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Effects of Twisting Parameters on Characteristics of Rotor-Spun Composite Yarns with Spandex

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Abstract: Spandex fibers have superior stretch and elastic recovery ability. Composite yarns containing spandex are frequently used to manufacture elastic textile products and accessories. We have developed a composite yarn spinning system that produces different kinds of composite yarns containing spandex on a modified open-end rotor spinning frame. By changing the twisting parameter of composite yarns, we studied the structure and properties of rotor-spun composite yarns with spandex. The results indicate that the twisting parameter has great influence on the structure and properties of rotor-spun composite yarns with spandex. The linear density of spandex filament has influence on the properties of composite yarns too. In comparison with normal rotor-spun yarn, the appearance of composite yarns is clearer, the structure is much tighter, and the properties are improved.

Keywords: Twisting parameter, Characteristic, Rotor-spun composite yarn, Spandex, Linear density

Introduction

Elastic fibers were first developed by Bayer in Germany, and developed and produced by Dupont in 1958. Since then, elastic fibers with trade names such as Lycra®, Glospan®, Dorlastan®, Linel®, etc., all commercial elastic fibers from spandex fibers, are made of long chain polymer fibers containing at least 85 % segment polyurethane [1]. Spandex fibers have superior stretch and elastic recovery ability, which is why clothes containing spandex fibers fit well and are comfortable. Composite yarns containing spandex are frequently required by textile fabric producers for manufacturing elastic textile products and accessories. Important market segments for elastic yarns are hosiery, swimwear, sportswear, underwear, lace, as well as fashionable clothing.

The most common methods of producing elastic yarns are core-spun on a modified ring frame, hollow spindle technique, air entangling, friction spinning, and Siro spinning [2-4]. These processes are characterized by different yarn properties, structures, and yarn count range. 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 fibers of yarn surface are still matters of concern [5,6]. These disadvantages may be improved by combining staple fibers with a continuous filament yarn in 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 of 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 present study, a composite yarn spinning system that produces different kinds of composite yarns containing spandex on a modified open-end rotor spinning frame was developed. Different kinds of rotor-spun composite yarns with spandex were produced under varying twisting parameters and the characteristics of these yarns were studied.

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Experimental

Materials

We used two kinds of spandex fibers (44.4 dtex and 77.8 dtex) as the filament yarns and a cotton sliver as the staple fiber. The properties of cotton and spandex are given in Table 1.

Table 1. Properties of cotton and spandex

Cotton		Spandex		
Mean fiber length (mm)	25.4	Dupont Lycra		
Fiber linear density (dtex)	1.65	Fiber linear density (dtex)	44.4	77.8
Fiber Micronaire value	3.88	Breaking strength (cN)	46.2	72.4
Sliver size (g/m)	3.7	Breaking elongation (%)	410	470

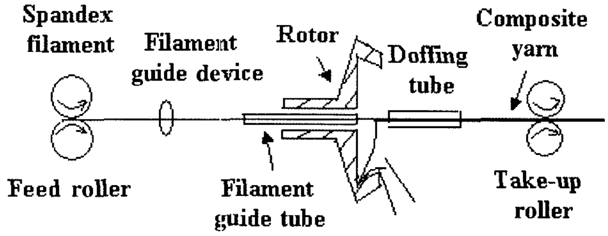


Figure 1. Schematic diagram of spinning process.

Table 2. Spinning parameters for composite yarns

Samples	1	2	3	4	5
Twist factor	430	450	470	500	530
Machine twist (tpm)	565	591	617	656	696
Take-up speed (m/min)	79.6	76.1	72.9	68.6	64.7
Cotton feed speed (m/min)	1.16	1.11	1.06	1.00	0.94
Spandex feed speed (m/min)	22.7	21.7	20.8	19.6	18.5

Preparation of Yarn Samples

The schematic diagram in Figure 1 showed an open-end rotor spinning process modified to allow spandex filaments to be fed into the rotor. The spandex filament was fed from a supply bobbin by the filament feed roller, then passed straight through the filament guide tube and was drawn into the rotor freely by suction, in which the spandex filament was combined with the staple fiber 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. The filament feed roller was able to feed the spandex filament positively with a wide range of constant feeding speeds.

Some spinning parameters for composite yarns were as follows: 58 tex normal linear density, 7000 rpm opening roller speed, 45000 rpm rotor speed (50 mm rotor diameter), 68.9 draft ratio, 3.5 spandex draft ratio. Draft ratio of the spandex filament was given by (composite yarn take-up speed)/(spandex feed speed). The other spinning parameters were listed in Table 2. For a comparison, we made normal rotor-spun yarns under the same spinning conditions respectively.

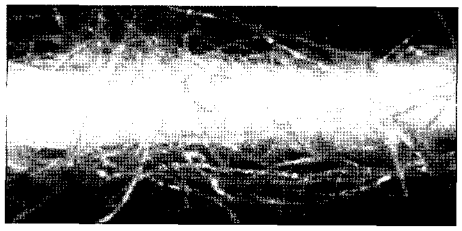
Testing of Yarn Morphology and Properties

The yarn longitudinal view was observed by Questar Hi-scope video microscope system. Breaking strength and elongation were determined from the mean of 60 tests with a test length of 500 mm, extension rate of 500 mm/min and pretension of 58 cN on XL-1 tensile tester. Elastic recovery ratio was obtained for ten samples with a test length of 100 mm, extension rate of 50 mm/min, pretension of 29 cN, initial extension of 5 % and retention period of 30s on AG-10 material tester. Irregularity *CV*% was measured with the yarn speed of 400 m/min and the testing time of 1 minute on YG135G irregularity tester. Hairiness was determined with the testing speed of 30 m/min and test length of 100 m on YG172 hair tester, and the hairs above 2 mm per meter was measured. Twist was measured by detwist-retwist method on Y331 yarn twist tester. All the tests were performed under a standard atmosphere of 20 ± 2 °C and 65 ± 2 % RH.

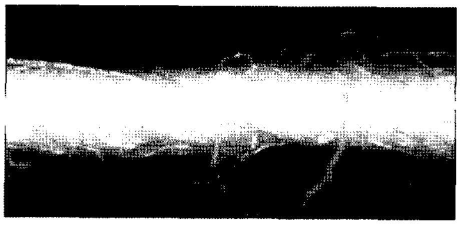
Results and Discussion

Yarn Morphology and Structure

Figure 2 shows the magnified longitudinal photographs of cotton/spandex composite yarn and normal rotor-spun yarn. Compared with the normal rotor-spun yarn, the appearance of composite yarns is more regular and clearer. 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 array of fibers and wrappers [11]. The morphology of wrapper fibers lying near the surface of rotor-spun yarns is relatively loose. Because of the insertion and wrapping of spandex filament, the morphology of wrapper fibers on the cotton strand surface becomes tighter and clearer than that of normal rotor-spun yarns.



(a) Normal rotor-spun yarns



(b) Composite yarns with spandex

Figure 2. Typical yarn morphology.

The spandex filament in the composite yarn is twisted with the cotton strand and follows a helical path. According to idealized helical yarn geometry [12], 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. During the spinning process of rotor-spun composite yarns, the take-up speed of composite yarns is higher than the spandex feed speed, so the spandex tension is greater than the staple fiber strand tension, and the spandex filament tends to lie in the inner layer of composite yarns as a core and can be covered by the staple fiber strand.

Yarn Twist and Twist Deviation

Figure 3 shows the relationship between the measured twist and machine twist of different samples. Rotor-spun yarn is known to have a two-part structure. The twist level of the fibers comprising the core yarn is different from those comprising the outer sheath, and both are usually lower than the machine value. The testing results show that the measured twist is less than machined twist. Compared with the normal rotor-spun yarn, the measured twist of cotton/spandex composite

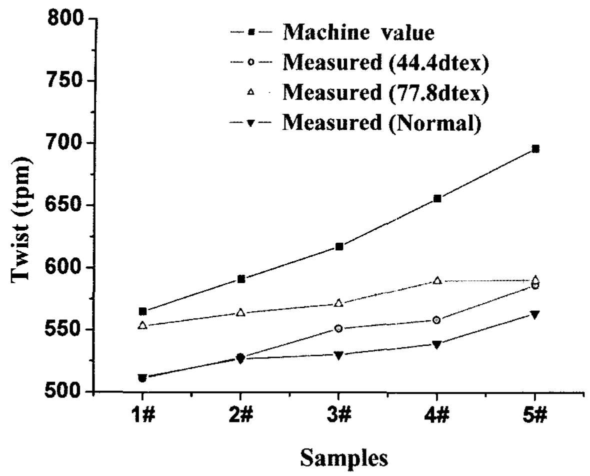


Figure 3. Yarn twist level.

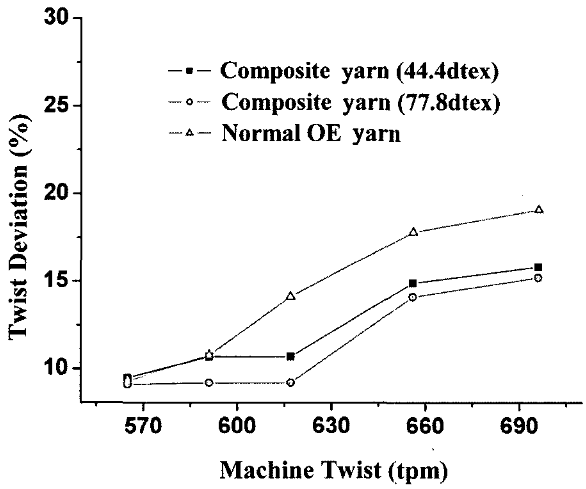


Figure 4. Yarn twist deviation.

yarn is higher. The measured twist of the composite yarn containing coarse-denier spandex is higher than that of the composite yarn containing fine-denier spandex.

Figure 4 shows the effects of machine twist on the twist deviation of rotor-spun composite yarns with spandex. The twist deviation given by twist deviation = 100 × (Machine twist − Measured twist)/Machine twist was used to assess the deviation between the measured twist and machine twist. The results show that the yarn twist deviation increases with machine twist. Compared with the normal rotor-spun yarn, the twist deviation of composite yarns is less. The twist deviation of the composite yarn containing coarse-denier spandex is less than that of the composite yarn containing fine-denier spandex.

Effects of Twisting Parameter on Yarn Properties

The breaking strength, breaking elongation, elastic recovery of composite yarns and normal rotor-spun yarns under different twist factors are given in Table 3. The breaking strength of composite yarns increases substantially up to around twist factors of 470 and 500 respectively and decline beyond to 530. As the twist factor increases, the breaking elongation of composite yarns tends to increase and elastic recovery has a tendency to decline. At the same twist factor, the breaking strength, elongation and elastic recovery of the composite yarn containing coarse-denier spandex are higher than that of the composite yarn containing fine-denier spandex. That is because the coarse-denier spandex has superior stretch and elasticity.

The composite yarns show a marked increase in the breaking strength, elongation and elastic recovery compared with the normal rotor-spun yarn. The morphology of wrapper fibers on the surface of the rotor-spun yarn is relatively loose and they have little contribution to the yarn strength. During the

Table 3. Properties of composite yarns and normal rotor-spun yarns

Samples		Strength (cN)	Elongation (%)	Elastic recovery (%)	Irregularity *CV* (%)	Hairiness (hairs/m)
Composite yarns (44.4 dtex)	430	830.4	7.4	98.1	11.4	0.48
	450	850.9	7.6	98.0	11.6	0.50
	470	905.2	7.6	97.9	10.7	0.00
	500	855.1	8.2	97.9	10.6	0.80
	530	860.3	8.2	97.8	10.7	0.80
Composite yarns (77.8 dtex)	430	907.3	7.4	98.5	10.4	0.80
	450	930.4	7.9	98.4	11.0	0.94
	470	939.1	8.4	98.4	10.3	0.38
	500	952.2	8.5	98.3	10.2	1.00
	530	924.7	8.5	98.3	10.1	1.06
Normal rotor-spun yarns	430	791.7	7.3	97.7	11.5	7.56
	450	793.4	7.4	97.6	11.6	9.04
	470	831.6	7.4	97.5	11.9	12.2
	500	836.3	7.5	97.4	12.0	19.4
	530	799.4	7.6	97.4	11.6	19.5

formation of composite yarns, owing to the insertion and wrapping of the spandex filament, the morphology of wrapper fibers becomes much tighter and the transverse pressure as well as cohesive forces among fibers will be increased, then the breaking load of the composite yarn will be increased. Because the spandex filaments have superior stretch and elastic recovery ability, the elongation and elastic recovery of composite yarns are higher than that of the normal rotor-spun yarn.

The irregularities and hairiness of composite yarns with spandex are given in Table 3. As the twist factor increases, the *CV*% of composite yarn has a tendency to decrease and the trend of hairiness is not significant. At the same twist factor, the *CV*% of the composite yarn containing coarse-denier spandex is less than that of composite yarn containing fine-denier spandex and the hairiness is slightly higher.

Compared with normal rotor-spun yarn, both the *CV*% and hairiness of composite yarns with spandex are less. The evenness of the composite yarn is better and its surface is clearer, that is consistent with the results obtained from the yarn longitudinal photographs (as shown in Figure 2). 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 fiber strand.

Conclusions

We have produced different kinds of composite yarns with spandex on a modified open-end rotor spinning frame. The spandex filament in the composite yarn is twisted with the cotton strand, and the morphology of the composite yarn is more regular and clearer than that of the normal rotor-spun yarn. The yarn twisting parameter has great influence on the properties of rotor-spun composite yarns with spandex. The twist deviation of composite yarn with spandex increases with machine twist. The properties of composite yarn containing coarse-denier spandex are better and the twist deviation is less than that of the composite yarn containing fine-denier spandex. In comparison with the normal rotor-spun yarn, the composite yarns with spandex have higher breaking strength, elongation and elastic recovery, less irregularity *CV*%, a lower degree of hairiness and less twist deviation.

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