Analysis of the Twist Influencing Factors of Self-twist Yarns

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Abstract

The factors influencing self twists include two main categories: structural parameters and process parameters on the self-twist spinning machine. Firstly from the twist formula of in-phase self-twist yarn over a half cycle length, six structural parameters can be obtained i.e. the oscillating stroke D, cycle length X, the distance L₀ from the nip of the front rollers to the nip of the self-twist rollers, the perimeter of strand P, the feeding distance e of two strands, and the distance L₁ from the nip of the self-twist rollers to the convergence guide O. Among these six parameters, the effect of the oscillating stroke D and cycle length X on the self-twist is opposite; therefore, the oscillating stroke D and cycle length X should have a reasonable configuration in order to get more self twists. At the same time, the greater the distance from the nip of the front rollers to the nip of the self-twist rollers can achieve more twists of self-twist yarn in the case of limited space. Twists over the half cycle length decrease with an increase in the circumference of strand P; along with that in the feeding distance e and distance L₀ from the nip of the self-twist rollers to the convergence guide. The twists are also influenced by the processing parameters, such as the spinning speed, the pressure of the self-twist rollers, and the spinning tension E₀ and E₁, from the nip of the front rollers to the self-twist rollers and from the nip of the self-twist rollers to the convergence guide, respectively. The lower the spinning speed and the higher the pressure of the self-twist rollers, the more self twists can be obtained. In the same way, the smaller the spreading tension E₀ and E₁, the more twists can be achieved. However, the value of spinning tension E₀ and E₁, cannot be lower than 1.025 and 0.92, otherwise the normal spinning process cannot be obtained.

Key words: strand, self-twist yarn, half cycle length, self twists, processing parameters.

Introduction

The twists of self-twist yarn are expressed by the twists over the half cycle length [1]. Self-twist is usually obtained by slubbing two strands through a pair of reciprocating self-twisting rollers [2]. It was also found that self twists are obtained by converging after two strands penetrate two nozzles, respectively [3].

Many researchers have concentrated their work on the effect of spinning processing parameters on yarn quality. Su and Lo [4] studied the optimum drafting conditions of fine-denier polyester spun yarn, and optimum spinning conditions were obtained, which are a break draft ratio of 1.3 and 56 mm roller gauge in conjunction with a higher roller pressure (14 kgf). Yasemin and Hassan [5] investigated the relationship between the fibre fineness, break draft, and drafting force. They found that fibre fineness interacts with the break drafting ratio to affect the drafting force and sliver irregularity. Saiyed et al. [6] focused their work on the influence of fibre friction, top arm pressure and the roller setting at various drafting stages on yarn properties. In a past research of self-twist spinning, Henshaw [7] built up a mathematical model of yarn structure and the relationships between the twists of self-twist yarn and those of each strand. Wang [8-9] further revised the relationships between the twists of self-twist yarn and those of each strand and studied the effect of evenness on the twists of self-twist yarn. Henshaw [10-11] studied the strength properties of self-twist yarn and their dependence on various yarn parameters, such as the cycle length and phasing for 60/64S wool fibres and also reported the factors that affect the distribution of strand twist and self-twist. Walls [2] investigated the twisting process and twist distribution of self-twist yarn, deduced a formula to calculate the twist, and pointed out the relationships between twists and relative parameters. In reference [12-13], two methods are proposed to calculate the distribution function of self-twist. The results show that the distribution function of self-twist expressed by the twist distribution of slivers A and B is closer to the measured result of self-twist yarn, and the formula of the distribution function of self-twist is obtained, which lays a theoretical foundation for the analysis in this paper. At present, there are relatively few researches on the influence of self-twist spinning on self twists. In this paper, the twist distribution function of self-twist yarn is expressed by the twist distribution function of slivers A and B, and the expression of the twist over the half-cycle length of self-twist yarn is obtained. The variation of self twists was tested, and the structure parameters and spinning parameters were analyzed with respect to their specific influence through
Calculation of the twists of self-twist yarn

Self twists are calculated by the twist distribution function of self-twist yarn, which is expressed by the twist distribution function for the L1 strand from the nip of the self-twist rollers to the convergence guide. The relationship $K = \frac{2\sqrt{2}}{\pi}$ between the twists of the strand and those of self-twist yarn deduced by Ellis [14] is adopted. $K$ is the relationship coefficient between the twists of the strand and those of the self-twist yarn. The self-twist spinning process schematic diagram is shown in Figure 1. Drafted strands A and B, twisted by a couple of reciprocating rollers, respectively, which accumulate a certain torque, are converged at the convergence guide O to form self-twist yarn by untwisting.

The twist distribution function $T_a(Z) = T_b(Z)$ [12] of strands A and B over yarn section $L_2$ is as follows: the length of strands A and B over yarn section $L_2$ is $\sqrt{\frac{e^2}{4} + L_2^2}$ thus Equation (1). Where, $D$ – reciprocating stroke of ST rollers; $P$ – perimeter of strand (mm); $X$ – length of one cycle; $Z$ – delivery length; $T_a(Z)$, $T_b(Z)$ – twist distribution function of strands A and B over section $L_2$ of the yarn, $\beta$ – phase angle of strand A or B.

The self-twist distribution functions are obtained from the twist distribution functions of the strands, shown as follows Equation (2). Where $T_0(Z)$ is the self-twist distribution function.

Substituting Equation (1) into (2), the twist distribution function of self-twist yarn can be given Equation (3).

Twists $T$ over the half cycle length can be obtained by integrating the twist distribution function of self-twist yarn over the half cycle length ($\frac{BX}{\pi} = \frac{\pi X}{2\pi} = \frac{X}{2}$): Equation (4).

It can be seen from Equation (4) that structural parameters such as the oscillating stroke – $D$, cycle length – $X$, the distance from the nip of the front rollers to the nip of the self-twist rollers – $L_1$, the perimeter of strand – $P$, the feeding distance of the two strands – $e$, and the distance from the nip of the self-twist rollers to the convergence guide O – $L_2$, have effects on the twists of self-twist yarns.

The influence of structural parameters on the twists of self-twist yarn

Experiment

Acrylic fibres of 3 denier fineness and 102 mm length and wool fibres of 22 µm diameter and 78 mm length were spun to produce acrylic sliver and wool sliver. Acrylic sliver weighted 10 g/m and wool sliver weighted 6 g/m were spun into self-twist yarns on S300 self-twist spinning systems. The average counts were 50 tex wool/acrylic blended self-twist yarn for structural parameters and 50 and 73 tex wool/acrylic blended self-twist yarn for different spinning speeds (50, 100, 150, 200, 235 m/min). 132 tex wool/acrylic blended self-twist yarns were spun at different pressures (300, 400, 500, 600 g) of self-twist rollers and at different spinning tensions. Yarn twist was tested by a YG155 twister. The self-twist per half cycle length was determined by untwisting the yarn at a 105 cm length (half cycle length) until the strands became parallel, and twenty data were taken on average.
The influence of different structural parameters on the twists of self-twist yarn

In Equation (4), the twists of self-twist yarn over the half cycle length is related with six factors i.e. the oscillating stroke D, cycle length X, the distance from the nip of the front rollers to the nip of the self-twist rollers L1, the perimeter of strand P, the feeding distance D and the feeding distance of two strands, the distance from the nip of the self-twist rollers to the convergence guide O. When one factor is researched, five other factors can be arbitrarily fixed to discuss the relationship between the twists of self-twist yarn over the half cycle length and any one of these factors. Firstly these six factors are all partially derived see Equation (5).

Because all the spinning structural parameters are given a positive value, in the above partial derivative, \( \frac{\partial T}{\partial D} > 0, \frac{\partial T}{\partial P} < 0, \frac{\partial T}{\partial X} < 0, \frac{\partial T}{\partial e} < 0, \frac{\partial T}{\partial L_1} > 0, \frac{\partial T}{\partial L_2} < 0 \) among the six parameters the twists of the self-twist yarn increase with an increase in D & L1, and decrease with an increase in X, P, e & L2.

\[
\begin{align*}
\frac{\partial T}{\partial D} &= \frac{\sqrt{2\pi} L_1 X}{P \sqrt{X^2 + 4\pi^2 L_1^2} \sqrt{X^2 + \pi^2 e^2 + 4\pi^2 L_2^2}} \\
\frac{\partial T}{\partial P} &= \frac{\sqrt{2\pi} D L_1 X}{P^2 \sqrt{X^2 + 4\pi^2 L_1^2} \sqrt{X^2 + \pi^2 e^2 + 4\pi^2 L_2^2}} \\
\frac{\partial T}{\partial X} &= \frac{\sqrt{2\pi} D [16\pi^2 L_1^2 (e^2 + 2L_2^2) - X^2]}{P \sqrt{(X^2 + 4\pi^2 L_1^2)^3} \sqrt{(X^2 + \pi^2 e^2 + 4\pi^2 L_2^2)^3}} \\
\frac{\partial T}{\partial e} &= \frac{\sqrt{2\pi} D L_1 X e}{P \sqrt{X^2 + 4\pi^2 L_1^2} \sqrt{(X^2 + \pi^2 e^2 + 4\pi^2 L_2^2)^3}} \\
\frac{\partial T}{\partial L_1} &= \frac{\sqrt{2\pi} D X^3}{P \sqrt{X^2 + \pi^2 e^2 + 4\pi^2 L_2^2} \sqrt{(X^2 + 4\pi^2 L_2^2)^3}} \\
\frac{\partial T}{\partial L_2} &= \frac{\sqrt{2\pi} D L_1 X}{P \sqrt{X^2 + 4\pi^2 L_1^2} \sqrt{(X^2 + \pi^2 e^2 + 4\pi^2 L_2^2)^3}}
\end{align*}
\]

Equation (5)
The influence of process parameters on the twists of self-twist yarn

The spinning speed [15], the pressure of the self-twist rollers, and the spinning tension $E_3$ from the nip of the front rollers to that of the take-up rollers are the main processing parameters which influence the twists of self-twist yarn.
The effect of spinning speed on the twist of self-twist yarn

The production efficiency of the self-twist spinning system can be affected by the spinning speed. It is beyond doubt that the spinning speed has an influence on the twists of self-twist yarn. The higher the spinning speed is, the shorter the time of two strands used to be self-twisted; and thus fewer twists can be added to the self-twist yarn (Figure 4.a).

The effect of the pressure of the self-twist rollers on the twist of self-twist yarn

Self-twist rollers are pressurised by weight, each being 100 g. Four groups – 300 g, 400 g, 500 g and 600 g were tested. The results showed that the greater the pressure of the self-twist roller, the more twists of self-twist yarn obtained (Figure 4.b).

The effect of the spinning tension on the twist of self-twist yarn

From the nip of the front rollers to that of the take-up rollers can achieve more twists of self-twist yarn over the half cycle length. That is to say, the smaller the spinning tension E1 and E2, the more twists obtained. But when the spinning tension E1 and E2 is too small to maintain spinning in the guide, the spinning tension E2 should be controlled in the range of (1.025-1.06), and E1 should be more than 0.92. It is found that the spinning process cannot be carried out smoothly when the spinning tension E2 is less than 0.92.

Conclusions

By calculating the twist formula of in-phase self-twist yarn over the half cycle length, six structural factors can be obtained i.e. the oscillating stroke D, cycle length X, the distance L1 from the nip of the front rollers to the nip of the self-twist rollers, the perimeter of strand P, the feeding distance of the two strands e, and the distance L2 from the nip of the self-twist rollers to the convergence guide O. Among these six parameters, when a particular yarn is spun, the effect of the oscillating stroke D and cycle length X on the self-twist is opposite, where the larger the oscillating stroke D, the greater the twist of self-twist yarn, and the greater the cycle length X, the smaller the twist of self-twist yarn. Therefore the oscillating stroke D and cycle length X should have a reasonable configuration in order to get the higher twist of self-twist yarn. At the same time, the greater the distance from the nip of the front rollers to the nip of the self-twist rollers, the more the twist of self-twist yarn in the case of the limited space when selecting these parameters. The twist over the half cycle length decreases with an increase in the circumference of strand P along with a decrease in the feeding distance e and increase in the distance L2 from the nip of the self-twist rollers to the convergence guide. In summary, the smaller these three factors, the better the degree of twisting.

The twists are influenced by processing parameters such as the spinning speed, the pressure of the self-twist rollers, and spinning tension E1 and E2 respectively, from the nip of the front rollers to the self-twist rollers and from the nip of the self-twist rollers to the convergence guide. In the case of the same specimen, the higher the spinning speed is, the more twists there are. At the same time, the higher the pressure of the self-twist rollers, the more twists of self-twist yarn obtained. In the same way, the smaller the spinning tension E1 and E2, the more the twist counts at the nip of the front rollers to that of the take-up rollers can achieve more twists of self-twist yarn over the half cycle length. That is to say, the smaller the spinning tension E1 and E2, the more twists obtained. But when the spinning tension E1 and E2 is too small to maintain spinning in the guide, the spinning tension E2 should be controlled in the range of (1.025-1.06), and E1 should be more than 0.92. It is found that the spinning process cannot be carried out smoothly when the spinning tension E2 is less than 0.92.

Table 1. Twists at different spinning tensions E1 and E2

<table>
<thead>
<tr>
<th>E1</th>
<th>E2</th>
<th>S</th>
<th>Z</th>
</tr>
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<tr>
<td>1.025</td>
<td>0.92</td>
<td>11.3</td>
<td>10.8</td>
</tr>
<tr>
<td>1.025</td>
<td>0.95</td>
<td>11.1</td>
<td>9.6</td>
</tr>
<tr>
<td>1.025</td>
<td>0.99</td>
<td>10.7</td>
<td>10.5</td>
</tr>
<tr>
<td>1.06</td>
<td>0.92</td>
<td>10.3</td>
<td>10.8</td>
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<td>1.06</td>
<td>0.99</td>
<td>9</td>
<td>8.9</td>
</tr>
<tr>
<td>1.096</td>
<td>0.92</td>
<td>8.5</td>
<td>8.4</td>
</tr>
<tr>
<td>1.096</td>
<td>0.95</td>
<td>8.1</td>
<td>7.9</td>
</tr>
<tr>
<td>1.096</td>
<td>0.99</td>
<td>7.4</td>
<td>6.6</td>
</tr>
</tbody>
</table>

Figure 4. Twists over the half cycle length with the spinning speed and the pressure of the self-twist rollers: a) twists over half cycle length and spinning speed, b) twists over half cycle length and pressure of self-twist rollers.
achieved. However, the value of spinning tension $E_1$ and $E_2$ cannot be lower than 1.025 and 0.92, and otherwise a normal spinning process cannot be obtained.

References


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