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Yarn hairiness on ring spinning with modified yarn path

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Yarn hairiness on a modified ring spinning system with a pair of offset device which can change the horizontal offset of spinning triangle continuously has been discussed in this paper. It is observed that the selection of appropriate right horizontal offset of spinning triangle can help to reduce the spun yarn hairiness with “Z” twist, whereas the selection of appropriate left offset can help to reduce the spun yarn hairiness with “S” twist. The corresponding appropriate horizontal offsets are given by experiments for five types of yarn, namely 20s, 30s, 40s, 50s and 60s with “Z” twist respectively. Finally, the explanations of hairiness reduction are given according to the fibre tension distributions at spinning triangle.

Keywords: Horizontal offset, Modified yarn path, Ring spinning, Yarn hairiness

Yarn hairiness is one of key factors affecting the appearance of spun yarns and fabrics as well as handle, thermal insulations and other apparel characteristics [1]. Therefore, the research on yarn hairiness has attracted more and more attentions in recent years [1-10]. However, yarn hairiness is a rather complex concept, and can be determined considering comprehensive factors, which make the study on yarn hairiness rather complicated [1, 2].

Recently, the studies on improving the hairiness of ring spun yarn by changing the spinning triangle shape actively, especially horizontal offset of the twisting point have attracted more and more attentions and get fruitful results [2-7]. There exist three main methods to study yarn hairiness [2], namely (i) Jetring approach [9], (ⅱ) reducing the yarn hairiness during winding [10] and （ⅲ） modifying yarn path [3,5] . The Jetring spinning system is essentially a modified ring spinning system, in which a single air jet is employed below the spinning triangle [11], thus making the yarn as strong as a traditional ring spinning yarn but with considerably less hairiness [9]. The Jetring spinning system can reduce the yarn hairiness by combing the ring spinning with air-jet spinning. Due to the high production rate of winding and the fact that the winding itself increases the yarn hairiness, reducing the yarn hairiness during winding has become a popular method [2] . Siro spun and solo spun methods reduce the yarn hairiness by two twists [8,12], and compact spinning reduces hairiness by negative pressure [13]. The last common method is modification of the yarn path, which is also the simplest method. It has been shown that modifying the yarn path with “*left diagonal*” or *“right diagonal”* configurations in the traditional ring spinning can reduce the yarn hairiness effectively, which is reacted by changing the spinning triangle shape actively, especially the horizontal offset of the twisting point [2-4,14]. However, it also leads to over offset, empty spindle and other problems easily because of mismatching of one ring spindle each time. Therefore, in this paper, the yarn hairiness on a modified ring spinning system with a pair of offset device which can change the horizontal offset of spinning triangle continuously has been studied.

Experimental

Ring Spinning System with Modified Yarn Paths

Spinning triangle is a critical region in the spinning process of stale yarn. Its geometry influences the distribution of fibre tension at spinning triangle and affects the properties of spun yarns correspondingly. In the spinning triangle, the yarn hairiness is produced since the head and tail of the border fibre cannot be rolled in yarn body easily, and at the same time the border and central fibre cannot break in twisting simultaneously as their tension are different. That is the geometry of the spinning triangle plays a key role on yarn hairiness. Therefore using appropriate methods to control the spinning triangle geometry actively and to improve yarn quality has been a core issue in spinning technology research, especially the yarn hairiness reduction. It has been shown that modifying the yarn path with “left diagonal” or “right diagonal” configurations in the traditional ring spinning can reduce the yarn hairiness, which is reacted by changing the spinning triangle shape,

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especially the horizontal offset of the twisting point [2]. However, it also leads to over offset, empty spindle and other problems easily because of mismatching one ring spindle each time [4]. Therefore, a modified ring spinning system with a pair of offset device which can change the horizontal offset of spinning triangle continuously is employed in this study.

Figure 1 shows that a pair of locating yarn rounds is incorporated into a conventional ring frame, which is installed between front roller and yarn guide and can be moved in the scale locating slot freely in order to change the horizontal offset continuously. The spinning triangle model with the right and left offset are shown in Fig. 2. Here, O is the middle point of the front roller nip line, C' is the twisting point, d is the horizontal offset of the twisting point C' to the symmetric axis of nip line OO', O' is the twisting point with $d=0$ correspondingly, and h is the height of the spinning triangle. In this study, the horizontal offset d is a continuous variable and we mainly consider its influence on yarn hairiness. For convenient analysis, we take the point O' as origin, and the horizontal offset d takes positive value with right offset, while negative value with left offset correspondingly.

The schematic diagram of the triangle in the modified ring spinning system with a pair of offset device is shown in Fig. 3. Here, Q is the origin of the scale locating slot, P is the locating point of the locating yarn round, D is the movement distance of the locating point and the value can be obtained from the scale locating slot, and H is the height from the front roller nip to the locating point; the value can be measured directly. It is observed from Fig. 3 that we can change the horizontal offset d continuously by moving the locating point of yarn up to P, and we have the following equation:

$$\frac{d}{D}=\frac{h}{H} \qquad \dots (1)$$

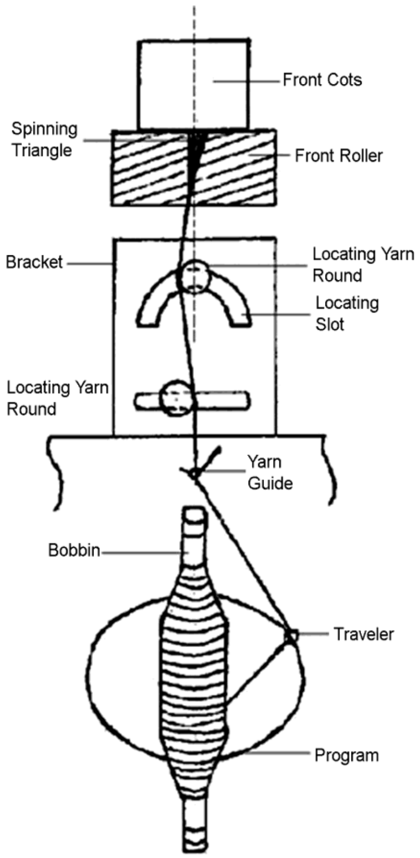

Fig. 1—Ring spinning system with offset device

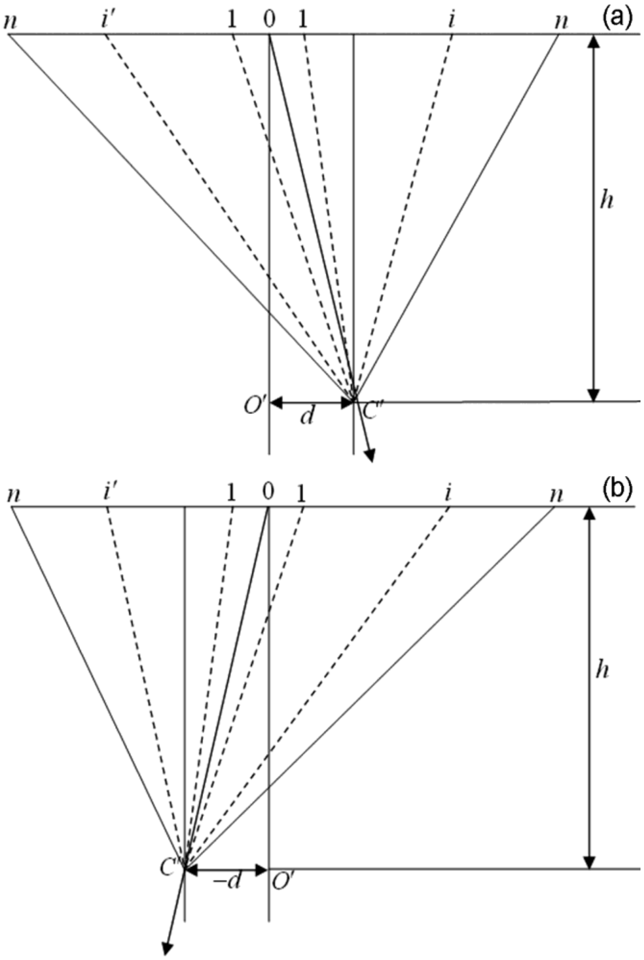

Fig. 2— Fibres distribution at spinning triangle with (a) right offset and (b) left offset

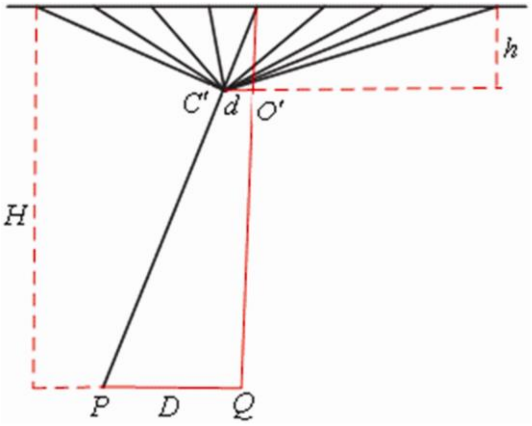

Fig. 3— Triangle diagram of modified ring spinning system

For obtaining the height of the spinning triangle h, the high speed camera should be used. Then, we can get the horizontal offset d directly from the movement distance D based on the (1). Therefore, the movement distance D is used to characterize the horizontal offset in the following discussion.

Hairiness Evaluation

In this study, 20^s, 30^s, 40^s, 50^s, 60^s cotton yarns were spun with the locating points of the locating yarn round in the origin, right 6mm, 12mm, 18mm, and left 6mm, 12mm, 18mm respectively with the twist direction "Z". The spinning parameters are given in Table 1. By using the hairiness tester YGl72A, the hairiness of the ring-spun yarn was evaluated (Table 2).

Table 1—Spinning parameters

Yarn count Ne	Roving count tex	Total draft	TM	Traveller type	Front roller speed, $r \cdot min^{-1}$
20	483	16.567	3.6	C1UL 2/0	243
30	483	24.850	3.8	C1UL 3/0	232
40	483	33.030	4.0	C1UL 5/0	218
50	425	36.443	4.0	C1UL 7/0	172
60	350	36.374	4.3	C1EL 10/0	158

Table 2— Testing results (the number of ≥3mm hairiness / 10m)

Horizontal offset	20s (CV)	30s (CV)	40s (CV)	50s (CV)	60s (CV)
0	69.10 (5.62)	54.60 (5.26)	44.80 (6.27)	66.90 (6.73)	40.00 (5.07)
6	57.80 (5.98)	39.00 (4.59)	31.30 (4.67)	50.20 (5.24)	37.50 (6.83)
12	48.30 (4.65)	31.60 (5.68)	30.80 (5.59)	46.80 (5.38)	28.80 (6.26)
18	49.30 (4.78)	40.40 (4.72)	38.80 (5.76)	61.40 (6.10)	33.30 (5.32)
-6	72.60 (5.78)	62.80 (5.62)	43.50 (5.34)	64.40 (6.23)	63.70 (5.79)
-12	86.90 (6.02)	72.30 (5.98)	55.10 (4.98)	66.30 (5.98)	65.50 (6.03)
-18	87.00 (5.92)	67.21 (6.05)	50.60 (5.21)	63.40 (6.14)	59.80 (6.09)

Results and Discussion

From Table 2, it is evident that the spun yarn with right offset has less hairiness than the normal yarn, and the optimal horizontal offset is 12mm for all five kinds of yarn. However, the spun yarn with left offset has more hairiness than normal yarn. That is, taking an appropriate right offset of the spinning triangle can help to reduce the spun yarn hairiness with "Z" twist. According to symmetry, we can speculate that taking appropriate left offset of the spinning triangle can help to reduce the spun yarn hairiness with "S" twist.

The explanations of the experimental results can be given using the fibre tension distribution in spinning triangle perspective. The spinning triangle is often assumed to be symmetrical for theoretical purpose, and the distribution of fibre tension is also symmetrical [14]. However, this is not true in practice (Fig. 4) [7].

For Z (S)-twist yarn, when the "Z" ("S") twisting is inserted into the fibres in the spinning triangle, the fibres on the right (left) side can be controlled by the pre-twisting process, i.e. there is pretension for the fibres on the right (left) side, whereas the fibres on the left side are loose relatively [Fig.5 (b)]. That is, the symmetric structure of the traditional ring spinning triangle leads to asymmetrical fibre tension distributions on both sides due to the twist propagation with different twist direction, which reveals that the head and tail of the fibres on the left (right) side cannot be rolled into yarn body easily and forms the hairiness. Therefore, the control of fibres on the left (right) side should be strengthened through asymmetrical spinning triangle, which can be realized by changing the horizontal offset. Generally speaking, for the Z-twist yarn, the right offset can ensure a better control for fibres on the left side than traditional ring spinning, and the fibres on the right side are still controlled by the pre-twisting [Fig.5 (d)]. However, the left offset will ensure a worse control for fibres on the left side [Fig.5 (c)] and leads to worse hairiness correspondingly. Therefore, with the appropriate right offset, yarn hairiness can be reduced with the twist direction "Z". Simultaneously, with the appropriate left offset, yarn hairiness can also be reduced with the twist direction "S".

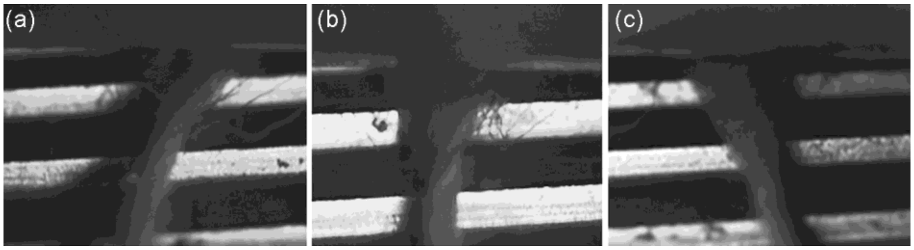

Fig. 4 —Spinning triangle structure captured by high speed camera (OLYMPUS i-speed3) [(a) spun yarn with left offset, (b) normal yarn, and (c) spun yarn with right offset]

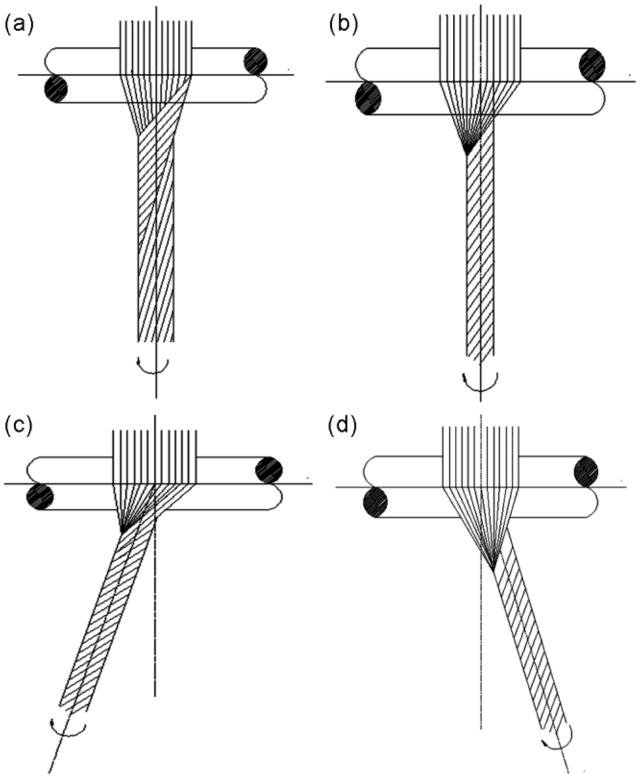

Fig. 5 —Simulated images of spinning triangle [(a) traditional ring spinning triangle structure, (b) actual ring spinning triangle, (c) modified ring spinning triangle with left offset, and (d) modified ring spinning triangle with right offset]

It is evident that the control for fibres on the left (right) side strengthens gradually with the increase in the right (left) horizontal offset for Z (S)-twist yarn. However, the yarn hairiness is not always reduced with increasing the offset. The reason is that, on the one hand, with the increase of right (left) offset, the control of fibres on the left (right) side will exceed the pretension for the fibres on the right (left) side, which also leads to asymmetrical fibre tension distributions on both sides. On the other hand, with the increase in the horizontal offset, the tension on the outer fibres increases fast. When the fibre tension increases to certain degree and exceed the maximum tolerance of fibre, the fibre will be broken and thus will not give benefit for the yarn quality. Therefore, the horizontal offset should be controlled, which can be verified with the experiment results given in Section **2.2**. According to the above analysis, it is speculated further that the optimal horizontal offset is the point on which the tension distributions on both sides of the spinning triangle is symmetrical.

In this study, the yarn hairiness in a modified ring spinning system with a pair of offset device which can change the horizontal offset of spinning triangle continuously has been discussed. It is shown that taking appropriate right offset of the spinning triangle can help to reduce the spun yarn hairiness with “Z” twist whereas appropriate left offset can help to reduce the spun yarn hairiness with “S” twist. The corresponding appropriate horizontal offsets have been given by experiments for five types of yarn, viz 20s, 30s, 40s, 50s and 60s with “Z” twist respectively. Finally, the explanations of the hairiness change are based on the fibre tension distribution in the spinning triangle perspective. It is speculated that the optimal horizontal offset is the point on which the tension distributions on both sides of the spinning triangle is symmetrical, which will be verified in our future studies.

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