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Frictional Coefficient Change of Groove Surface in Compact Spinning with a Suction Groove

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Abstract
Compared with conventional ring spinning, compact spinning with a suction groove can reduce hairiness and improve yarn quality, and it has certain advantages to long staple fibre. In this article, we analyse the changing rule of rotational speed and study the change curve of the frictional coefficient in the gathering zone. The results show that the fibre bundles' rotational speed at each point along the surrounding arc gradually decreases from the maximum to zero in the gathering area, but the rotating speed of the fibre bundles is constant in the suction hole. The angle between the parallel component speed and that at each point is near to a linear change in the no suction hole, with there being no change in the suction hole. The parallel component of the frictional coefficient for each point is a variable in the no suction hole, being constant in the suction hole.

Key words: *suction groove, compact spinning, frictional coefficient, twisting.*

Introduction

The Switzerland Rieter c, Germany Suessen, Germany Zinser and Italy Marzoli companies showed their compact spinning machines at the Paris ITMA in 1999. Owing to the fact that they reduce the triangle of spinning, their advantages are reduced hairiness and enhanced yarn strength, as well as improvement in fabric performance. Technological research on compact spinning with a suction groove has mainly focused on theoretical study and experiment of spinning feasibility. Dou H. studied the motion trajectory of a fibre bundle in the flow field of a compact spinning system with a pneumatic groove. Zou Z.Y. and Liu S. et al. preliminarily studied the twist transfer process in compact spinning with a suction groove for cotton fibre. All of the above did not discuss frictional coefficient changes. Based on compact spinning with a suction groove as the research object, this paper will discuss deeply the variation in the frictional coefficient for the gathering area for ramie compact spinning and provide a theoretical basis for the mechanical analysis.

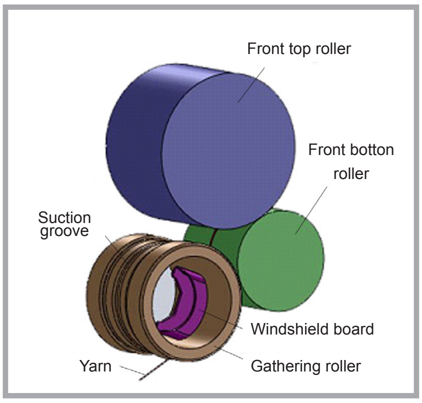

Figure 1. Equipment of compact spinning with suction groove.

Compact spinning with suction groove

Figure 1 shows a compact spinning system with a suction groove. The gathering area mainly consists of a front bottom roller, front top roller and hollow gathering roller. Same size suction holes are evenly divided in the groove. A stationary inner container of the hollow gathering roller, which has an open slot, clocks up the internal airflow through the suction holes. One end of the gathering roller is closed, and the other end is open. ***Figure 2*** shows the gathering process of the fibre bundle. O_1, O_2 and O_3 are the centers of the suction groove, the front bottom roller and the front top roller, respectively. Fibre bundles are delivered from the nip at point A between the front top roller and front bottom roller. They leave the front bottom roller at point B into the gathering roller at point C, are condensed at point D by air pressure and enter into the groove bottom. The condensed fibre bundles are twisted into a yarn at point F along arc DE and then leave at point E.

Analysis of the frictional coefficient in the gathering area

Transferring analysis of the resistance torsion moment

When fibre bundles enter the suction groove, they will be condensed by the airflow force produced by the negative pressure and shape agglomeration of the groove, and contact the groove bottom at point D. Over point D, the fibre bundles are condensed by more air pressure produced by more air holes. ***Figure 3*** shows a schematic diagram of the suction hole distribution in the gathering area. In ***Figure 3***, *j* means the suction hole. Arc DE simultaneously condenses and twists the

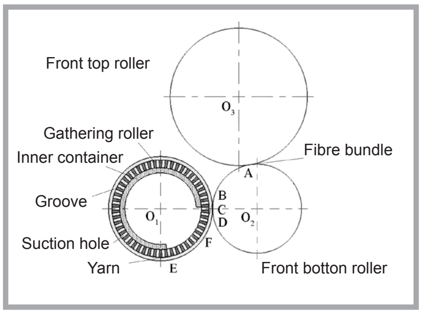

Figure 2. Gathering process of fibre bundle.

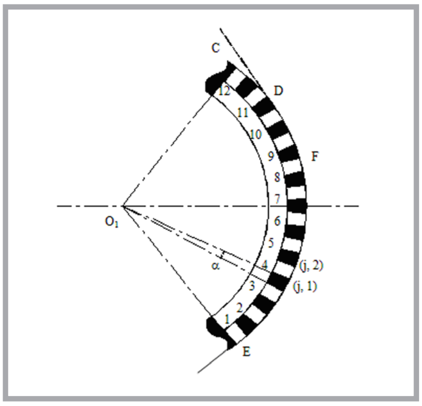

Figure 3. Schematic diagram of suction hole distribution in the gathering area.

area. In ***Figure 4*****,** the frictional resistance can be divided into two parts which are the resistance F_t produced by spinning tension and that produced by the airflow force F_a. During the twist process from points E to D , the twist is resisted by the twist resistance moment M_t produced by spinning tension and by the twist resistance moment M_a produced by negative pressure airflow in the suction holes. The torsion moment M produced by the rotation of the ring traveller adds a certain twist to fibre bundles, which consists of M_t and M_a. Because of the resistance moment M_t and M_a, the yarn rotary force decreases gradually; the reduction of the torsion moment M is nonlinear; the twist at some position along arc DE is reduced to zero, and twist transfer forward to the nip of the front top roller and front bottom roller is avoided.

Analysis of frictional coefficient along surrounded arc

Figure 5 shows the fibre bundle speed and frictional coefficient in the gathering area. Among them, V is the actual speed of fibre bundles, V' and V'' mean, respectively, the parallel speed and perpendicular speed to the direction of advancement of fibre bundles; μ is the frictional coefficient between fibre bundles and the groove, and μ' and μ'' mean, respectively, the frictional coefficient parallel to and perpendicular to the direction of advancement of fibre bundles.

To facilitate the calculation, we can suppose that the twist decreases gradually to zero from suction holes 1 to 10. In other words, the rotational speed V'' of fibre bundles decreases gradually from the maximum to zero. The reduction in speed is very small when it goes by a suction hole and interval of the surrounding arc, but the rotating speed is constant when passing through a suction hole. Therefore we think that V'' will change linearly from suction holes 1 to 10 at the no suction stage. The vertical speed $V_{j,2}$ at each point can be expressed by:

$$V''_{j,1} = V''_{j,2} \quad (j = 1, 2, 3, ..., 10) \qquad (1)$$

$$V''_{j,2} = \frac{10-j}{9} V_{max} \qquad (2)$$

$$(j = 1, 2, 3, ..., 10)$$

Where V_{max} is the rotational speed of fibre bundles at the beginning; $V''_{j,1}$ and $V''_{j,2}$ are both sides of the vertical speed at the suction hole j, respectively. ***Figure 6*** shows the change in $V''_{j,2}/V_{max}$ at each point in a no suction hole of the gathering area.

V_1 is equal to the speed of the front bottom roller. According to ***Equations 1*** and ***2***, the angle θ_j of the parallel speed component formed and the actual speed at each point can be calculated by:

$$\theta_j = \theta_{j,1} = \theta_{j,2} = \arctan \frac{V''_{j,2}}{V_1} =$$

$$= \arctan \frac{(10-j)V_{max}}{9V_1} \qquad (3)$$

$$(j = 1, 2, 3, …, 10)$$

When $j = 1$, $V''_{1,1} = V''_{1,2} = V_{max}$,

$$\theta_1 = \theta_{max} = \arctan \frac{V_{max}}{V_1}.$$

When $j = 10$, $V''_{10,1} = V''_{10,2} = 0$, $\theta_{10} = 0$.

Figure 7 shows the change in θ_j/θ_{max} at each point in the gathering area. The angle θ_j decreases gradually from the maximum to zero, the decline trend is ladder like.

When the fibre bundles move forward in the gathering zone, the frictional resistances of every point are different, namely the frictional coefficients of every point are different. At each point on the surrounding arc, the parallel component μ_j of the frictional coefficient can be calculated by ***Equation 4***.

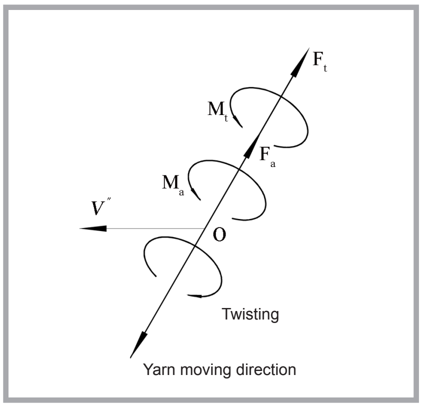

Figure 4. *Twist resistance moment of yarn in twisting.*

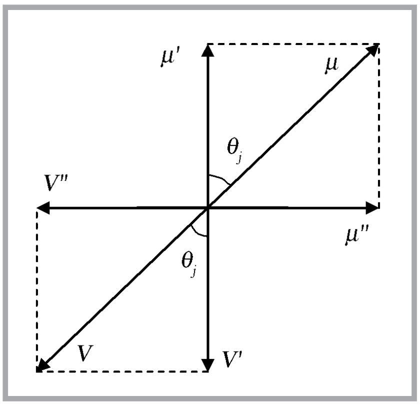

Figure 5. *Fiber bundle speed and frictional coefficient in the gathering area.*

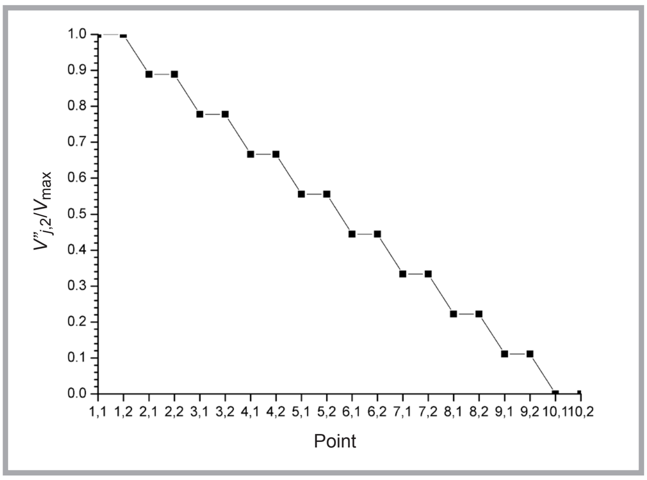

Figure 6. *Change of* $V''_{j,2}/V_{max}$ *at each point in the gathering area.*

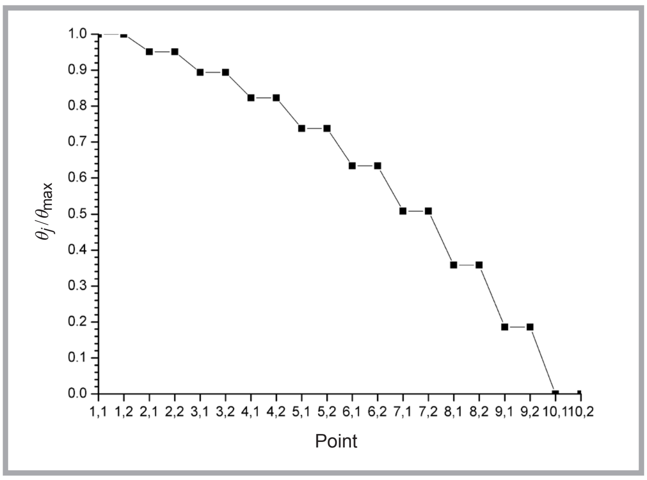

Figure 7. *Change in* θ_j/θ_{max} *at each point in the gathering area.*

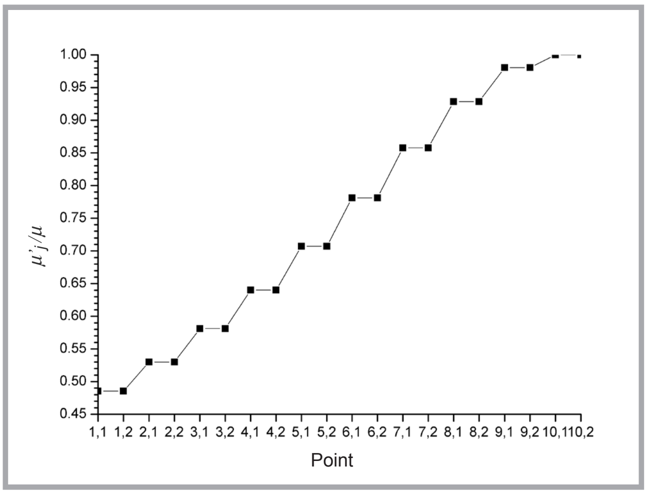

Figure 8. *Change in μ'_j/μ at each point in the gathering area.*

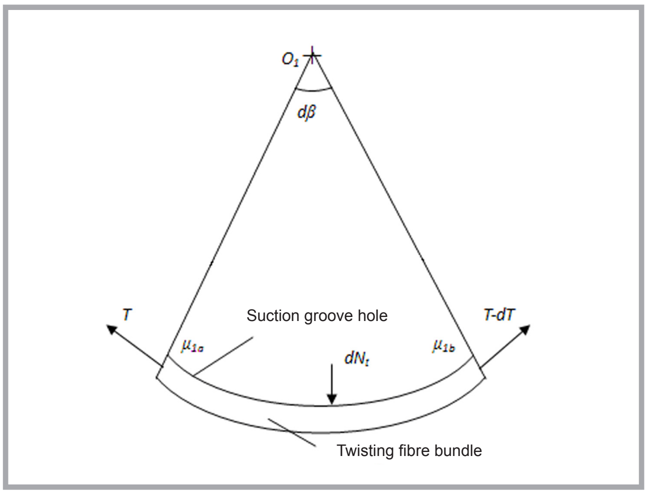

Figure 9. *Change in spinning tension in the infinitesimal radian.*

$$\mu'_j = \mu'_{j,1} = \mu'_{j,2} = \mu\cos\theta_j =$$

$$= \mu\cos\left[\arctan\frac{(10-j)V_{max}}{9V_1}\right] \quad (4)$$

(j = 1, 2, 3, …, 10)

Figure 8 shows the change curve of μ'_j/μ at each point in the gathering area. From the exit to entrance in the gathering area, the parallel component of the frictional coefficient increases gradually.

Figure 9 shows the change in spinning tension in the infinitesimal radian. The spinning tension decreases from T to T - dT, and the parallel component of the frictional coefficient changes from μ_a to μ_b. The change in the parallel component of the frictional coefficient μ_b decides the radian β, with the amplitude of change being small. For convenience of calculation, it can be regarded as a linear change.

Therefore, μ'_b corresponding to the arbitrary radian β, in a no suction hole along an interval surrounding arc can be expressed by

$$\mu'_\beta = \mu'_a + \frac{\beta}{\alpha}\left(\mu'_b - \mu'_a\right) \quad (5)$$

Where μ'_a is the parallel component of the frictional coefficient of the left endpoint along the arbitrary surrounding arc, μ_b the parallel component of the frictional coefficient of the right endpoint along the arbitrary surrounding arc, radian β the twist propagation through the radian, and radian α between the two adjacent suction holes is shown in ***Figure 3.***

Conclusion

In compact spinning with a suction groove, the twist resistance moment is produced by spinning tension and negative pressure, and influences the process of twist propagation.

The frictional coefficient between the fibre bundles and the groove is the main factor influencing the twist resistance torsion moment produced by spinning tension and negative pressure. When the frictional coefficient is appropriately changed, it can play an important role in preventing the twist from being uploaded and obtaining the best spinning process. When the material and roughness of the groove surface are changed, the frictional coefficient between fibre bundles and the groove is also changed.

The parallel component of the frictional coefficient for each point is a variable at a no suction hole, and it is constant at a suction hole.

In compact spinning with a suction groove, the transfer mechanism of the torsion moment is still in the early stage of theory analysis, where some parameters are ignored and some assumptions are based on the ideal condition. Therefore, this needs more theory and practice in the future.

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