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FIBRE STRAIGHTENING DURING THE FORMATION OF DISC SPUN YARN

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Abstract:

Disc spinning is a new spinning technique that is still under investigation in many research institutes and universities. It is not yet a commercial system, although it is promising. The appearance of the outer layer of produced yarns is similar to that of ring spinning, but is produced at higher rates. It includes the major spinning stages such as fibre opening, feeding to the forming zone and yarn consolidation by twisting, then yarn winding. Opened fibres are condensed on the outer surface of a rotating screened surface disc and simultaneously twisted by using an external twister. Air suction acts through a slit located just beneath the screened surface at a certain angle that controls the laying angle of the fibre bundle on the screened surface. The formed yarn is then drawn at a predetermined angle with respect to the slit direction. It is suggested that both slit angle and the direction of the withdrawal of the yarn during its formation with respect to the slit affect fibre extent on the forming zone and, accordingly, yarn properties. Papers about this new technique are limited, especially those considering the effect of design parameters on fibre straightening during yarn formation. In this article, parameters expected to affect fibre extent in the forming zone during yarn formation were suggested and treated theoretically to maximise fibre straightening during yarn formation.

Key words:

Disc spinning, fibre straightening, yarn formation, screened surface, twister

Introduction

The basic principle of disc spinning has been illustrated in prior publications [1-5], but it is convenient to recall the basic features of this new system. Figure 1a schematically illustrates a disc spinning system. Fibres are fed in a form of carded sliver to a taker in the opening head, similar to that used in OE (Open End) rotor machines. Opened fibres are then transferred to a screened surface disc. The disc is constructed of two concentric discs as shown in Figure 1b. The inner disc is fixed to the machine body and does not rotate. The surface of this disc is a solid, non-permeable material and contains a slit of a certain dimension at a predetermined angle. Strong air suction is applied from the inner disc centre through a suction nozzle attached to this slit, so the effect of this suction is concentrated along this slit. A thin barrier is fixed onto the edges to control air passage through the slit. The outer disc is a screened surface disc and can be rotated in all directions forwards and backwards. The opened fibres, which are running in an air stream, are condensed to the required size on this surface and simultaneously twisted by an external twister; as a result, yarn is formed and is drawn by take-up rollers. The disc surface can be either V-shaped and grooved or flat screened. In the first case, fibres can be collected on disc surface in only one direction, namely along the groove. In the second case, fibres can be collected on any predetermined angle as required. The disc surface in this study is a flat-screened surface. The formed yarn is wound onto a required size package by using a winding assembly similar to that used in rotor or friction spinning systems.

Comparing the process of yarn formation in each of ring, rotor, friction and disc spinning, it can be concluded that in ring spinning a twist is inserted into assembled opened fibres that arrange in a linear form to a required size, but winding and twisting are linked together and occur simultaneously. In rotor and friction spinning, there is a break between winding and twisting, but the fibre arrangement is collected simultaneously with twist insertion, resulting in a special yarn structure [6]. In disc spinning, this fibre collection process is achieved on a screened surface while the twist is imparted through an external twister, resulting in a unique twist structure. More theoretical and experimental work is required for these aspects. The problem with disc spinning is the complexity of fibre alignment during yarn formation. From the experimental results shown by Mansour et al. [3], yarn quality needs to be improved, especially yarn strength, which has been shown for cotton yarns and coarse count to be in the range of 12 gm/tex. Therefore, it is necessary to conduct intensive research to determine the conditions for gaining better yarn quality at higher production rates.

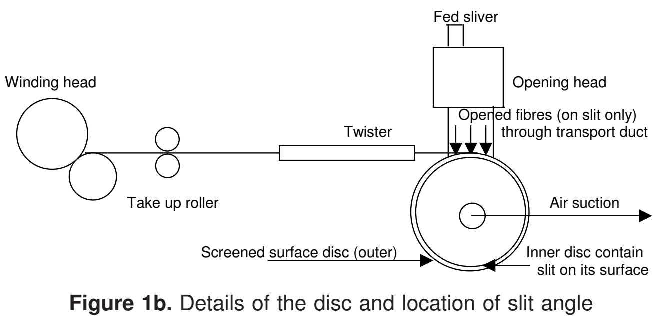

Figure 1b. Details of the disc and location of slit angle

From a physical point of view, yarn strength can be improved through better fibre alignment and straightening in the produced yarns. Better fibre straightening means better yarn properties, so it is important to identify or at least expect the working conditions that improve fibre straightening in this new system. The aim of this article is to theoretically investigate fibre alignment at the forming zone during disc spun yarn formation. Two different cases of the withdrawal of the formed yarn were considered. These cases are defined according to the direction of the slit angle (i.e. the angles at which fibres are condensed onto the disc surface). It is assumed that fibre straightening depends on both the direction of yarn withdrawal and the angle at which fibres are condensed onto the disc surface (slit angle).

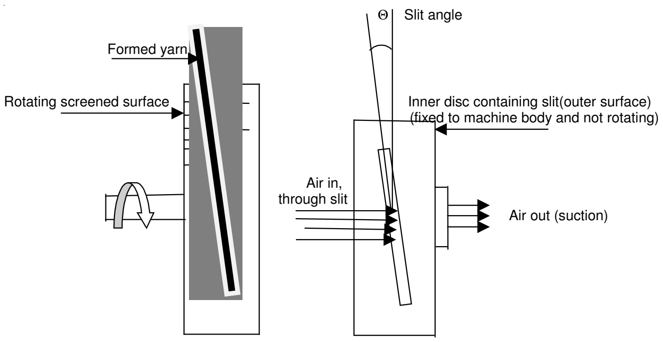

Figure 1b. Details of the disc and location of slit angle

Theoretical consideration

Yarn withdrawal is in a direction perpendicular to a tangent parallel to the disc axis

Figure 2 shows this case where:
Lo - is the fed fibre length in mm,
L - is the straightened fibre length in mm,
Vy - is the yarn withdrawal speed (production speed) in mm/min,
Vd - is the disc surface speed in mm/min,
Θ - is the slit angle (as illustrated in Figure 1b).

At time dt,

$$\Delta s = V_y dt \tag{1}$$

$$\Delta L = V_d dt \tag{2}$$

$$L^2 = O_1B_1{}^2 + O_1A_1{}^2 = L_0{}^2 \sin^2\Theta + (\Delta s + \Delta L + L_0 \cos\Theta)^2$$

Substituting from (1) and (2), then

$$L^2 = L_0{}^2 \sin^2\Theta + (V_y dt + V_d dt + L_0 \cos\Theta)^2$$

then

$$\frac{\partial t}{\partial L} = \frac{2(V_y dt + V_d dt + L_0 \cos\Theta)(V_y + V_d)}{2\sqrt{L_0{}^2 \sin^2\Theta + (V_y dt + V_d dt + L_0 \cos\Theta)^2}}$$

$$At \quad \frac{\partial t}{\partial L} = 0 \quad and \quad dt = 0$$

Either

$$L_0 \cos\Theta = 0 \;\; then \;\; \Theta = \Pi/2 \;\; or$$

$$(V_y + V_d) = 0 \;\; then \;\; V_y = -V_d$$

Therefore, it is clear that arranging the opened fibres at an angle Q = Π/2 and or equalising the take-up speed with the disc surface speed will result in maximising fibre extent during yarn formation and, consequently, better yarn properties.

Yarn withdrawal is in the direction of the suction slit

Figure 3 illustrates this case. From the geometry of the figure, it is clear that:

$$L^2 = O_1B_1{}^2 + O_1A_1{}^2 = (O_1B_{0'} + B_{0'}B_1)^2 + O_1A_1{}^2$$

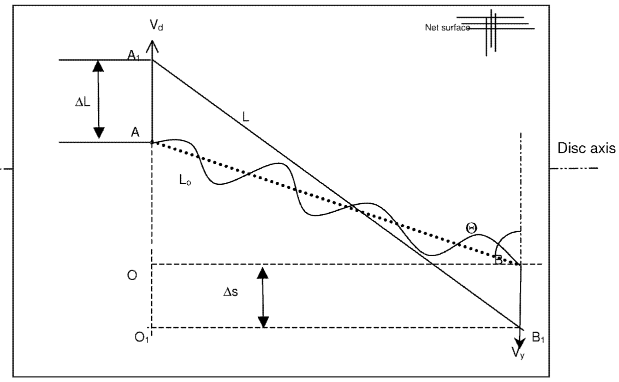

Figure 2. Yarn withdrawal is in a direction perpendicular to a tangent parallel to the disc axis.

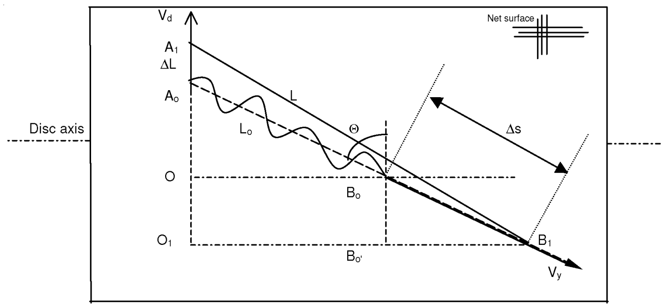

Figure 3. Yarn withdrawal is in the direction of the suction slit.

$$L^2 = (L_0 \sin\Theta + \Delta s \sin\Theta)^2 + (\Delta s \cos\Theta + L_0 \cos\Theta + \Delta L)^2$$

Then

$$L = \sqrt{(L_0 \sin\Theta + V_y dt \sin\Theta)^2 + (V_y dt \cos\Theta + L_0 \cos\Theta + V_d dt)^2}$$

$$\frac{\partial L}{\partial t} = \frac{2(L_0 \sin\Theta + V_y dt \sin\Theta)V_y \sin\Theta + 2(V_y dt \cos\Theta + L_0 \cos\Theta + V_d dt)(V_y \cos\Theta + V_d)}{2\sqrt{(L_0 \sin\Theta + V_y dt \sin\Theta)^2 + (V_y dt \cos\Theta + L_0 \cos\Theta + V_d dt)^2}}$$

$$At \;\; \frac{\partial L}{\partial t} = 0, \;\; dt = 0 \;\; then,$$

$$L_0 V_y + L_0 V_d \cos\Theta = 0, \;\; therefore$$

$$\cos\Theta = \frac{V_y}{V_d}, \;\; then$$

$$\Theta = \cos^{-1}\frac{V_y}{V_d}$$

This means that the maximum fibre straightening during yarn formation depends on the ratio between the yarn withdrawal speed and surface speed of the disc. These findings should be taken into consideration when building and developing a disc spinning system to ensure that the slit angle should be designed to be adjustable. This means that the opening head should be located on an adjustable bed to follow the tilting of the suction slit, and special motion transmission is required.

Conclusion

1. Fibre straightening during disc spun yarn formation depends on the direction of the yarn take-up with respect to the suction slit angle.

2. When yarn take-up is achieved tangential to the disc surface and perpendicular to a tangent parallel to the disc axis, maximum fibre straightening can be achieved by either designing the slit angle to be equal to Π / 2 and/or equalising the take-up speed with the disc surface speed.
3. When yarn withdrawal is in the direction of the suction slit, the slit angle should be designed to be equal to cos-1 the ratio between the yarn take-up speed and disc surface speed.
4. It is recommended to apply intensive research when taking into consideration the possible interactions between variables.

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