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Comparison of fibre migration in different yarn bodies

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The qualities of yarn have been studied by analyzing the fibre migration in the yarn body. The effects of spinning method and raw fibre property on fibre migration have been studied using the tracer fibre technique. Compact-spun (60s Ne), ring-spun (60s and 10s Ne) and rotor-spun (10s Ne) (cotton) yarns have been prepared. However, for the compact-spun yarns, both pure cotton and polyester/cotton blended yarns have been prepared. Two mixing steps have been used, namely (i) the dyed cotton fibre mass is homogeneously mixed with the undyed cotton fibre mass by hand, and (ii) the mixed fibre agglomerates are then subjected to carding to obtain a more uniform mixture. Finally, five sets of yarns are obtained through the consequent spinning process. Fibre measuring system is used to watch the movement of tracer fibres and to get the migration parameters as well as their envelope lines. The results show that the fibre migration of the ring spinning yarn is the most obvious, followed by the compact spinning yarn. The rotor spinning yarn has so many wrapped structures that the fibre migration is not obvious. Polyester/cotton blended yarn, which has better yarn levelness, higher breaking strength and less hairiness, shows higher degree of fibre migration than the yarn made of pure cotton.

Keywords: Compact spinning, Cotton, Fibre migration, Ring spinning, Rotor spinning, Tracer fibre, Polyester/cotton

1 Introduction

Since a long time, the traditional ring spinning technology has some obvious shortcomings. One of these defects is the twist triangle area in front of the front roller jaws, making these fibres to bear inhomogenous force in the twisting process. The emergence of compact spinning technology, however, provides an effective way to reduce or even eliminate the twist triangle area[1]. Compact spinning technology is one of the most important new methods of spinning, implemented by adding a fibre-converging device in front of the drafting system on a ring spinning frame. The yarn structure and quality have improved since the fibre tension distribution in the spinning triangle is more uniform[2-4]. Actually, compact spinning, where the fibres are compressed, is a modification of conventional ring spinning, thus producing a superior quality yarn[5,6].

Rotor spinning technology, also known as the air spinning technology, is relatively a novel type of open-end spinning technology. This technology has the advantage of high production efficiency, short process flow, good working environment and high degree of automation. At present, rotor spinning is considered second most in cotton yarn production, following ring spinning.

In the early 1950s, Morton and Yen[7] introduced "migration" to denote changes in the position of a single fibre along the length of a yarn. They also defined the "coefficient of migration" (a dimensionless quantity) to express the degree of fibre migration according to a radial distance over a yarn length[8]. They first observed the fibres migration in the yarn body utilising tracer fibre technology. Under the condition that the dyed fibre properties are consistent with the undyed fibre properties, tracer fibre technology causes mixing of less than 1% of the dyed fibre with undyed fibre for spinning. The spun yarn is then dipped into a liquid having the same refractive index as that of the undyed fibre. At this time, since the undyed fibre has the same refractive index as the liquid, it exhibits transparent color, whereby the dyed fibre is visibly noticeable. The dyed fibres are called tracer fibres.

As is known, the changes in fibre feature, arrangement and distribution in yarn cause the change in yarn structure, consequently changing the yarn appearance characteristic and inherent quality. According to previous studies[9-12], section-slicing technology, tracer fibre technology and image processing can also be used to study the arrangement

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and distribution of fibre in yarn. In this work, tracer fibre technology was to study the fibre migration in yarns, spun by three spinning methods and using different raw fibre materials. The YG002C fibre system was used to observe and collect relevant data. Then, the migration coefficient of fibres is calculated. This helped in establishing the relationship between yarn quality and fibre migration.

Since there is not much research available on the comparison of fibre migration in three types of spinning methods, this work intends to give more practical experiments and theoretical analysis, thus enhancing the fundamental understanding of the relationship between fibre migration and yarn properties.

2 Materials and Methods

The parameters of cotton and polyester staple fibres are shown in Table 1.

2.1 Preparation of Cotton Yarn

Cotton (5g), reactive dye (0.4g), salt (7.5g), alkali (2.5g) and water (250mL) were used.

The prepared tracer fibres were mixed evenly with the standard cotton fibres with a ratio of 0.8%. Then, the mixed fibre group sequentially went through carding, first passage drawframe and second passage drawframe, and finally shaped into drawn sliver. One part of these drawn slivers was directly spun into rotor yarns by rotor spinning device (F1604 rotor device); and the remaining part of these drawn slivers was allowed to go through roving device and spinning device. Finally, these were spun into compact yarns and ring yarns using compact spinning device (QFA1528) and traditional ring spinning device (FA507B) respectively.

2.2 Preparation for Polyester/Cotton Blended Yarn

Disperse black dye with a ratio of 2% (with respect to the fabric), spreading agent NNO (sodium salt of polynaphthalene sulphonic acid) (1g/L), ammonium dihydrogen phosphate (2g/L), acetic acid (0.5g/L), sodium hydrosulfite (2g/L), caustic soda (2g/L), bath-ratio 1:50, and *p*H 5 – 6 were used for the experiment.

The prepared tracer fibre was mixed evenly in the ratio of 0.8% with polyester fibre and the polyester-cotton standard fibre. Then, the mixed fibre groups in proper order were allowed to go through carding, first passage drawframe, second passage drawframe, roving and compact spinning (QFA1528 type machine).

2.3 Yarn Property

The properties and quality of yarns produced from different spinning systems are shown in Table 2. Test equipments such as automatic single yarn strength tester YG-068C; Uster Zweigle HL400 hairiness tester of Switzerland; Uster Tester-5S800 Evenness tester of Switzerland, were used.

Test environmental conditions such as temperature of 21°C ± 2°C and a relative humidity of 65 ± 3%, were used. Before testing, those yarns should be placed in this condition for more than 24h to balance them.

Spinning conditions for these five sets of yarn, like twist and draft and some others, were in equivalent.

3 Results and Discussion

By connecting the crest points or trough points on one tracer fibre helical path into one line, we can observe fibre migration in the yarns, as applied by many researchers before[13]. This line is named fibre helix route's envelope, which is also the migration curve line needed in this study.

3.1 Fibre Migration Parameters

3.1.1 Calculation Methods

Three fibre migration parameters are mainly calculated, viz (i) the average radial distance relative

Table 1 — Performance parameters of raw fibre materials

Fibre	Length, mm	Degree of fineness dtex	Elongation at break, %	Strength cN	Work of fracture uJ	Breaking strength cN/tex
Cotton	31	1.65	8.57	5.12	26.05	31
Polyester	38	1.33	13.32	6.31	46.20	47

Table 2 — Properties and quality of five sets of yarn

Yarn	Coefficient of variation (CV%)	Hairiness (≥3mm)	Breaking tenacity cN/tex	Tensile strength cN	Elongation at break, %
Polyester/cotton-blended compact spun yarns (60s)	12.68	84	21.00	207.86	9.02
Pure cotton compact spun yarns (60s)	13.27	101	14.54	151.22	5.60
Ring spun yarns (60s)	13.74	183	10.88	101.18	4.42
Ring spun yarns (10s)	14.13	198	16.51	997.01	7.67
Rotor spun yarns (10s)	14.21	177	13.59	815.71	7.42

to yarn central axis for one tracer fibre envelope ($\bar{Y}$), (ii) the coverage area relative to baseline for one tracer fibre envelope, namely disperse extent, represented by standard deviation (D), and (iii) migration coefficient (MD). Specific calculation measures are as follows:

Assume

$$Y = (r/R)^2 \qquad \dots (1)$$

$$\bar{Y} = \frac{\sum Y}{n} \qquad \dots (2)$$

where r is the radial distance from one crest point of one tracer fibre helical path to yarn central axis of this crest point; R, the yarn radius at this crest point; Z, the yarn central axis; and n, the amount of tested crest points on the yarn Z-axis direction.

Then

$$D = \left[\frac{\sum (Y - \bar{Y})^2}{n}\right]^{\frac{1}{2}} \qquad \dots (3)$$

$$MD = D/\bar{Y} \qquad \dots (4)$$

3.1.2 Measurement

Before using video microscope to observe fibre migration, the yarn should get steeping treatment first. Based on the theory of different light absorption abilities of different colors of fibres, the tested yarn should be steeped into turpentine and bromonaphthalene solution, making sure that the refractive index of the unstained fibre is the same as the solution. By doing that, the unstained yarn will show a transparent color in the video microscope, and the tracer fibres can be observed clearly. Thirty (30) tracer fibres out of one kind of yarn were observed at random by the microscope.

Figure 1 shows the morphological characteristics of tracer fibres and their own relative yarns. The black fibre in the yarn is the tracer fibre. and magnification is ×100 times.

In this study, the average distance from the crest point to the yarn central axis is used. According to the calculation method, values of Y, D and MD are calculated for different yarns (Table 3).

3.1.3 Results Analysis

It has already been believed[7,8] that there are mainly two forms of migration within the yarn, viz geometric migration and tension migration. Since different yarn-making systems were applied in this study, the tension migration mechanism is the main reason for fibre migration rather than the geometric migration mechanism.

Table 3 shows that the fibre migration degree in compact spun yarn is lower than that in ring spun yarn by 5.6%, whereas in rotor spun yarn, it is reduced by 1.2% as compared to that in the ring spinning yarn. This is mainly because there are agglomeration effects at the front jaw during compact spinning. The reduction in size of spinning triangle and its consequence in the tension gradient kick up the lower degree of migration in compact-spun yarn than in ring-spun yarn. Table 2 also shows that the compact-spun yarn has higher yarn strength than ring-spun yarn. This is because higher packing density coupled with better integration of fibres into the yarn body generates higher yarn strength. However, rotor spinning has its own special spinning way, in which drawn slivers are directly made into needed yarns without going through roving procedure. Owing to its special spinning way, rotor spun yarn has a special structure, core fibres inside and wrapping fibres outside. Therefore, rotor spinning has special fibre migration.

Under certain conditions, migration of polyester fibre in polyester-cotton blended yarn is little more conspicuous than cotton fibre in pure cotton yarn, almost larger by 0.3%. This is mainly because polyester fibre is longer than cotton fibre, which

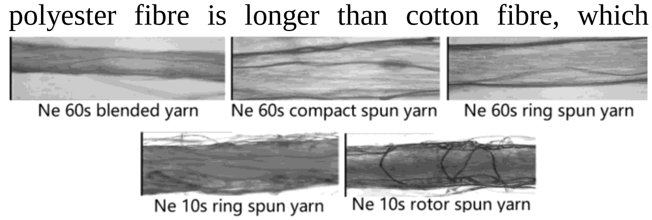

Fig. 1 — Images of five sets of yarn with tracer fibre

Table 3 — Migration parameters of five sets of fibre

Yarn	Average relative radial position ($\bar{Y}$)	Standard deviation (D)	Migration coefficient (MD)
Polyester/cotton blended compact spun yarns (60s)	0.216	0.194	0.940
Pure cotton compact spun yarns (60s)	0.237	0.222	0.937
Ring spun yarns (60s)	0.221	0.219	0.989
Ring spun yarns (10s)	0.250	0.896	0.896
Rotor spun yarns (10s)	0.261	0.231	0.885

makes more fibres interaction during spinning. At the same time, polyester fibre is finer than cotton fibre, which makes it easier to transfer by force.

3.2 Fibre Envelope Line

Fibre envelope line can also be applied as characterization of fibre migration. Fibre envelope refers to one line, connecting peak points or trough points on fibre helical path. Fibre envelop lines in different spinning methods are shown in Fig. 2, where abscissa represents coordinate value of peak point on the tracer fibre helical path. The line is drawn by connecting 20 peak points at random on one tracer fibre.

It is observed that polyester-cotton blended yarn has more concentrated peak points distribution, and the average radial position of tracer polyester fibre is smaller. These can be explained by two reasons. The first reason is that being longer fibre, polyester fibre will get in touch with more surrounding fibres, thus leading to get stronger force from surroundings. So, when being twisted, polyester fibre tends to move towards the inner side of one yarn. Instead, shorter fibre, like ordinary cotton fibre, prefers to the outside. The second reason is that the thicker fibre is stiffer, possessing greater resistance when moving. So,

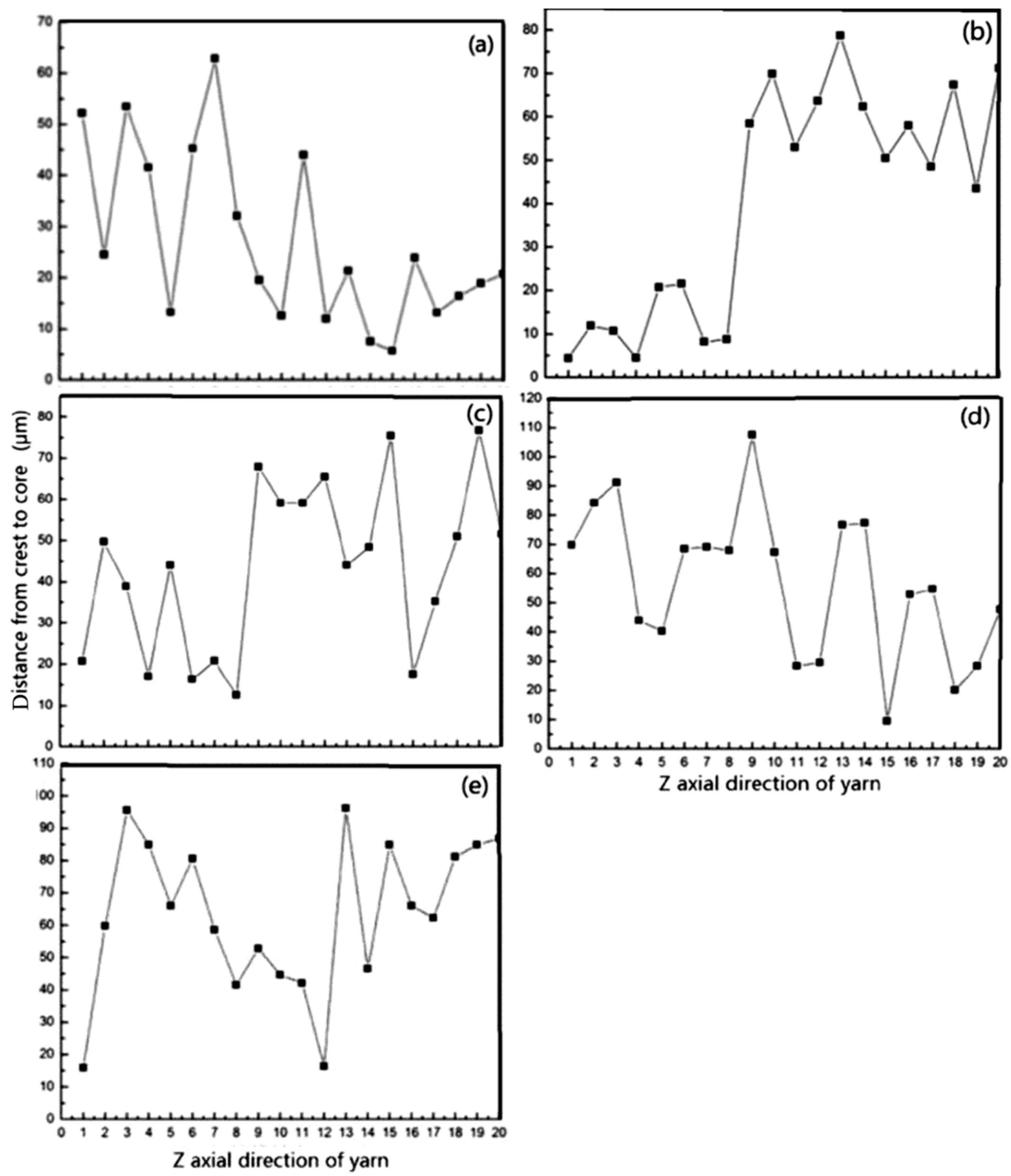

Fig. 2 — Fibre helix envelope lines of (a) polyester-cotton blended yarn (60s), (b) compact spun yarn (60s), (c) ring spun yarn (60s), (d) ring spun yarn (10s) and (e) rotor spun yarn (10s)

thicker fibre, like ordinary cotton fibre, prefers to stay the outer side of one yarn instead of moving towards the inner side when getting twisted by force.

As is known, compact spinning technology refers to reduce the width of sliver at twisting triangle area when sliver passes through the front roller, which contributes to a closer distance between fibres or fibre groups, thus facilitating the interaction between fibres. Hence, in compact spinning, fibre migration phenomenon is less obvious than that in ring spinning.

Within the rotor spinning cup, one end of fibre bundle must be held by the cup wall, and the other end would get whirly twisting, thus being made into yarn in a free-end way. During this special yarn-making system proceeding, the fibre bundle hardly goes through one process where sliver width is larger than yarn diameter, which is common phenomenon for fibre bundle in ring spinning system. Therefore, fibre motion in rotor spinning is more stable than that in ring spinning. Moreover, drawn sliver does not need to enter roving process, and instead, it goes into rotor spinning directly. This way, fibre suffers less drawing force, getting less influenced from tension mechanism during migration. So, fibre transfer coefficient is smaller.

4 Conclusion

Fibre migration phenomenon in compact spinning yarn is found less obvious than in ring spinning yarn and its edge fibre has higher utilization rate, which creates less yarn hairiness and significantly increasing the yarn strength. Rotor spinning yarn shows a different fibre transport system because of its special yarn-making way. Its fibre migration magnitude is smaller than that in ring spun yarn. In addition, it has shorter head fibres and less hairiness than ring spun yarn. Further studies reveal that polyester fibre migration in polyester/cotton blended yarn is larger than that of cotton fibre in pure cotton yarn, and most of them are distributed in the center of yarn. Based on this feature, blended yarn can respectively utilize synthetic fibre and natural fibre as main inner fibre and outer edge fibre in yarn. The former fibre has excellent physical and mechanical properties, and natural fibre has better appearance conditions and higher feel-comfort level. By taking into account excellent performance of both kinds of fibres, the best quality characteristics of blended yarn can be produced.

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