Hong Cui[1,*],
Xiuli Gao[2],
Dawei Gao[1],
Hongqin Lin[1]

Analysis of the Twist Influencing Factors of Self-twist Yarns

DOI: 10.5604/01.3001.0012.9985

[1] **College of Textiles and Clothing, Yancheng Institute of Technology,**
Yancheng, Jiangsu, 224000, China
* e-mail: cuih72@163.com

[2] **College of Textiles, Henan Institute of Engineering,**
Zhengzhou, Henan, 450007, China

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 L_1 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 L_2 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 L_2 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 E_1 and E_2 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 spinning tension E_1 and E_2, the more twists can be achieved. However, the value of spinning tension E_1 and E_2 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

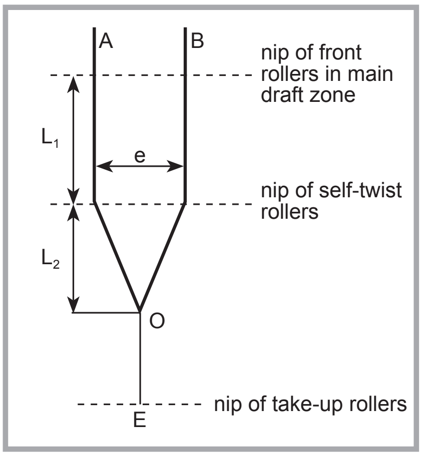

Figure 1. Schematic diagram of self-twist spinning process. Where: L_1 – distance from the nip of front rollers to the nip of self-twist rollers, L_2 – distance from the nip of self-twist rollers to the convergence point O, O – convergence point of strands A and B, e – distance between two strands.

experiments on the structure and spinning parameters. The aim of this study was to obtain optimum structure parameters and process parameters of self-twist spinning by analysing the factors affecting the self-twist, so as to obtain better quality of self-twist spinning yarn.

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 L_2 strand from the nip of the self-twist rollers to the convergence guide. The relationship $K=2\sqrt{2}$ 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, β – 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 $T_{st}(Z)$ 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 $(-\frac{\beta X}{2\pi}$ $-\frac{\beta X}{2\pi}+\frac{X}{2})$: ***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.

$$\begin{cases} T_A(Z)=T_B(Z)=\dfrac{2\pi^2 DL_1}{P\sqrt{X^2+4\pi^2L_1^2}\sqrt{X^2+\pi^2e^2+4\pi^2L_2^2}}\sin\left(\dfrac{2\pi Z}{X}+\beta\right) \\ \beta=\arctan\dfrac{X^2-2\pi^2L_1\sqrt{e^2+4L_2^2}}{\pi X2(L_1\sqrt{e^2+4L_2^2})} \end{cases} \tag{1}$$

$$\begin{cases} T_{st}(Z)=\dfrac{1}{K}\left[T_A(Z)+T_B(Z)\right] & T_A(Z)T_B(Z)\geq 0 \\ T_{st}(Z)=0 & T_A(Z)T_B(Z)<0 \end{cases} \tag{2}$$

$$\begin{cases} T_{st}(Z)=\dfrac{1}{\sqrt{2}}\left[\dfrac{2\pi^2DL_1}{P\sqrt{X^2+4\pi^2L_1^2}\sqrt{X^2+\pi^2e^2+4\pi^2L_2^2}}\sin\left(\dfrac{2\pi Z}{X}+\beta\right)\right] \\ \qquad T_A(Z)T_B(Z)\geq 0 \\ T_{st}(Z)=0 \qquad T_A(Z)T_B(Z)<0 \end{cases} \tag{3}$$

$$\begin{gathered} T=\int_{-\frac{\beta X}{2\pi}}^{-\frac{\beta X}{2\pi}+\frac{X}{2}}\frac{1}{\sqrt{2}}\left[\frac{2\pi^2DL_1}{P\sqrt{X^2+4\pi^2L_1^2}\sqrt{X^2+\pi^2e^2+4\pi^2L_2^2}}\sin\left(\frac{2\pi Z}{X}+\beta\right)\right]dZ \\ T=\frac{\sqrt{2}\pi DL_1X}{P\sqrt{X^2+4\pi^2L_1^2}\sqrt{X^2+\pi^2e^2+4\pi^2L_2^2}} \end{gathered} \tag{4}$$

Equations (1), (2), (3) *and* ***(4).***

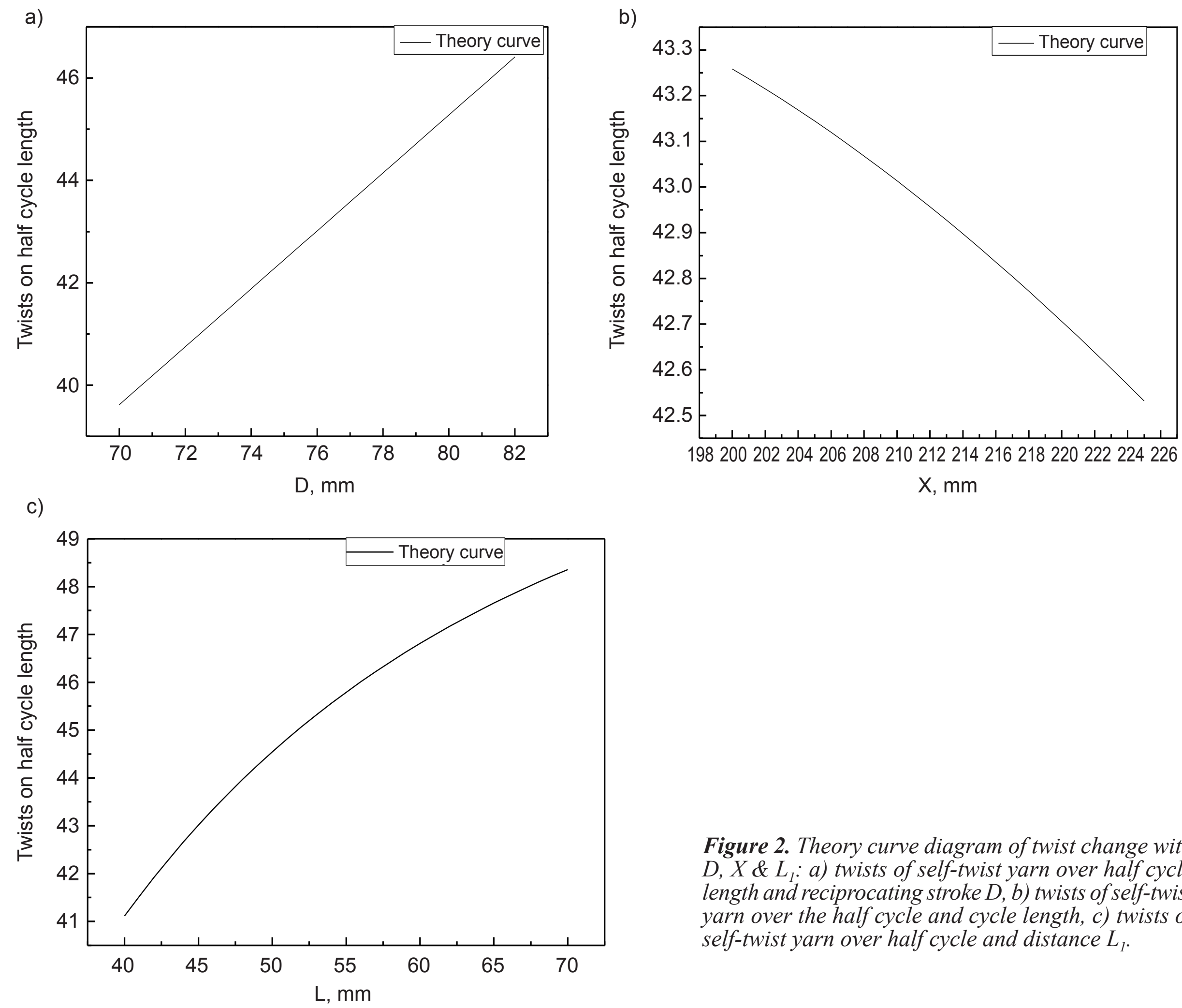

Figure 2. *Theory curve diagram of twist change with D, X & L_1: a) twists of self-twist yarn over half cycle length and reciprocating stroke D, b) twists of self-twist yarn over the half cycle and cycle length, c) twists of self-twist yarn over half cycle and distance L_1.*

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 L_1, the perimeter of strand P, the feeding distance e 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 &L_1, and decrease with an increase in X, P, e & L_2.

$$\frac{\partial T}{\partial D} = \frac{\sqrt{2}\pi L_1 X}{P\sqrt{X^2 + 4\pi^2 L_1{}^2}\sqrt{X^2 + \pi^2 e^2 + 4\pi^2 L_2^2}} \qquad \frac{\partial T}{\partial P} = \frac{\sqrt{2}\pi D L_1 X}{P^2\sqrt{X^2 + 4\pi^2 L_1{}^2}\sqrt{X^2 + \pi^2 e^2 + 4\pi^2 L_2^2}}$$

$$\frac{\partial T}{\partial X} = \frac{\sqrt{2}\pi D[16\pi^4 L_1^2(e^2 + 2L_2^2) - X^2]}{P\sqrt{(X^2 + 4\pi^2 L_1{}^2)^3}\sqrt{(X^2 + \pi^2 e^2 + 4\pi^2 L_2^2)^3}} \qquad \frac{\partial T}{\partial e} = \frac{-\sqrt{2}\pi^3 L_1 X e}{P\sqrt{X^2 + 4\pi^2 L_1{}^2}\sqrt{(X^2 + \pi^2 e^2 + 4\pi^2 L_2^2)^3}} \tag{5}$$

$$\frac{\partial T}{\partial L_1} = \frac{\sqrt{2}\pi D X^3}{P\sqrt{X^2 + \pi^2 e^2 + 4\pi^2 L_2^2}\sqrt{(X^2 + 4\pi^2 L_1{}^2)^3}} \qquad \frac{\partial T}{\partial L_2} = \frac{-8\sqrt{2}\pi^3 L_1 L_2 X}{P\sqrt{X^2 + 4\pi^2 L_1{}^2}\sqrt{(X^2 + \pi^2 e^2 + 4\pi^2 L_2^2)^3}}$$

Equation (5).

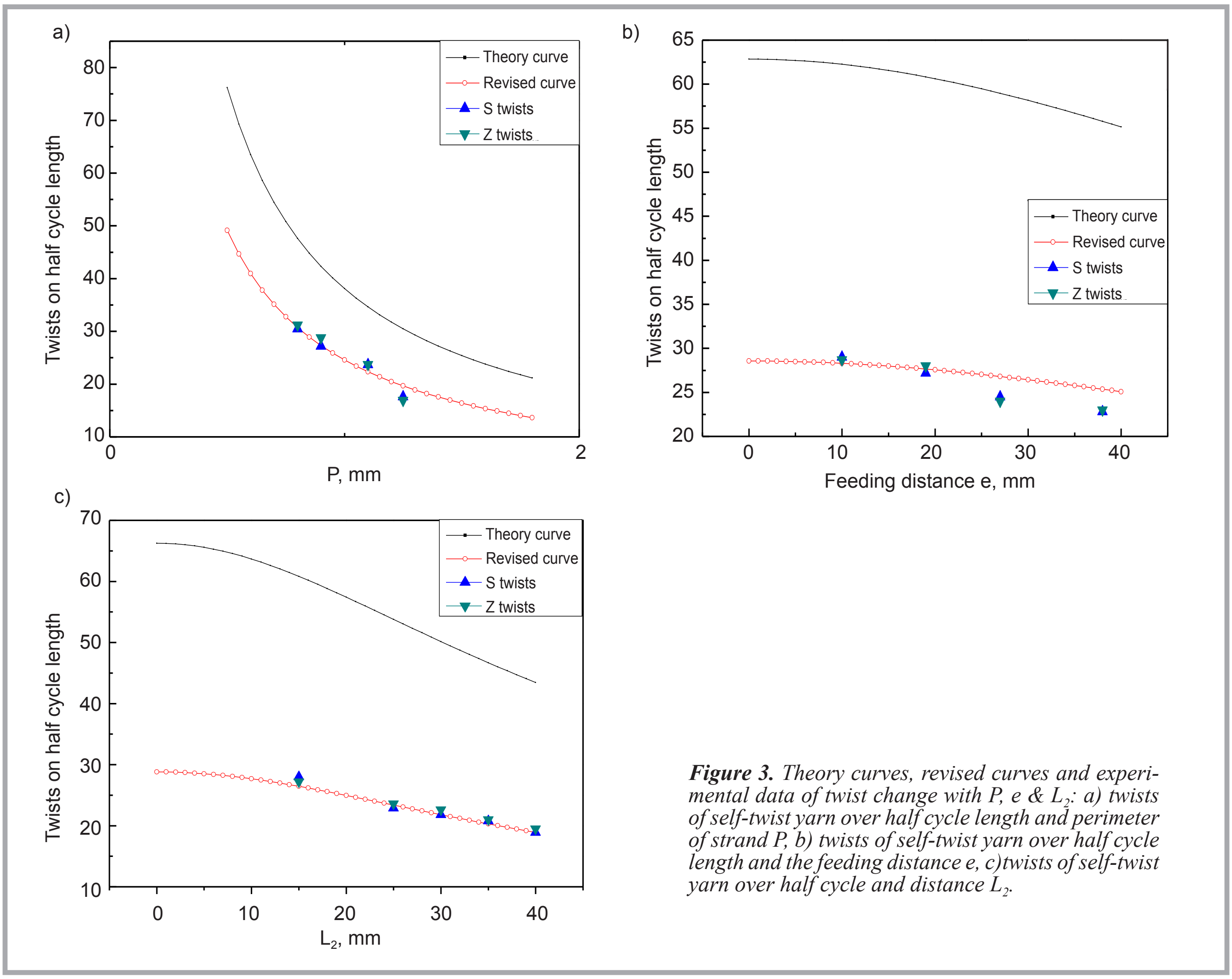

Figure 3. *Theory curves, revised curves and experimental data of twist change with P, e & L_2: a) twists of self-twist yarn over half cycle length and perimeter of strand P, b) twists of self-twist yarn over half cycle length and the feeding distance e, c)twists of self-twist yarn over half cycle and distance L_2.*

Theory curves of the twists of self-twist yarn change with D, X & L_1, shown in ***Figure 2***.

Theory curves, revised curves and experimental data of the twists of self-twist yarn are shown in ***Figure 3***. Because the twisting efficiency of self-twist yarn is relatively low, only 40-50%, the twist distribution function curve needed to be revised according to the average twist efficiency.

It can be seen from ***Figure 2.a-2.c***, in the relations between the reciprocating stroke D, cycle length X, the distance L_1 from the nip of the front rollers to the self-twist rollers and the twists of self-twist yarn, there is a linear relation between the twists of self-twist yarn and the reciprocating stroke D, where the twists of self-twist yarn increase with an increase in the oscillating stroke D and distance L_1 from the nip of the front rollers to the self-twist rollers, and decrease with an increase in the cycle length X. That is to say, a larger oscillating stroke D, a greater distance L_1 from the nip of the front rollers to the self-twist rollers, and a smaller cycle length X can achieve more twists of self-twist yarn. However, the reciprocating stroke D and cycle length X are contradictory, but they should reasonably match in order to obtain better yarn quality. The reason is that an increase in the reciprocating traverse D inevitably leads to a increase in the cycle length X. The larger the distance L_1 from the nip of the front rollers to the self-twist rollers is, the more twists of self-twist yarn can be obtained. But its value is limited in a certain range.

As shown in ***Figure 3.a-3.c***, in the relations between the perimeter of strand P, the feeding distance of two strands e, the distance L_2 from the nip of the self-twist rollers to the convergence guide O, and the twists of self-twist yarn, there exists a difference between theoretical twists and actual twists, and there is a 40-50% average twist efficiency for self-twist yarn. The figure shows the theory curve, correction curve and actual twist value. From the curves in ***Figure 3***, the twists of self-twist yarn decrease not only with an increase in the perimeter of strand P but also with an increase in the feeding distance of two strands e and with an increase in the distance L_2 from the nip of the self-twist rollers to the convergence guide O. The smaller the values of these three factors are, the more twists are obtained. When the actual twists are measured over the half cycle length, they are distributed in the vicinity of the correction curve. This illustrates that ***Equation (4)*** can correctly reflect the twists of self-twist yarn.

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_1 from the nip of the front rollers to that of the self-twist rollers and E_2 from the nip of the self-twist rollers to that of the take-up rollers are the main processing parameters which influence the twists of self-twist yarn.

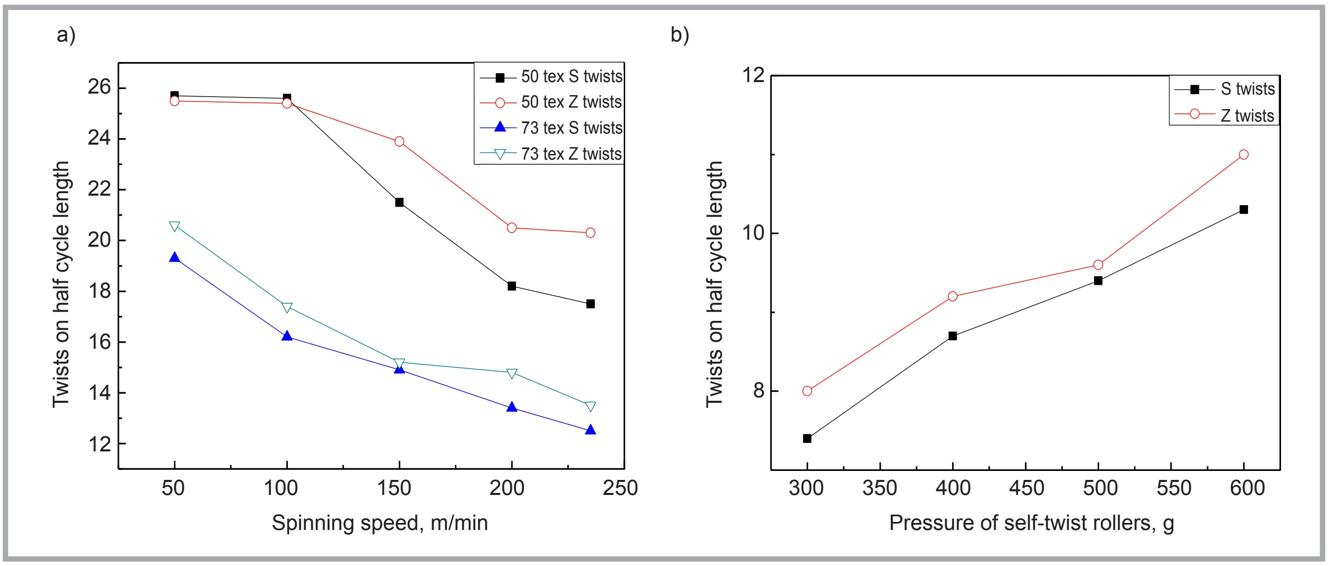

Figure 4. *Twists over the half cycle length with the spinning speed and the pressure of the self-twist rollers: a) twists over half cycle length and spinning speed, b) twists over half cycle length and pressure of self-twist rollers.*

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, 40, 500 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 self-twist rollers and from the nip of the self-twist rollers to that of the take-up rollers, the self-twist yarn should keep a certain tension to ensure a smooth spinning process. Tension size will directly affect the process of self-twist and twists. Smaller spinning tension E_1 from the nip of the front rollers to that of the self-twist rollers can gain more twists of self-twist yarn over the half cycle length, as seen from ***Table 1***. When the same spinning tension E_1 is adopted, smaller spinning tension E_2 from the nip of the self-twist 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 E_1 and E_2, the more twists obtained. But when the spinning tension E_1 and E_2 is too small to maintain spinning in the guide, the spinning tension E_1 should be controlled in the range of (1.025-1.06), and E_2 should be more than 0.92. It is found that the spinning process cannot be carried out smoothly when the spinning tension E_2 is less than 0.92.

Table 1. *Twists at different spinning tensions E_1 and E_2.*

E_1	E_2	S	Z
1.025	0.92	11.3	10.8
1.025	0.95	11.1	9.6
1.025	0.99	10.7	10.5
1.06	0.92	10.3	10.8
1.06	0.95	9.1	9.2
1.06	0.99	9	8.9
1.096	0.92	8.5	8.4
1.096	0.95	8.1	7.9
1.096	0.99	7.4	6.6

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 L_1 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 L_2 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 L_2 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 E_1 and E_2,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 E_1 and E_2, the more twist counts 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

1. Henshaw DE. *Self-twist Yarn[M]*. Merrow Publishing Co., Ltd., Watford, England, 1971.
2. Walls GW. Oscillating Rollers for Self-twist Spinning [J]. *J. Text. Inst.* 1970, 61(6): 245-259.
3. Telitsyn AA, Delektorskaya IA. Specifics of Forming a Self-twisted Product in Asymmetrical Torsion Device. *FIBRES & TEXTILES in Eastern Europe* 2014; 22, 3(105): 58-60.
4. Ching-Iuan Su and Kuo-Jung Lo. Optimum Drafting Conditions of Fine-Denier Polyester Spun Yarn [J]. *Textile Research Journal* 2000, 70(2): 93-97.
5. Yasemin Aydogmus Korkmaz and Hassan M. Behery. Relationship Between Fiber Fineness, Break Draft, and Drafting Force in Roller Drafting [J]. *Textile Research Jounal* 2004, 74(5): 405-408.
6. Saiyed M. Ishtiaque, Apurba Das and Ritesh Niyogi. Optimization of Fiber Friction, Top Arm Pressure and Roller Setting at Various Drafting Stages [J]. *Textile Research Jounal* 2006, 76(12): 913-921.
7. Henshaw D.E.A. Model for Self-twist Yarn. *J.Text. Inst.* 1970, 61(3): 97-107.
8. Shen Wang, ZhiYou Zhang. The argument of the relationship between twist of self-twist yarn and the single strand. *Journal of Textile Research* [J]. 1987, 8 (11): 691-694.
9. Shen Wang, Zhiyou Zhang. Effect of Evenness of Self-twist Yarn on Self-twist [J]. *Cotton Textile Technology* 1983(9): 2-6.
10. Henshaw DE. Self-twist Yarn[J]. *J. Text. Inst.* 1969, 60(11): 443-451.
11. Henshaw DE. Twist Distribution in Self-twist Yarn [J]. *J. Text. Inst.* 1970, 61(6): 269-278.
12. Hong Cui, Yu Chongwen. Study of Self-twist Distribution Functions in Different Convergence Modes[J]. *FIBRES & TEXTILES in Eastern Europe* 2012; 20, 5(94): 26-29.
13. Hong Cui, Chunxia Wang,Libin Lv. Characterization of the Twist Distribution Function and Twist Unevenness of Self-twist Yarns [J]. *FIBRES & TEXTILES in Eastern Europe*, 2016, Vol. 24, 1(115): 45-48. DOI: 10.5604/12303666.1172085.
14. Ellis BC, Walls GW. Towards the Better Understanding of Self-twist Structures [J]. *J. Text. Inst.* 1973, 64, 386-389.
15. Hong Cui, Chongwen Yu. Influence of Spinning Speed at Self-twist Spinning System on Yarn Quality. *Advanced Textile Materials* 2011; 1: 560-563.

Received 27.02.2017   Reviewed 15.10.2018