Simulation of Number of Fibres in Roll Drafting Process

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Abstract: Roll drafting is the key part of yarn manufacturing in ring spinning. Because of the fibre length distribution and the accelerated points of fibres in the drafting zone, the drafted strand usually tends to become uneven in terms of its linear density. The reported study mostly focuses on the accelerated points of fibre ends in the drafting zone, and also tries to find out the relation of the changing accelerated points and the irregularity of the drafted yarn. This approach investigates the role of the accelerated points, giving a parabolic-type probabilistic density function to fit the accelerated points of the floating fibres. Therefore, the stochastic simulation of the fibres in the drafting zone is conducted. The simulation process starts from a random fiber bundle nipped by the back roller, and then generates the accelerated point of each fibre by Mont Carlo method. For the given gauge distance and drafting ratio, any strand with a certain fibre length distribution can be simulated in the drafting system. The simulated curve of the number of fibres in the profile of the strand is given with different drafting parameters, which describes the attenuation of the strand in drafting. The results will help us to understand the drafting process and give a method of predicting yarn irregularity from fibre length distribution and drafting parameters.

Keywords: Roll drafting, simulation, attenuation curve, Monte Carlo method.

1. Introduction

Roll drafting is one of the important devices in ring spinning system. The sliver is turned into a thinner yarn as a product through the drafting device with two rollers that have different speeds within a certain gauge length of distance. However, roll drafting can also cause a worse unevenness for the drafted yarn, which may cause a quality problem in yarn linear density. The research in drafting device is to obtain a drafting process with high drafting ratio and high quality of drafted yarn. The important step in the research is to study the attenuation process of the sliver in the drafting, and the variation of the number of fibres in the cross section of the sliver at any point of the drafting zone. The research can reveal the principle of the drafting process and apply the drafting technology with important theoretical calculations.

The simulation method has often been used in drafting study. The past research included a lot of simulation approaches. The simulation of the drafting process helps understand the principle of the drafting process and is available in the analysis of the drafting process. Different simulation methods may result in different outcomes, which offer different information for the drafting research. Mathematical method in simulation is the basic method, but the difficulty involved is enormous because of the complexity of the drafting system. Huh [1] conducted the simulation of the drafting process from some basic physical laws and obtained the dynamic behaviour of the fibres in the drafting zone. In his research, the attenuation curve of the sliver is given and the variation of the curve is analyzed. The stochastic simulation is another path in the research of the drafting process. In this field, Johnson [2] used a computer to give the simulation results of the number of fibres at points in the drafting zone. For many years, a lot of researchers studied the drafting process from different viewpoints, which add some important results to the drafting theory [3-8].

However, there is rarely any research done in the drafting simulation concerning the fibre length distribution. The fibre length distribution should not be neglected. Experiment and production practice proved that fibre length distribution has a dramatic impact on the quality of drafted yarn unevenness. Longer fibres can be drafted into a comparatively even yarn and shorter fibres usually cause a worse irregularity in yarn linear density. So it is necessary to take into account the fibre length distribution in the study of drafting system.

This approach, on the basis of the Yan's model [9] of accelerated points of floating fibres, conducts a stochastic simulation using Mont Carlo method. By changing the drafting parameters, the simulation achieves a series of results concerning the attenuation curves in the drafting process. The results are consistent with Huh's theory in terms of the dynamic behaviour of the fibres in the drafting zone. This result is significant in the research of the influence of fibre

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length distribution on drafting and in the optimization of drafting parameters.

2. A stochastic model of the accelerated points of the fibres in the drafting zone

There is much research in the history about the accelerated points of fibre ends in the drafting zone. Generally, it is believed that the dispersion of the accelerated points of fibres in the drafting zone is the key to the unevenness of the drafted yarn. So many researchers focused on the distribution of the accelerated points so as to find the reasons of the factors influencing the accelerated points. Yan's model introduces a parabolic density function to describe the distribution of the accelerated points, which gives a explanation of the unevenness caused by drafting process.

Yan's model can be described implicitly by a simple fact. When a longer fibre enters the drafting zone and becomes a floating fibre, it will have a shorter interval for changing the speed. The shorter fibre will have a longer interval for changing speed. The probability density function of the accelerated points can be viewed as a parabolic type, which can be calculated on the probability theory.

In order to develop the model, we assume that the fibres in the sliver thus in the drafting zone are straight and parallel, and the length distribution can be expressed as its probability density function $f(l)$. When a fibre with the length a is nipped by the back roller, it can not be accelerated because the force is large enough to hold it to move at the speed of the back roller. When the fibre tail end leaves the back roller, the possibility that it gets accelerated occurs. We assume the distance between the two rollers is L, and the coordinate origin is at the back roller, then the accelerated probability of the fibre will increase in the interval $[a,L]$ with the closer distance to the front roller. We can assume that the distribution of the accelerated point of the considered fibre with length a in the interval $[a,L]$ has a parabolic density function starting from the point a and finishing at L. As assumed above, fibres with different lengths may have different accelerated distribution but all those distribution density functions are in parabolic form (see Figure 1). The probability density function is expressed as follows:

$$g_a(x) = A(x-a)(x-L) \tag{1}$$

where A is a coefficient only related to a and L. According to the principle of the probability density function, the function should satisfy the following equation:

$$\int_0^{\infty} g_a(x)dx = \int_a^L g_a(x)dx = \int_a^L A(x-a)(x-L)dx = 1 \tag{2}$$

Then we have

$$A = -\frac{6}{(L-a)^3} \tag{3}$$

$$g_a(x) = A(x-a)(x-L) = -\frac{6}{(L-a)^3}(x-a)(x-L) \tag{4}$$

The validation of the assumption has been proved by experiments.

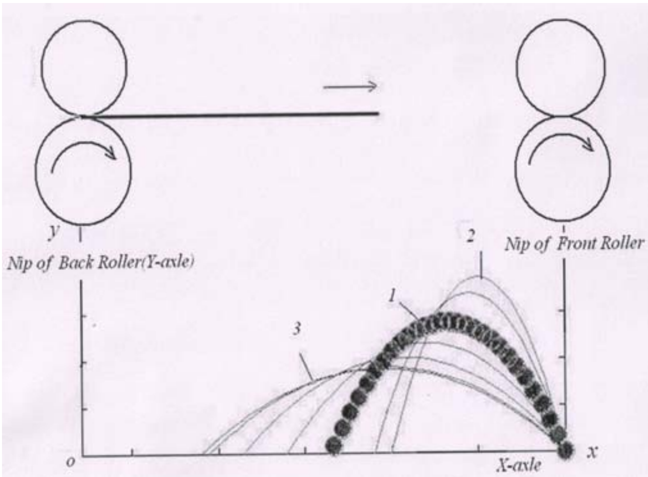

Figure 1 Density functions of the accelerated points.

Figure 1 shows the accelerated points in the drafting zone and the curve in black circular points refers to the average density function at different lengths.

3. Steps of the stochastic simulation

For a given distribution of fibres and a gauge length, a fibre can be generated randomly. The fibre length distribution can be obtained from a test and is denoted by a rectangle. For a given number of fibres, each fibre length can be generated by Monte Carlo method.

After generating the fibre length, the accelerated point of this fibre can be generated from the equation (4). And the time of a fibre passing through a point in the drafting zone can be recorded. This process can be repeated for thousands of fibres, and the attenuation curve of the strand can be obtained.

Changing the drafting parameters, a series of curves can be obtained.