composite yarns have a tendency to increase, and the filament yarn tends to lie near the inner layer of the composite yarn.

In the case of OFR=1.06, the breaking strength of composite yarns tends to increase with the increase in twist factors. In the case of OFR=0.97, while the twist factor increases, the breaking strength of composite yarns increases substantially up to around twist factors of 470, and declines thereafter to 530.

With the increase in twist factor, the breaking elongation of composite yarns tends to increase, the CV% has a tendency to increase and the change of hairiness is not significant.

The yarn tensions at the filament over-feed ratio of 0.97 are higher than that at the filament over-feed ratio of 1.06. Compared with the composite yarn (OFR=1.06), the breaking strength of composite yarn (OFR=0.97) is less, the breaking elongation is higher and the CV% is less.

Compared with the normal rotor-spun yarn, the morphology of wrapper fibres near the composite yarn surface is tighter and clearer. The composite yarn shows a marked increase in breaking strength and extension. The CV% of composite yarns is low, and the improvement of hairiness is great.

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