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# Modeling and drafting process simulation of cotton slivers based on an octahedron structure

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**Abstract**

In order to study the variation of the drafting force of cotton slivers, a three-dimensional model of cotton slivers was proposed. The model is based on the three-dimensional network structure of the fibers in the cotton sliver. The three-dimensional network structure is simulated by an octahedron. Based on the similarity between dynamic drawing and static drawing, the static drawing simulation of the model is carried out by using ANSYS software, and the static drawing force of different quantitative cotton slivers is simulated. The results show that the average relative error of the static stretch force and dynamic drafting force is 8.09%, and the maximum relative error is less than 15%. Then, the equations of the dynamic drafting force and static stretch force are obtained by linear regression, and the drawing force under other quantitative conditions is successfully predicted. Finally, static stretching is used to simulate the influence curve of different roller spacings on the dynamic drafting force, and the results show that the simulation results are consistent with the actual situation. Therefore, the octahedral cotton sliver model is effective, and the simulation results also provide a reference for the approximate prediction of dynamic drafting force.

**Keywords**

Drafting force of cotton sliver, octahedral pore structure, dynamic drafting force, static stretch force, ANSYS

The spinning process is mainly divided into cotton pretreatment, drawing and drafting, and twisting into yarn. The main processes of cotton pretreatment are impurity removal, loosening, opening, and carding. The main function of these processes is to make the disordered cotton fibers straighten initially and then re-aggregate to form a continuous strip. Through cotton pretreatment, the fiber morphology of cotton whiskers is still irregular, and there are many hooks in the fibers. At this time, the obtained cotton whiskers need to be drafted many times. The drafting force is the sum of the friction resistance when the fast fibers of the former roller are pulled out from the surrounding slow fibers in the drafting process. It is one of the important indexes to measure the quality of the drafting process, which is related to the yarn quality of the subsequent process. Therefore, it plays an important role in the whole spinning process.

There has been a series of theoretical research results on the research of drafting force in the drafting area, and many scholars have independently designed test devices to measure it.[1] Zhang and Yu[2] designed a drafting force testing device to study and analyze the drafting force in roller drafting, and compared and analyzed the influence of different drafting multiples, the number of cotton whiskers, and the roller speed on the traction force. Di and Jun[3] installed a load cell device in the drafting area to measure the drafting force. Although the traction force measuring device is based on a small experimental drafting frame, it can still reflect the change of traction force in the process of drafting. Plonsker and Backer[4] used the draft tester to

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study the drafting force and the movement state of the sliver, and to explore its influence on the yarn quality. Zhang and Yu[5] designed and manufactured a new device to measure the dynamic drafting force on the drafting frame. The effects of the draft ratio, number of input cotton whiskers, and roller speed on the draft force, coefficient of variation of the draft force, and unevenness of the output cotton slivers are analyzed. Based on the analysis of the existing drafting theory, testing equipment, and testing methods, Ren et al.[6] proposed and designed a testing method and equipment for the drafting force of the back zone of the cotton spinning machine, and tested the drafting force on the cotton spinning machine by using the self-designed drafting force testing device. The results show that the detection device can reflect the size and fluctuation of the draft force in the back area of the cotton spinning machine. The research of the above scholars on the traction force is mainly through the installation of a self-designed measuring device in the draft area to measure the traction force.

Under some assumptions, using the physical principles of mass balance and momentum balance, Huh and Kim[7] established a constitutive model to simulate the tapering curve of the cotton whisker in the drafting region in the steady state. In this model, Kim et al.[8–10] used methods such as adding autocorrelation random disturbance to analyze the dynamic behavior of roller drafting in the instantaneous state. Komori and Itoh[11] regarded the cotton whisker as a continuous medium and established a roller drafting model based on the principle of hydrodynamics. The hypothetical system simulating viscoelastic fluid flow was taken as a standard model to simulate the change of fiber bundle velocity with system parameters. Cherkassky[12] first proposed the method of using discrete event simulation system to simulate the uneven thickness of one-dimensional fiber material, and analyzed the influence of fiber length and fiber tip on the model. Subsequently, Cherkassky[13] once again established a theoretical roller drafting model in the discrete event simulation system, and used the simulation results for the training data when establishing the neural network model.[14] The above scholars have established various drafting models to study the dynamic behavior of fibers and cotton slivers in the drafting zone.

It can be seen from the above that most of the current research on the drafting force of cotton whiskers approximates the drafting force by establishing a numerical model and designing a drafting force measuring device, and has not attempted to perform three-dimensional modeling of cotton whiskers and simulation. In this paper, the three-dimensional mesh structure of the cotton sliver is simulated by the octahedral pore structure of porous materials, and the macro geometric three-dimensional model of cotton slivers is established. Because it is difficult to realize the simulation of the dynamic drafting of cotton slivers, and there is a certain similarity between the static drafting and the dynamic drafting,[15] this paper selects static simulation instead of dynamic simulation, and improves the octahedral geometry, so that it is easier to converge in the simulation, and the simulation data of the drafting force with different quantifications are compared with the dynamic drafting force in the front drafting zone draw frame to prove the validity of the model. At the same time, the dynamic drafting data and the static drafting data are used for linear regression. The linear relationship between the two is calculated and the drafting force under other quantifications is predicted. Finally, the model is used to simulate the influence curve of different roller spacings on the drafting force. In this paper, the dynamic drafting force data is measured following Zhang,[15] and the measuring device is as shown in Figure 1.

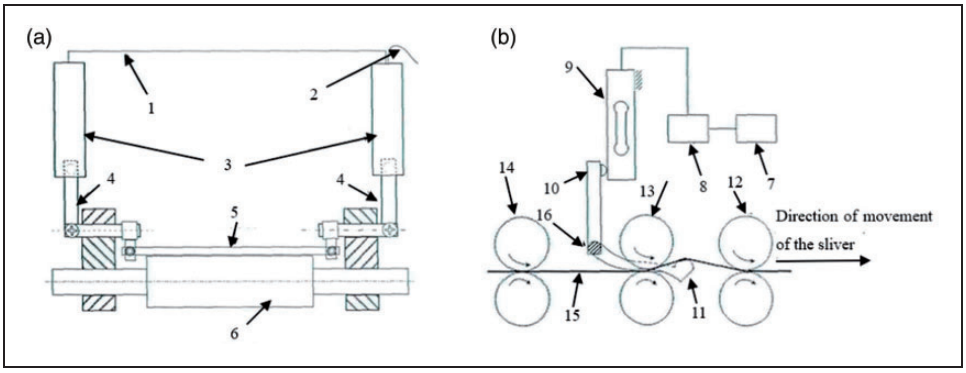


**Figure 1.** Dynamic drafting force measuring device. 1: connection line; 2: connection for the digital display; 3: weighing display instrument; 4: pressure arm; 5: pressure bar; 6: front roller; 7: computer; 8: digital display instrument; 9: weighing sensor; 10: pressure arm; 11: upper support pressure bar; 12: front roller; 13: middle roller; 14: rear roller; 15: cotton sliver; 16: fixed shaft.

## Establishment of the three-dimensional model of the cotton sliver

### *Morphological structure of the cotton sliver*

There are a large number of fibers in the cotton sliver, and the arrangement of fibers is irregular. Although the cotton fibers have been opened and combed before drafting, and the shape of the fibers is close to a line shape, due to the existence of the hook shape characteristics of the cotton fibers, the cotton fibers in the cotton sliver are intertwined with each other. Due to the winding of cotton fibers and the large number of fibers, it is almost impossible to establish a three-dimensional model that fully conforms to the shape and structure of the cotton sliver. Therefore, a necessary simplification must be made in the study of the establishment of the geometric model of the cotton sliver, so as to reduce the cost of calculation.

Through the observation of the cotton sliver, we know that its cross-section is approximately rectangular, the shape is long strip, and the fibers in the cotton sliver are intertwined with each other to form the cohesive force. In the observation of the cotton sliver structure, it is found that the arrangement of the fibers in the cotton sliver has the characteristics of pores, and there are certain pores between the fibers to form a three-dimensional network structure. Compared with the pore structure of the fibers in cotton, the pore structure of the fibers in the cotton sliver is more regular, which is also more conducive to pore modeling.

### *Three-dimensional modeling of the cotton sliver*

In order to simplify the problem and solve it conveniently, it is necessary to make some assumptions about the actual problem. Based on the modeling theory of three-dimensional porous materials, the macro tensile model mainly includes the following simplified assumptions.

1. Suppose that the cotton slivers are formed by a large number of pore space network structures: in terms of material composition, the cotton slivers are constructed with cotton fiber as the matrix material. Each cotton sliver contains tens of thousands of cotton fibers, and the model cannot reflect all the cotton fibers. Therefore, in terms of the geometric structure, the pore edge of the octahedron is formed by a cotton fiber aggregate, which is replaced by cylinders with a certain cross-sectional size.
2. The internal pores of the cotton fiber assembly are basically all open-pore structures. Assuming that the pore structure is regular, the space pore filling method of the open-pore structure porous material is used for filling, and the filled pore unit cell structure is arranged and distributed uniformly.

A porous material is a material with a large number of pores inside, and the pore edges are used as the matrix material to form a network structure. In actual porous materials, the pore structure has different shapes, mainly divided into the structures shown in Figure 2.[16]

Among the many three-dimensional polyhedral pore structures mentioned in Figure 2, the tetrakaidecahedron structure has better compressive properties, and the regular octahedron has better tensile properties. This article selects the octahedral pore structure to model the cotton slivers. Its geometric unit cell structure contains eight faces formed by eight triangles, composed of six vertices and eight prisms of equal length, as shown in Figure 3.

In fact, each cotton sliver is composed of tens of thousands of cotton fibers. Therefore, it is considered that a number of cotton fibers are assembled into cotton fiber bundles as prisms to build the model. Here, the circle is taken as the cross-section shape of the prism, the octahedral structure vertex in Figure 3 is taken as the stretching starting point, and the hole edge line is taken as the stretching direction. The cylindrical hole edge is formed by stretching, as shown in Figure 4. We repeat the above operation and stretch the other hole lines in turn to obtain the octahedral cotton sliver model, as shown in Figure 5. The intersection of the octahedral prism in Figure 5 is the same material connection.

At the intersection of the octahedral prism, the sharp angle of the model is obvious. Through the first finite element analysis, we know that the existence of the sharp angle leads to stress concentration and the convergence of the model is difficult. Therefore, in order to reduce this kind of influence, the sharp angle of the model is changed to the intersection structure with a fixed arc in the later model. That is to say, the overlapped octahedron and the tip part of the octahedron are cut off. In order to make the reconstructed model conform to the octahedron structure and reduce the cut-off length as far as possible, we take 4.4 mm and connect the cut-off part through the lofting function in Solidworks software. This octahedron is called the heteromorphic octahedron cell model in this paper. The process of model establishment is shown in Figure 6.

The octahedral cell model obtained in the last step of Figure 6 is arrayed in the directions of length, height, and width to obtain different quantitative octahedral cotton sliver models. The array process is shown in Figure 7, where (b) is the length direction array, (c) is the width direction array, and (d) is the height direction array.

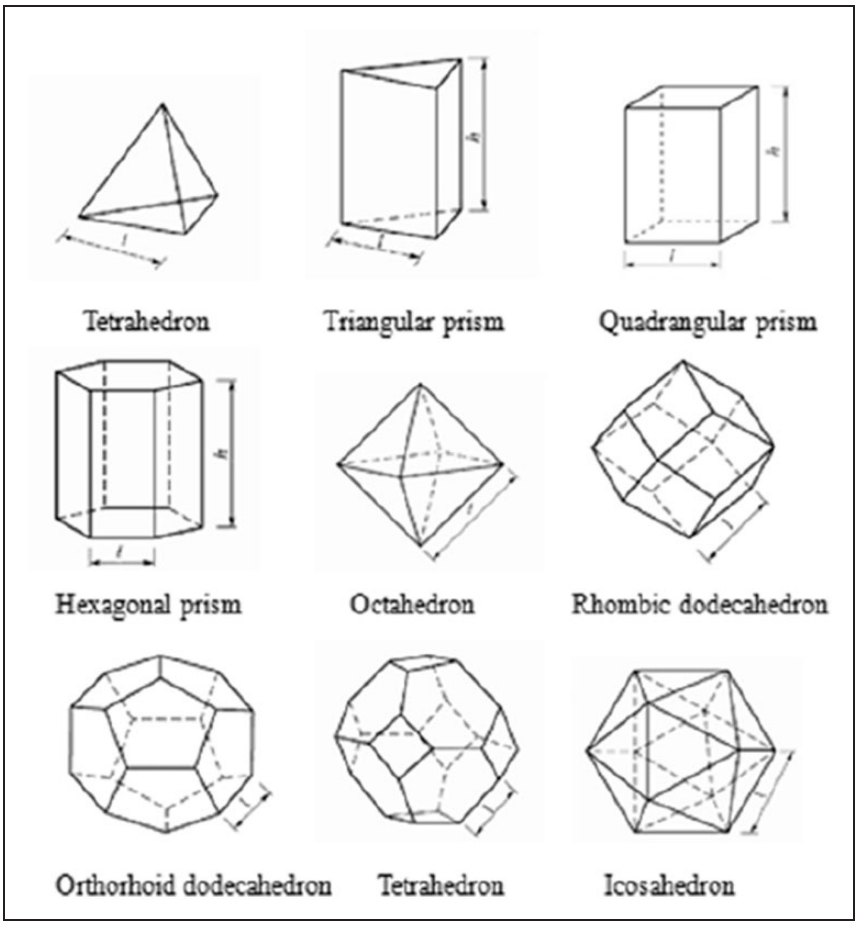


**Figure 2.** Three-dimensional polyhedral pores.

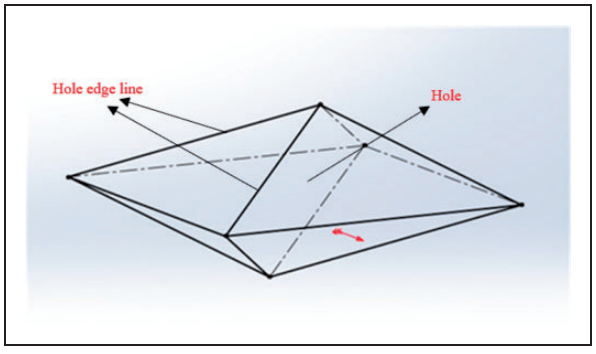


**Figure 3.** Octahedral pore structure.

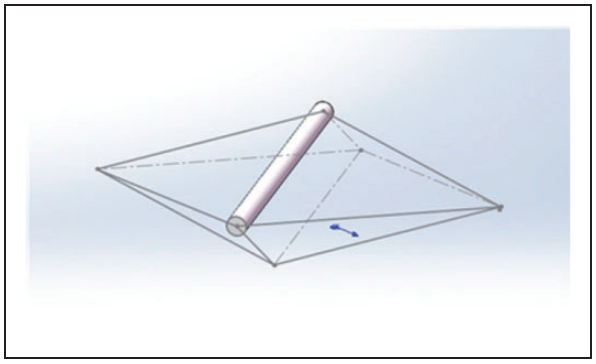

**Figure 4.** Pore margin.

When establishing the cotton sliver model by the above method, different cotton sliver quantifications are used as the identification parameters of the model, so that the model quantification is consistent with the actual cotton sliver. In order to meet the requirements of the distance between the rollers of the experimental drafting, the length of the octahedral cotton sliver model and the distance between the rollers of the front drafting zone are kept consistent at 42.5 mm. The model established is shown in Figure 8. In this paper, an octahedral cotton sliver model is established based on the pore structure of the cotton sliver, and the complex arrangement of fibers in the cotton whisker is ignored. The connection mode between each octahedral unit cell is the fixed connection of the same material to form a whole structure.

The quantity of the octahedral cotton model in Figure 8 is calculated by the evaluation function of the three-dimensional modeling software Solidworks, and then divided by the length of the model to obtain the quantity of whiskers. The quantitative error between the model and the actual experimental whiskers is shown in Table 1.

It can be seen from Table 1 that the quantitative error of the octahedral cotton sliver three-dimensional model and the experimental cotton slivers is within 10%, so the cotton sliver model can better simulate different quantitative values of cotton slivers.

The cotton sliver model includes the optimized octahedron, so it is necessary to verify whether the optimized octahedron has the structural characteristics of an ordinary octahedron. Different quantitative cotton slivers are all derived from the single octahedral model array formed in the last step of Figure 6. Therefore, the relative density of the different quantitative octahedral cotton sliver models is the same value. For the octahedral pore structure with a relative density less than 0.2, for an octahedron with prism length $l$ and prism section size $t$, there exists the following formula[16]

$$\frac{\rho^*}{\rho_s} \approx C_2 \left(\frac{t}{l}\right)^2 \tag{1}$$

where $C_2$ a constant, close to a unit quantity of 1.

The relative density of the octahedral model with the above quantitative value of 17 g/m was calculated

$$\frac{\rho^*}{\rho_s} = \frac{0.000195}{1.53 \times 10^{-3}} = 0.123 \tag{2}$$

where $\rho^*$ is the density of the octahedral whisker model, which can be obtained by the ratio of the mass to volume of the model, and $\rho_s$ is the density of the octahedral compact material, that is, the density of the cotton fiber

$$\left(\frac{t}{l}\right)^2 = \left(\frac{2.513}{8}\right)^2 = 0.094 \tag{3}$$

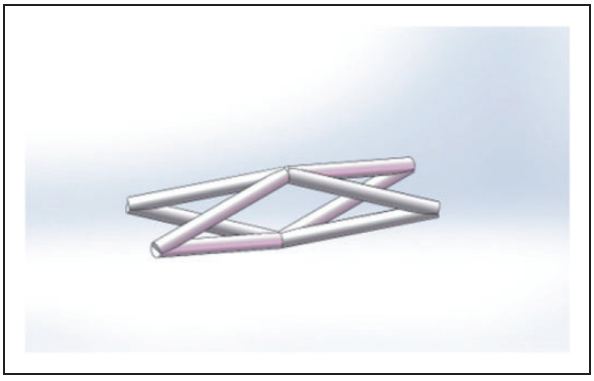

**Figure 5.** Three-dimensional model of the octahedron.

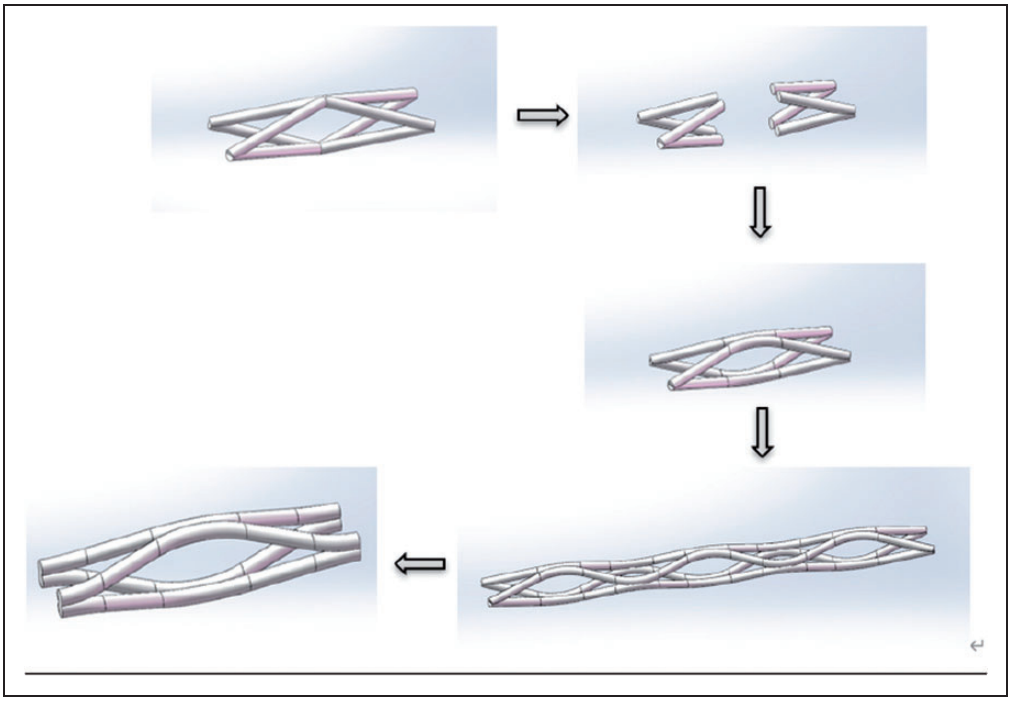

**Figure 6.** The establishment process of a single octahedron three-dimensional model.

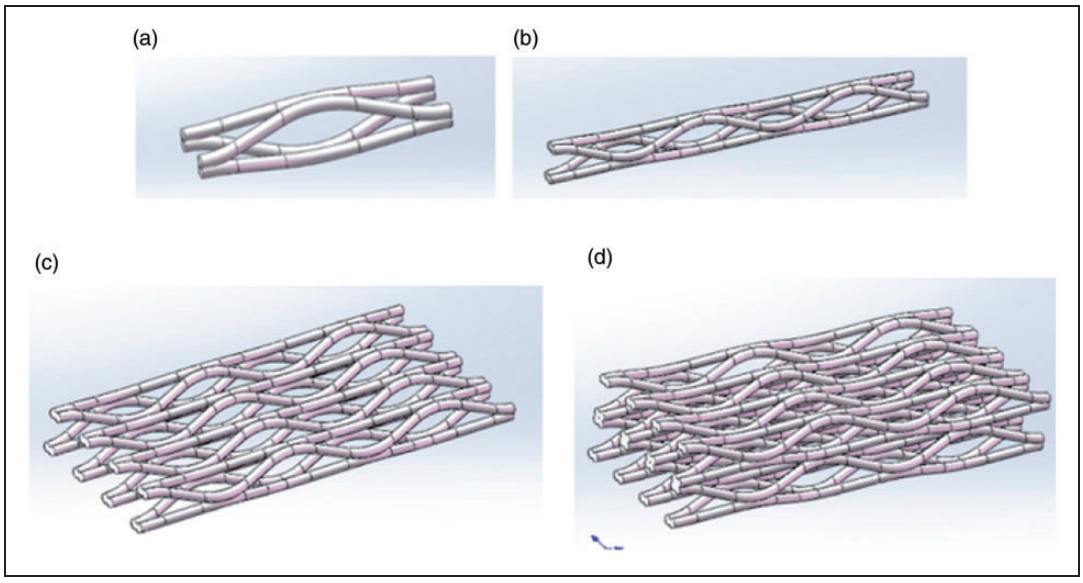


**Figure 7.** Octahedral cotton sliver modeling process.

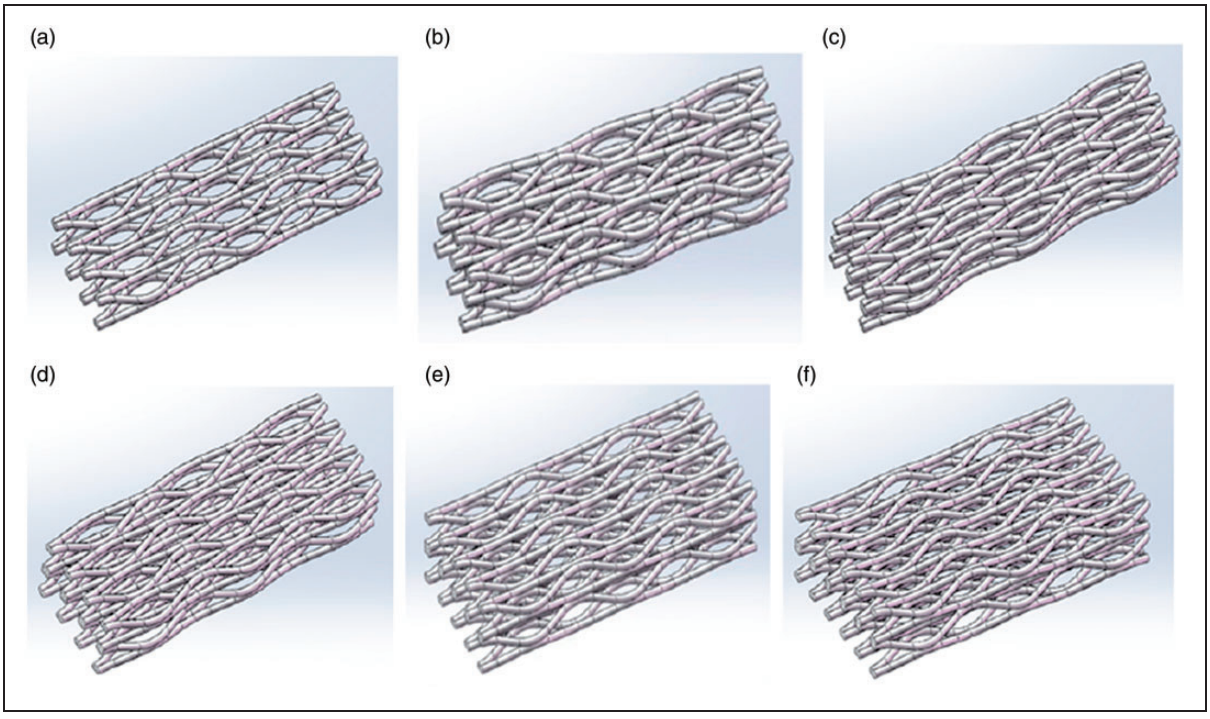


**Figure 8.** Three-dimensional models of octahedral cotton sliver with different quantifications: (a) quantitative 12.94 g/m; (b) quantitative 18.72 g/m;(c) quantitative 23.81 g/m; (d) quantitative 25.81 g/m; (e) quantitative 32.26 g/m; (f) quantitative 38.71 g/m.

where $t$ is the cross-sectional dimension of the octahedral prism and $l$ is the length of the octahedral prism.

Comparing the solution values of the relative density of Equations (2) and (3), we can see that the constant $C_2$ of Equation (1) is a unit quantity close to 1, so the above model conforms to the structural characteristics of the octahedron.

## Simulation of the octahedral cotton sliver model

### *Determination of static tensile length*

The roller draft in the drafting frame needs to determine the draft multiple. This paper selects the DHU

**Table 1.** Quantitative error of cotton slivers

| Actual cotton sliver quantitative (g/m) | Model cotton sliver quantitative (g/m) | Relative error |
|---|---|---|
| 8.96 | 9.72 | 8.48% |
| 13.44 | 12.94 | –3.72% |
| 17.92 | 18.72 | 4.46% |
| 22.40 | 23.81 | 6.29% |
| 26.88 | 25.81 | –3.98% |
| 31.36 | 32.26 | 2.87% |
| 35.84 | 38.71 | 8.01% |
| 40.32 | 43.84 | 8.7% |

A301 draw-up machine developed by Donghua University, which is mainly composed of a frame, a cover shell, a head drive, a tail drive, a guide strip, a motor, a roller, upper and lower coil plates, electrical equipment, and other parts. Its draft device is the pressure rod drafting system, which is widely used in actual production. The center distance of the roller in the front and back draft areas is 42.5 mm × 44 mm, and the drawing ratio is 6.4, among which the drawing ratio of the front draft area is 3.7 and the ratio of the rear draft area is 1.7.[15] The dynamic draft data of this paper are all from the stretch force in the front drafting area of the DHU A301.

The static drawing of the cotton sliver is only the tensile, the static drawing of the cotton sliver is only the tensile length, without the speed difference between the front and rear rollers, and there is no setting of the drafting multiple. In order to facilitate the static drawing, some scholars have used a formula to convert the dynamic drafting multiple into the static tensile length, and the practicability of the formula for the determination of the static tensile length is verified by experiments[15]

$$\frac{R}{R_x} = \frac{L + L_x}{L - L_x} \tag{4}$$

where $R$ and $R_x$ are the cotton sliver weight before and after drafting, $R/R_x$ is the drafting multiple, $L$ is the roller spacing, and $L_x$ is the draw elongation.

Substituting the distance between the rollers in the front drafting zone and the drafting multiple of the front drafting zone

$$3.7 = \frac{42.5 + L_x}{42.5 - L_x} \tag{5}$$

We obtain $L_x = 24$ mm.

**Table 2.** Material parameters of different cross-section shapes

| Strut cross-sections | $c$ | $k$ |
|---|---|---|
| Circle | 0.07985 | 1.1 |
| Square | 0.08333 | 1.2 |
| Equilateral triangle | 0.09623 | 1.2 |
| Plateau border | 0.13380 | 1.2 |

## *Determination of the elastic modulus of the octahedral cotton sliver model*

For solving the elastic modulus of the octahedral model, Su et al.[17] obtained the calculation formula of the octahedral elastic modulus and the determination of parameters in the formula through theoretical derivation and experimental demonstration, as follows

$$E_1 = \frac{2c\rho E_s}{[1 + 4k(1 + \mu_s)] \cdot 2c\rho + \sqrt{3}} \tag{6}$$

where $\rho$ is the relative density of the octahedral model, $E_s$ is the elastic modulus of the octahedral compact material, $c$ and $k$ are material constants, and $\mu_s$ is the Poisson's ratio of the octahedral compact material. The values of material constants $c$ and $k$ are shown in Table 2.[17]

For a circular section, $c = 0.07958$, $k = 1.1$, which is brought into Equation (6), we have

$$E_1 = \frac{2 \times 0.07958 \times 0.123^2 \times 9.18 \times 10^7}{[1 + 4 \times 1.1(1 + 0.4)] \times 2 \times 0.07958 \times 0.123 + \sqrt{3}} = 118,422 \text{ Pa} \tag{7}$$

## *Add loads and constraints*

Based on the octahedral cotton sliver model, the finite element software ANSYS is used to simulate the drafting. The material properties of each unit are set according to the above calculation results. The elastic modulus of the model is 118,422 Pa, the Poisson's ratio is 0.4, and the density is 1530 kg/m$^3$. Proper mesh generation is beneficial to the efficiency and accuracy of the solution. Because the octahedron model is complex, it is not suitable to use mapping and sweeping; free mesh generation is more suitable. According to the static tension experiment, the simulation boundary conditions are set as one section of circular section, which is fixed, and the other section is constrained by displacement. The main purpose of this simulation experiment is to explore the tensile force during tension. In order to reduce the calculation cost, other degrees of freedom of the model are set as fixed. For

nonlinear problems, the convergence of the calculation process is related to many factors, such as the mesh generation, setting of constraint conditions, setting of convergence criteria, and so on. In order to make the solution easier to converge, this paper sets the minimum number of sub steps to 100 and the maximum to 200, and activates the linear search. At the same time, it is necessary to set the appropriate convergence value for the calculation. In ANSYS software, convergence criteria can be specified based on physical quantities, such as displacement, force, rotation angle, and moment. Generally, the L2 norm is used to calculate the residual error, and the square sum squared root mean square (SRSS) value is checked to realize the calculation convergence. In this paper, the convergence value is set based on the convergence criterion of force and displacement at the same time, because setting the convergence criterion based on displacement alone may cause calculation deviation. The sparse matrix direct method solver is selected to solve the problem.

### *Simulation results of the octahedral mode*

After the solution, we check the stress nephogram of different quantitative octahedral cotton sliver models, as shown in Figure 9.

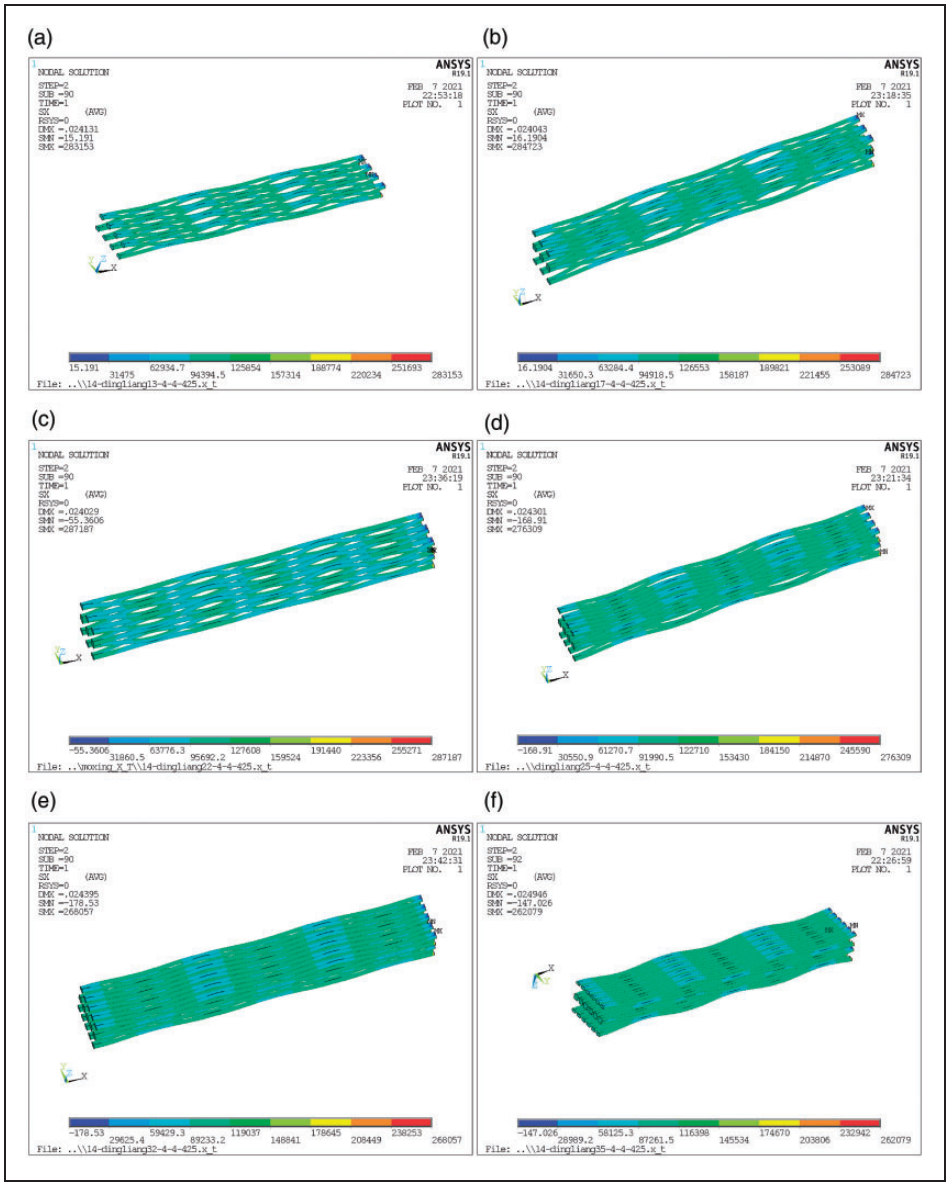


**Figure 9.** Stress nephogram of each quantitative cotton sliver: (a) quantitative 12.94 g/m; (b) quantitative 18.72 g/m; (c) quantitative 23.81 g/m; (d) quantitative 25.81 g/m; (e) quantitative 32.26 g/m; (f) quantitative 38.71 g/m.

The force required for static stretching of the octahedral model to 42.5 mm can be obtained through the simulated support reaction force, which is compared with the experimental data of dynamic drafting of the cotton sliver by Zhang,[15] as shown in Table 3.

It can be seen from Table 3 that the influence trend of the cotton sliver weight on the static drawing force and dynamic drafting force is the same, and the force increases with the increase of the weight. The maximum error between the simulation results and the experimental results is always less than 16%. The arrangement and shape of fibers and the setting of drafting conditions will affect the drafting force of the cotton sliver. Under the influence of many factors, the maximum relative error of the simulation is less than 16% and the average absolute relative error is 8.09%. Therefore, we think that the octahedral cotton sliver model can approximately simulate the drafting force of the whiskers. It also shows that it is feasible to build a method to simulate the drafting force based on the characteristics of cotton sliver pores without considering the fiber effect inside the cotton sliver.

The draft force increases with the increase of the model. From the perspective of relative error, the cotton sliver model has a better simulation effect on low quantitative whisker drafting, and the relative error increases with the increase of model quantitative value. There are two factors that may cause this phenomenon: one is the influence of the model itself. The model in this paper is formed by octahedron superposition. Because the octahedron cannot completely simulate the network structure of fibers in the cotton sliver, there is a certain error with the actual network structure in the cotton sliver. With the quantitative increase of cotton slivers, the greater the number of octahedron superpositions, and the greater the error superposition. For a low quantitative whisker, the error superposition is small, and the simulation results are more accurate, and with the increase of quantitative value, the error superposition increases and the accuracy of the simulation results decreases. The second is the quantitative factor of the cotton sliver model. It can be seen from Table 3 that the relative error decreases with the decrease of quantitative error. When the quantitative error is 3.72%, the error of tensile force and tensile force is as small as 0.2% and when the difference is 8.01%, the error between tensile force and tensile force reaches 14.47%, so we can get that with the quantitative increase, the difficulty of octahedral modeling increases, the quantitative error increases, and the simulation error increases.

In the actual wire drafting, the cotton sliver weight will be controlled between 26 and 35 g/m, and will not increase infinitely. From Table 3, it can be seen that in this interval, the error is within the acceptable range and the simulation has a certain accuracy, so the wire octahedron model can better simulate the cotton sliver drafting force.

Taking eight groups of data in Table 3, which are 8.96–40.32 g/m, we create the curve diagram of dynamic drafting force and static stretching force, as shown in Figure 10.

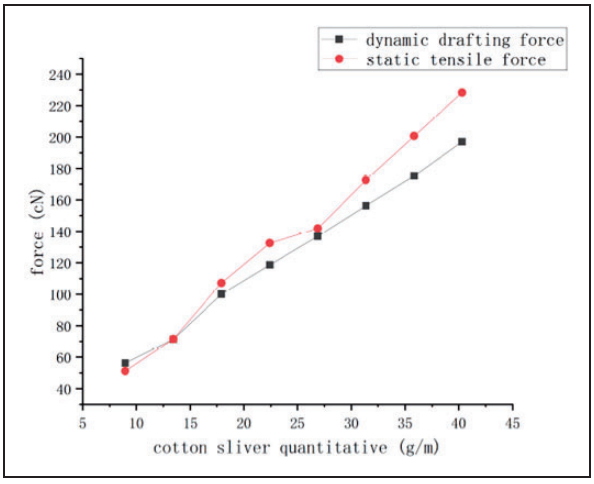


**Figure 10.** Static stretching force and stretching force curve.

**Table 3.** Model simulation of tensile force and experimental drafting force

| Cotton sliver quantification (g/m) | Experimental dynamic drafting force (cN) | Model quantification (g/m) | Simulation of static tensile force (cN) | Quantitative relative error | Relative error of force |
|---|---|---|---|---|---|
| 8.96 | 56.210 | 9.72 | 51.096 | 8.48% | −9.10% |
| 13.44 | 71.369 | 12.94 | 71.511 | −3.72% | 0.20% |
| 17.92 | 100.017 | 18.72 | 107.170 | 4.46% | 7.15% |
| 22.40 | 118.693 | 23.81 | 132.560 | 6.29% | 11.68% |
| 26.88 | 136.903 | 25.81 | 141.840 | −3.98% | 3.61% |
| 31.36 | 156.236 | 32.26 | 172.530 | 2.87% | 10.43% |
| 35.84 | 175.269 | 38.71 | 200.630 | 8.01% | 14.47% |
| 40.32 | 196.930 | 43.84 | 228.360 | 8.7% | 15.92% |

It can be seen from Figure 10 that with the increase of the quantity of cotton slivers, the draft force and the tensile force increase gradually, and the relationship between them is nearly linear. However, with the increase of the quantity of whiskers, the increase of the dynamic draft force is relatively stable, and the quantity of cotton slivers and the tensile force are closer to a linear relationship, while the static tensile force fluctuates greatly, showing instability, which may be related to the cotton sliver model. However, the two curves are relatively close on the whole, and the overall trend is the same. In order to observe the relationship between static tensile force and static tensile force more clearly and intuitively, we take the draft force and tensile force data of 13.44–35.84 g/m in Table 1, and create the curve as shown in Figure 11.

It can be seen from Figure 11 that except for the fluctuation of draft force and tensile force when the cotton sliver weight is 26.88 g/m, the performance of draft force and tensile force is relatively stable under other quantitative conditions. Excluding individual data jumping, it can be considered that there is a good linear relationship between draft force and tensile force. Using this linear relationship, we try to find out the equation of drawing force and stretching force by linear regression, and the linear regression equation is shown as Equation (8)

$$y = 0.821x + 13.351 \tag{8}$$

where $y$ is the dynamic drafting force and $x$ is the static stretching force.

The square of the correlation coefficient in the above regression equation $R^2 = 0.9897$, which shows that

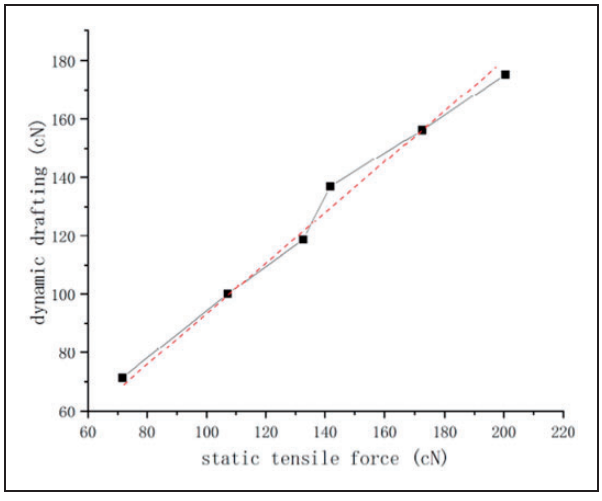


**Figure 11.** Curves of dynamic drafting force and static tensile force.

there is a good linear relationship between the static tensile force and the dynamic draft force. The above equation has been tested to be significant. In order to realize the prediction of the dynamic drafting force, static tensile force with quantitative values of 8.96 and 40.32 g/m is introduced into Equation (8); the predicted value of the dynamic drafting force under this quantitative value can be obtained, the actual measured dynamic drafting force is compared, and the relative error is calculated, as shown in Table 4.

It can be seen from Table 4 that although there are some differences between static stretching and dynamic drafting, they also have some similarities. The relationship between dynamic drafting force and static stretching force can be established, and the dynamic drafting force can be predicted.

### *Analysis of results*

Obviously, there are many differences between the static stretching in this simulation experiment and the dynamic stretching. The simulation results cannot fully reflect the drafting force of the cotton sliver drafting, but the simulation data of the model has certain accuracy, and can predict the dynamic drafting force by establishing the relationship between the static stretching force and the dynamic drafting force. Therefore, the establishment of the model provides a new method for predicting the drafting force. In the past, the drafting force was measured by a measuring device. For a variety of quantitative cotton slivers, it needs to be measured many times, which is time-consuming and labor-consuming. Through the operation in "Establishment of the three-dimensional model of the cotton sliver" and "Simulation of the octahedral cotton sliver model", the drafting force can be measured in advance, which provides reference data for the formulation of subsequent processes. In this paper, the simulation analysis is only done under one drafting ratio with different cotton sliver quantifications. By changing the structure of the octahedron, we can simulate more drafting ratios, and we can simulate the influence of different roller spacings on the drafting force at the same drafting ratio.

## The influence of different roller spacings on drafting force

In this section, the roller spacing of dynamic drafting is replaced by the length of octahedral strand model. In the actual drafting, six and eight cotton slivers are merged. In "Establishment of the three-dimensional model of the cotton sliver", the quantitative value is 26.88 g/m by merging six cotton slivers. Therefore,

**Table 4.** Comparison of predicted value and measured value of drafting force

| Cotton sliver quantification (g/m) | Simulation value of static tensile force × (cN) | Predicted value of dynamic drafting force y (cN) | Measured value of dynamic drafting force (cN) | Relative error |
|---|---|---|---|---|
| 8.96 | 51.096 | 55.300 | 56.260 | −1.7% |
| 40.32 | 228.360 | 200.835 | 196.930 | 1.9% |

**Table 5.** Stretching force of different length cotton sliver models

| Length of the cotton sliver model (mm) | Stretching force (cN) |
|---|---|
| 32 | 173.43 |
| 37 | 152.15 |
| 42 | 141.84 |
| 47 | 126.38 |
| 52 | 114.76 |
| 57 | 106.34 |
| 62 | 99.46 |

the 26.88 g/m cotton sliver model is selected for the following simulation calculation. The stretched lengths of the cotton sliver are 24 mm, and we calculate the stretch force under different cotton sliver model lengths through ANSYS, as shown in Table 5.

Seven groups of data are selected in Table 5 and the curve of static tensile force and the length of cotton sliver model is shown in Figure 12.

It can be seen from Figure 12 that the static stretching force of the cotton sliver decreases with the increase of the model length. From the curve slope in the figure, it can be seen that as the length of the cotton sliver model gradually increases, the change of the tensile force gradually decreases, and as the length of the cotton sliver model decreases, the change of the tensile force increases. In Figure 11, the stretching force suddenly increases when the length of the cotton sliver model is between 30 and 35 mm.

For dynamic drafting, when the distance between the rollers gradually becomes greater than the fiber length, the frictional force of the rear roller has less and less effect on the fast fiber, and the drafting force also becomes smaller and the amplitude of change becomes smaller. Conversely, when the distance between the rollers decreases, the frictional force of the rear roller has more and more effect on the fast fiber, and the drafting force also gradually increases and the increasing amplitude becomes larger. At this time, the drafting force undergoes a sudden increase. This has a certain similarity with the change of the static stretching force mentioned above, indicating that the simulation experiment is consistent with the actual situation, and static stretching using the octahedral cotton sliver model can reflect some processes of dynamic drafting to a certain extent.

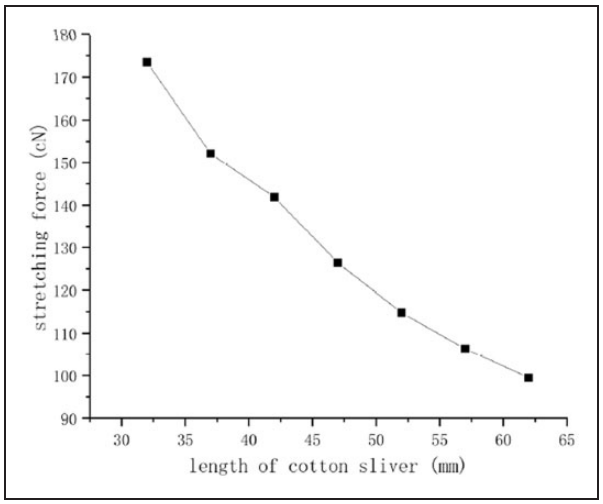


**Figure 12.** Curve of static stretch force and the length of the cotton sliver model.

## Conclusion

In this paper, by observing the structure of the cotton sliver, the octahedron model is proposed to simulate the network structure of the cotton sliver, and the octahedron model of the cotton sliver is established through reasonable assumptions. The correctness of the model is proved by different cotton sliver quantitative simulation results under a fixed drafting ratio, which enriches the solution method of stretching force, and provides a certain reference for the development of different drafting force measurement methods. At the same time, the simulation does not need to use the real cotton sliver, and the model ignores the interaction between a large number of fibers, which greatly simplifies the solution of the traction force. In a large number of experimental cases, this method can save a great deal of cost while ensuring a certain accuracy. The model has good accuracy for different cotton sliver quantitative values of the fixed drafting multiple, and does not have simulation accuracy for the same quantitative

value and different drafting multiples. At the same time, because the model is a whole macro model, it cannot simulate any state of fiber in the cotton sliver during drafting.

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