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Finite-element Analysis of Cotton Serrated Ginning State Based on Three-dimensional Braided Modeling

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ABSTRACT

In order to analyze the stress state of the seed cotton in the process of ginning cotton, a theoretical model for cotton, namely three-dimensional braided cotton was developed. The model consists of cotton fiber bundles arranged according to the unit cell structure of a three-dimensional four-directional braided composite material. The fiber bundle has a circular section and the shape of the cross section remains unchanged along the axial direction. Based on this model, the serrated ginning process is simulated using finite-element analysis. By analyzing of the effects of different moisture regain and speed on the serration cotton ginning process, the results show that the simulation results agree with the actual situation and the model has certain applications. Compared to the laminated cotton model, the three-dimensional braided cotton model has been improved obviously. In terms of model structure, the three-dimensional braided cotton model is closer to the actual situation of cotton than the existing laminated cotton model. The whole model in the laminated cotton model is an entity, which is bonded together by multiple layers of single-layer panels at different angles. The three-dimensional braided cotton model takes into account the intertwining of fibers and apces, but does consider the distribution of cottonseed which will be the focus research.

KEYWORDS

Cotton gin; finite-element model; ANSYS; moisture regain; laminated cotton model; three-dimensional braided model

关键词

化学处理; 吸附剂; 染料去除; 椰子椰; 亚甲基蓝; 生物量

摘要

为了分析轧棉过程中籽棉的应力状态, 建立了棉花三维编织棉的理论模型。该模型由棉纤维束按三维四向编织复合材料的单元胞结构排列而成。纤维束具有圆形截面, 截面形状沿轴向保持不变。基于此模型, 采用有限元分析方法模拟锯齿轧花过程。通过分析不同回潮率和速度对梳棉机轧棉过程的影响, 仿真结果与实际情况吻合较好, 具有一定的应用前景。与叠层棉模型相比, 三维编织棉模型有了明显的改进。在模型结构方面, 三维编织棉模型比现有的叠层棉模型更接近棉花的实际情况。叠层棉模型中的整体模型是一个实体, 它由多个不同角度的单层板粘合在一起。三维编织棉模型考虑了纤维与apces的相互缠绕, 但考虑了棉籽的分布, 是今后研究的重点。

Introduction

The textile industry is a pillar industry in China. As the main raw material of the cotton textile industry, cotton is an important part of China's economic development. Serration cotton ginning is a complex dynamic process. Cotton fibers are intertwined with each other; the force and condition of the cotton fiber itself are very difficult, if not impossible, to actually measure under the action of the saw blade

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rotation. In order to better analyze the ginning process and achieve high quality and high yield, it is particularly important to use computer technology to simulate and analyze the ginning process.

The prerequisite for using computer technology to analyze the cotton ginning process is to establish a reasonable model on the computer. Dong (2016) proposes using the least-squares support vector machine method to conduct experimental modeling and establishes a relationship model among the feed roller speed, the serration drum speed, and the state of the cotton lap. Li, Chen, and Wang (2015a) use the two main factors of affecting the quality of cotton as the basic feature of the BP neural network model and establish a BP neural network forecasting model for the quality index of the raw machine-harvesting. Chen et al. (2019) puts forward a new model for cotton based on the idea of composite laminate. ANSYS is used to simulate the ginning process, which proves that the laminate model is reasonable to some extent. However, compared with two-dimensional composite laminates, three-dimensional braided composites have better design properties.

As a new lightweight and efficient structural material, the micro-structure and macro-mechanical properties of three-dimensional braided composites material have gradually become a research hotspot in the field of mechanics and advanced materials. Tang and Postle (2000, 2001, 2002) establish a four-step three-dimensional braided composite fiber volume content model and predict the tensile modulus and shear modulus of the three-dimensional braided composite material by numerical simulation and mathematical modeling. Nonlinear finite-element analysis of three-dimensional braided composites is carried out with the parameters of braiding structure. Based on the laminated cotton model and the idea of three-dimensional braided composites, a new model called three-dimensional braided cotton model is presented in this paper. The three-dimensional braided cotton model is closer to the actual situation of the cotton structure. However, in this paper, the model will not consider the distribution of cottonseed.

Establishment of cotton model

The laminated cotton model assumes that the cotton interior is made up of a certain number of cotton fibers, each of which has a different arrangement angle. The whole model of the laminated cotton model is an entity while the cottonseed is actually an irregular ellipsoid with a certain gap between the fibers. Therefore, taking into account the intertwining between cotton fibers, the three-dimensional braided cotton model is proposed based on the existing model of laminated cotton model and the idea of three-dimensional braided composite materials.

Morphological structure of cotton

In order to establish the cotton model, it is particularly important to observe the actual distribution of cotton fibers. The distribution of cotton fibers was observed through a magnifier, as shown in Figure 1a.

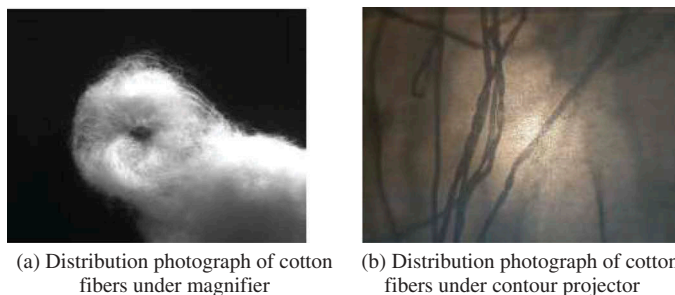


Figure 1. Distribution photograph of cotton fibers. (a) Distribution photograph of cotton fibers under magnifier. (b) Distribution photograph of cotton fibers under contour projector.

It can be seen that one end of the cotton fiber is born on the surface of the cottonseed and the other end is closed. Cotton fibers present curvature in the natural state, and there are all angles in the three-dimensional space. The cotton fibers in cotton are densely distributed, but there are gaps between the fibers and they are not compacted together. The distribution of the fiber near the cottonseed is higher, and the distribution of the fiber on the cotton surface is relatively fluffy and sparse.

In order to further observe cotton fibers, the cotton is magnified 100 times by a contour projector, as shown in Figure 1b. It can be seen that the cotton fibers are flattened and twisted in the longitudinal direction. The cotton fibers are slender and long, and have irregular shape in the longitudinal direction. The cotton fibers are constantly changing along the length of the fibers, and the overall shape is spirally twisted.

Meso model of cotton fiber bundle

The spatial relationship of the fiber in the actual cotton looks very complicated. In order to facilitate analysis, the three-dimensional braided cotton model is formed by arranging the fiber bundles according to a certain rule. It is assumed that the fiber bundle has a circular cross-section and the cross-sectional shape remains unchanged along the axial direction. Chen, Li, and Li (2002) use the least-squares approximation to predict the trend line of carrier movement and the yarn paths are analyzed systematically in the braiding process. On this basis, the internal unit cell structure of the three-dimensional four-directional braided composite material is obtained. Using this rule, the geometric relationship between fiber bundles in a unit cell of cotton can be determined, as shown in Figure 2a. Using the geometric analysis model, a unit cell model of cotton fiber bundle is established in the three-dimensional modeling software SOLIDWORKS, as shown in Figure 2b.

Meso model of three-dimensional braided cotton model

The three-dimensional braided composite preforms are divided into three regions, including internal, surface and corner, and three cell models corresponding to them (Xia 2011). When the macro size is large, the proportion of the corner unit cell is smaller, so the cell model of three-dimensional braided cotton model can be replaced by the inner cell and the surface cell. The interior of the model has periodicity. Therefore, by analyzing the above unit cell structure and combining with the actual size of cotton, a complete geometric model can be established in SOLIDWORKS, as shown in Figure 3.

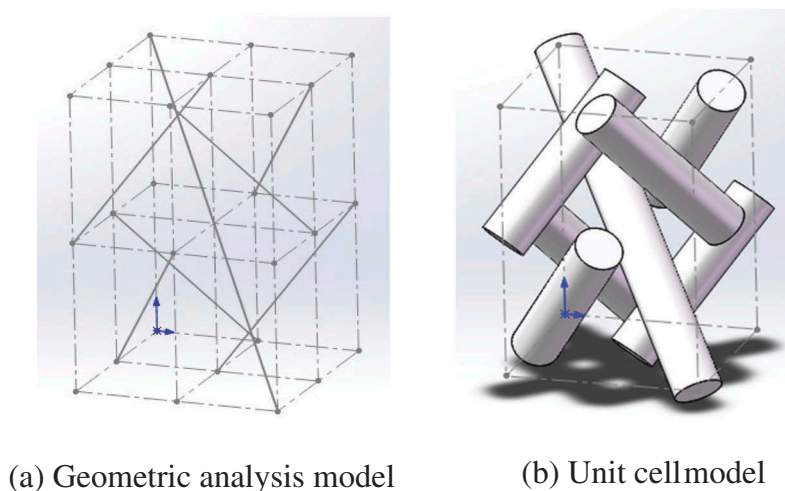


Figure 2. Unit cell model of cotton fiber bundle. (a) Geometric analysis model. (b) Unit cell model.

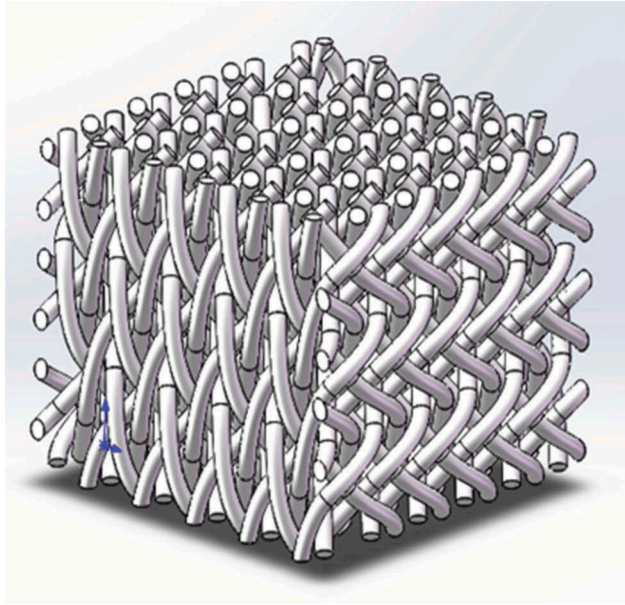


Figure 3. Three-dimensional braided cotton model.

Analysis of the influence of moisture regain on cotton fiber properties

The moisture regain is the first factor to be considered in cotton picking, storage, and processing. The moisture regain of cotton is moderate, so as to ensure good processing performance and produce high quality cotton.

Experiment of cotton fiber performance under different moisture regain

In order to simulate the influence of different moisture regain of cotton fiber on the ginning, the XQ-2 fiber strength meter is used to test the stress relaxation of cotton fiber under different moisture regain. The moisture regain of cotton is 5%–10%, considering the experimental equipment and the control of the moisture regain. The relaxation test was 60s at regular intervals. The data are shown in [Figure 4](#).

The mechanical properties of cotton fibers are described by the Burgers mechanics model (Ge 2017), and the stress relaxation equations of the three-parameter model can be obtained as follows:

$$\sigma(t) = \frac{\varepsilon_0}{\sqrt{p_1^2 - 4p_2}} [(\alpha q_2 - q_1)e^{-\alpha t} + (q_1 - \beta q_2)e^{-\beta t}] \quad (1)$$

In Equation (1), $\alpha, \beta = \frac{p_1 \pm \sqrt{p_1^2 - 4p_2}}{2p_2}$, $p_1 = \frac{\eta_2}{E_1} + \frac{\eta_1}{E_1} + \frac{\eta_2}{E_2}$, $p_2 = \frac{\eta_1 \eta_2}{E_1 E_2}$, $q_1 = \eta_2$, $q_2 = \frac{\eta_1 \eta_2}{E_1}$. σ represents stress, ε_0 represents strain, E represents elastic modulus of spring, η represents viscosity coefficient of sticky pot.

The value of each parameter in the viscoelastic model can be obtained by fitting Equation (1) using software and combining experimental data. [Figure 4](#) shows the stress relaxation test curves for cotton fibers at different moisture regain and the application of Burgers mechanical model to simulate the viscoelastic properties of cotton fibers.

From [Figure 4](#), it can be seen that the Burgers model can simulate the mechanical properties of cotton fiber well. By fitting the test data, the values of the parameters in the Burgers model under different moisture regain rates can be obtained as shown in [Table 1](#). In addition, $t_1 = 1/\alpha$, $t_2 = 1/\beta$.

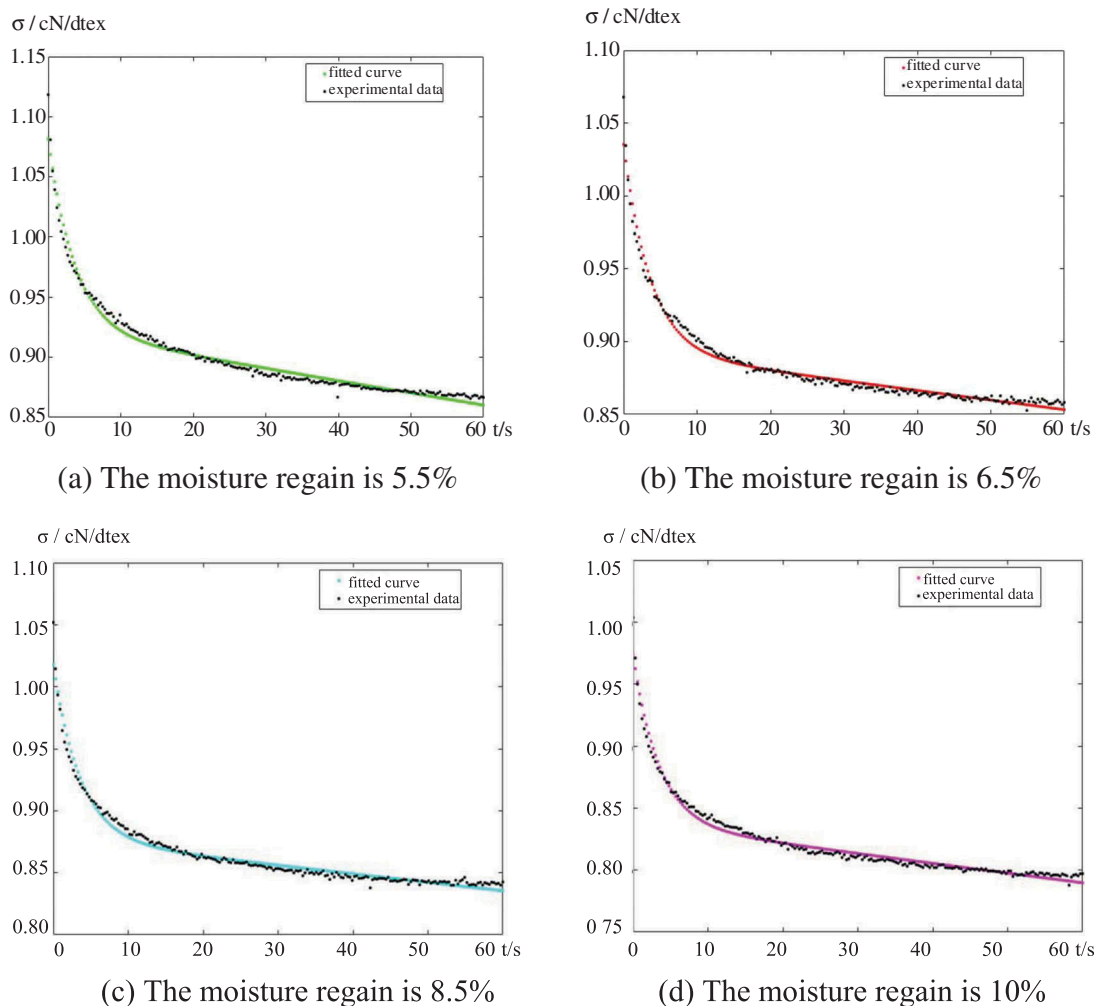


Figure 4. Stress relaxation test curve of cotton fiber at different moisture regain & stress relaxation fitting curve of model. (a) The moisture regain is 5.5%. (b) The moisture regain is 6.5%. (c) The moisture regain is 8.5%. (d) The moisture regain is 10%.

The stress relaxation characteristics of cotton fibers at different moisture regain rates can be obtained by taking the parameter values in Table 1 into Equation (1). The results are summarized as shown in Table 2. The comparison diagram of stress relaxation fitting curve of Burgers model of cotton fiber under different moisture regain is drawn in MATLAB, which is shown in Figure 5.

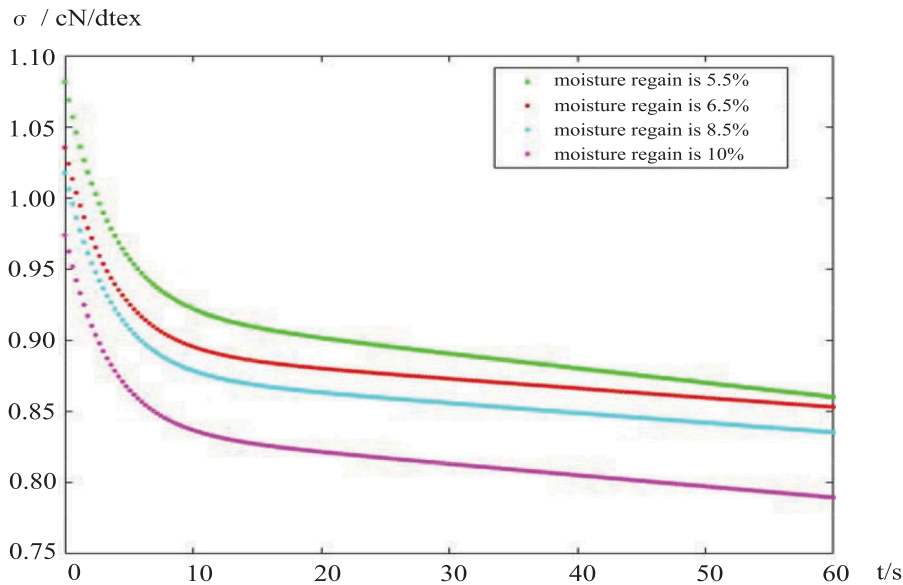
From Figure 5, it can be seen that the cotton fiber has a faster flow in high moisture regain and the speed of stress relaxation is faster. The greater the moisture regain is, the shorter the relaxation time t_1 is. The reason is that increasing the relative humidity can weaken the secondary bond force between the macromolecular chains in the fiber and accelerate the stress relaxation process.

Table 1. Stress relaxation parameters of cotton fiber under different moisture regain.

Moisture regain (%)	$E1^{(1)}$ (cN·dtex ⁻¹)	$E2^{(1)}$ (cN·dtex ⁻¹)	$\eta_1^{(2)}$ (cN·s·dtex ⁻¹)	$\eta_2^{(2)}$ (cN·s·dtex ⁻¹)	Relaxation time t_1 s
5.5	158.295	27.037	681.715	19880.471	3.676
6.5	164.095	25.883	691.573	29091.795	3.639
8.5	159.873	25.439	671.215	27103.253	3.620
10	150.915	24.346	608.535	21348.383	3.470

Table 2. Stress relaxation equation of cotton fiber under different moisture regain.

Moisture regain (%)	Stress relaxation equation
5.5	$\sigma(t) = 0.159e^{-0.27206t} + 0.922e^{-0.00116t}$
6.5	$\sigma(t) = 0.142e^{-0.27482t} + 0.894e^{-0.00077t}$
8.5	$\sigma(t) = 0.141e^{-0.27621t} + 0.877e^{-0.00081t}$
10	$\sigma(t) = 0.136e^{-0.28816t} + 0.838e^{-0.00098t}$

**Figure 5.** Comparison of stress relaxation fitting curves of cotton fiber with different moisture regain.

Determination of viscoelastic parameters

Cotton fiber is a typical viscoelastic material. In finite-element software ANSYS, there are three ways to input viscoelastic parameters, that is, curve fitting, and the Maxwell and Prony method (Yuan and Sun 2012). For general viscoelastic materials, the constitutive relation can be transformed into the form of Prony and the corresponding value can be input according to the requirements of the material viscoelastic parameters in ANSYS (Potvin 2001). Through the above data processing, the viscoelastic material parameters of the cotton fiber under different moisture regain can be obtained as shown in Table 3 in which $t1$ and $t2$ represent relative time, $a1$ and $a2$ represent relative modulus.

Finite-element simulation of serrated ginning

Definition of material and meshing

The SOLID 185 units are used for both serration and cotton. The elastic modulus of serration is 2.07×10^5 MPa; Poisson's ratio is 0.29 and the density is 7850 kg/m^3 . The elastic modulus of cotton is 2.4×10^3 MPa; Poisson's ratio is 0.4 and the density is 400 kg/m^3 . Ge (2017) obtains the

Table 3. The viscoelastic material parameters of cotton fiber under different moisture regain.

Moisture regain	$t1^{(3)}$	$t2^{(3)}$	$a1^{(4)}$	$a2^{(4)}$
5.5%	3.676	861.528	0.147	0.853
6.5%	3.639	1301.856	0.137	0.863
8.5%	3.620	1235.529	0.138	0.862
10%	3.470	1018.896	0.140	0.860

viscoelastic material parameters of the cotton fiber at the moisture regain of 7.5%. The viscoelasticity of the cotton is described by Prony (Potvin 2001), $t_1 = 3.53$, $a_1 = 0.123$, $t_2 = 924.09$, and $a_2 = 0.877$ are input into the corresponding program.

The overall structure size of the three-dimensional braided cotton model is $20 \text{ mm} \times 20 \text{ mm} \times 18 \text{ mm}$. After preliminary pre-simulation, it can be concluded that the cotton has greater local force on the effect of serration. In order to avoid the unfavorable effects such as long calculation time or even unsolvable in finite-element simulation, the model is simulated by intercepted the size of $12 \text{ mm} \times 12 \text{ mm} \times 12 \text{ mm}$. Due to the various saw blades installed in parallel on the drum, some cotton balls may be in contact with the two saw blades simultaneously. The divided model is shown in Figure 6.

Finite-element simulation

The method of surface-to-surface is selected to establish the contact. Periodic boundary conditions are applied to the model. The serration can only move along the Z-axis. Cottonseed is represented by a certain range of nodes in the central portion of the cotton. The rotation of the nodes along the X-axis, the Y-axis and the translation along the Z-axis are restrained. The specified analysis type is transient analysis. The rotary speed of the serration is 435 r/min; the solution time is $0.5 \times 10^{-3} \text{ s}$. Figure 7 is the stress nephogram of the final step and Figure 8 is the strain nephogram of the final step.

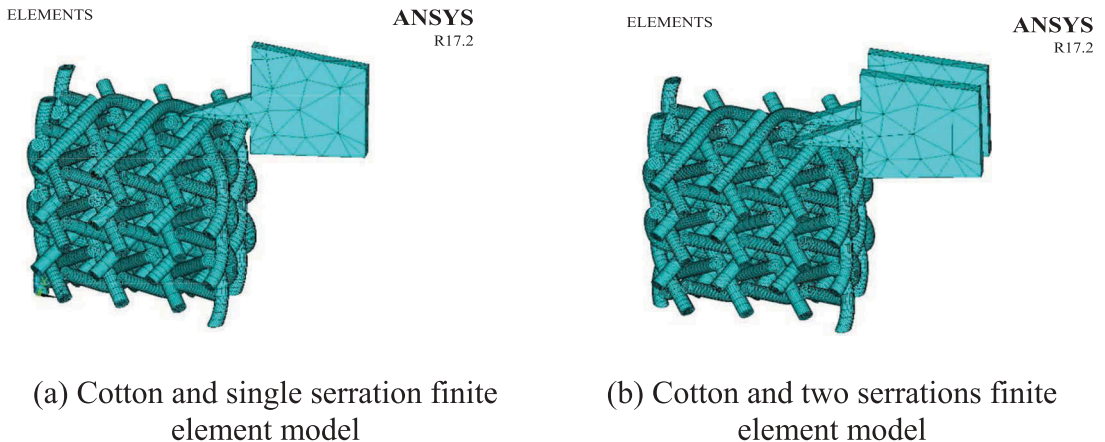


Figure 6. Finite-element model. (a) Cotton and single serration finite-element model. (b) Cotton and two serrations finite-element model.

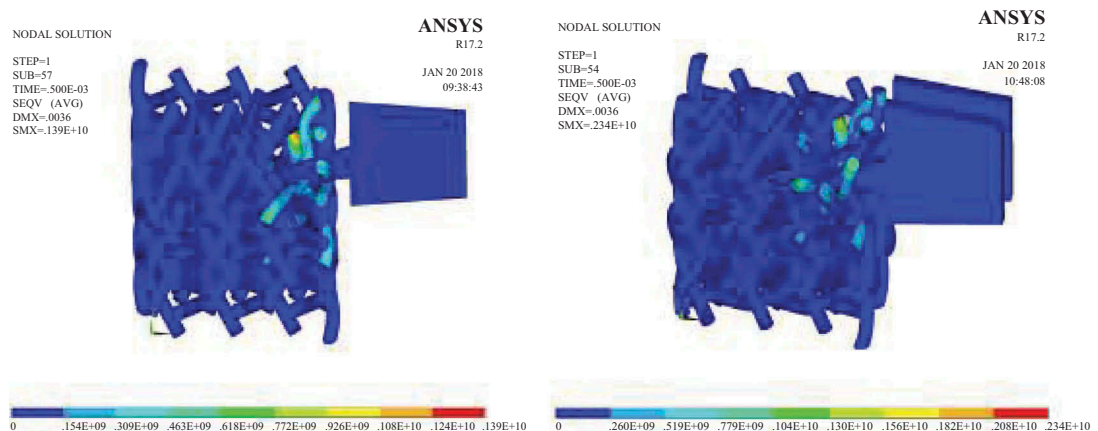


Figure 7. Stress nephogram of model (units of scale 1:1).

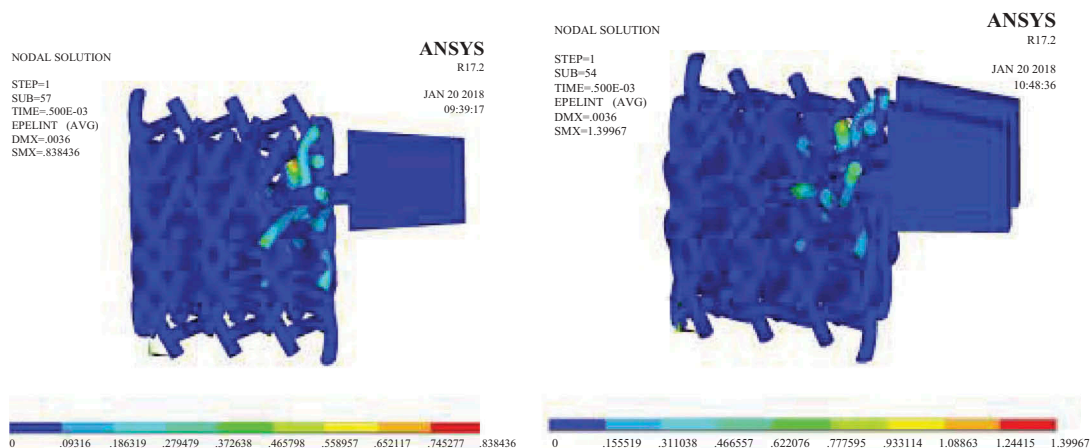


Figure 8. Strain nephogram of model (units of scale 1:1).

In Figure 7, the cotton fiber has a large deformation. The maximum stress is reached in the last step. The stress distribution of cotton is directly related to serration. Most areas on the cotton are light blue and blue, and the stress is between 154 MPa and 309 MPa. The few areas are dark blue, green and yellow, and the stress is above 309 MPa. From the strain nephogram, the fiber bundles which are most affected by the serration are light blue and blue, and the strain is between 9.32% and 18.63%. The strain of cotton and serration is larger than the fracture rate of 7%-8% when the seed cotton breaks. Based on hypothesis of material continuity in the finite-element analysis, it is known that the raw cotton has already formed in actual production before this strain is reached.

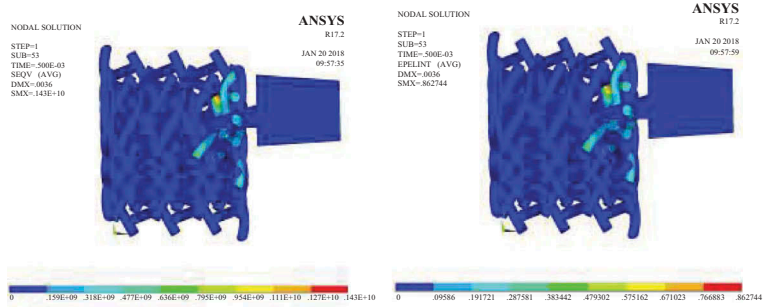
Through the post-processing, the force of each node on the bottom surface of the serration is obtained. The specific joint force ranged from 0.14658 to 1.53230 (42 observations total). It can be seen that the maximum force received by the bottom surface node of the serration is 1.5323 N. According to the third law of Newton, the maximum force of cotton is 1.5323 N. Through the experiment of cotton ginning, it can be concluded that the force required when the cotton fiber is broken by the serration is 1.719N. The specific experiment is shown in Appendix I. Compared with the experimental results, the error between the experimental average of 1.719 and the theoretical maximum of 1.5323 is small, which indicates that the three-dimensional braided cotton model is reasonable.

From the stress and strain nephogram of the double-serration model, it can be seen that the stress change of the cotton is approximately between 260 MPa and 519 MPa and the strain is approximately between 15.55% and 31.10%. Comparing the results of the two models, the effects of double-serration are more severe than those of single-serration, but the effects on cotton are similar. In the actual ginning process, due to the limited installation distance of the saw blade, it is difficult for a cotton to contact with more than three saw blades at the same time. Therefore, the simulation results of the above two models basically cover the stress situation of cotton during ginning.

Analyses of the impact of working conditions on the ginning process

Analyses of the impact of moisture regain on the ginning process

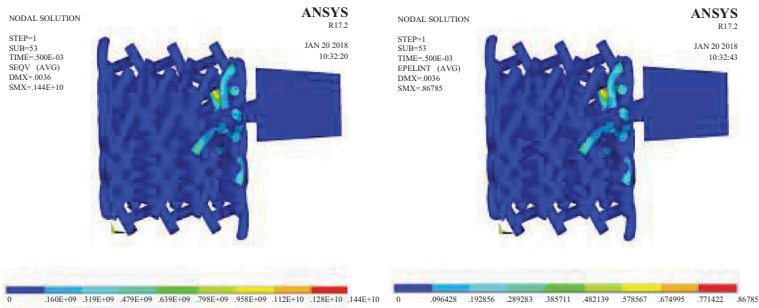
When the speed of the serration is 435 r/min, the moisture regain of cotton is 5.5%, 6.5%, 8.5% and 10%, respectively. By repeating the above simulation, the stress and strain nephogram of cotton under different moisture regain are obtained and shown in Figure 9.



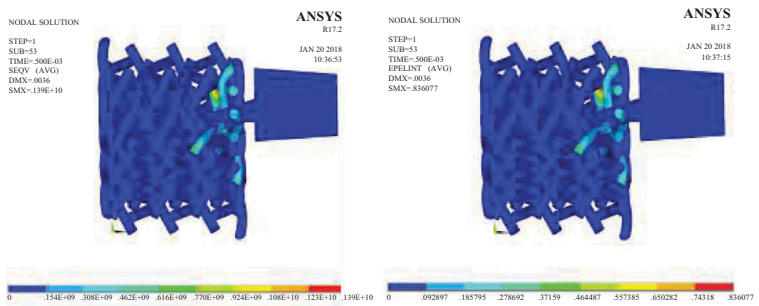
(a) The stress and strain nephogram of model when the moisture regain is 5.5%



(b) The stress and strain nephogram of model when the moisture regain is 6.5%



(c) The stress and strain nephogram of model when the moisture regain is 8.5%



(d) The stress and strain nephogram of model when the moisture regain is 10%

Figure 9. Stress and strain nephogram of model at different moisture regain at the speed of 435 r/min (units of scale 1:1). (a) The stress and strain nephogram of model when the moisture regain is 5.5%. (b) The stress and strain nephogram of model when the moisture regain is 6.5%. (c) The stress and strain nephogram of model when the moisture regain is 8.5%. (d) The stress and strain nephogram of model when the moisture regain is 10%.

From Figure 9a, it can be seen that the maximum stress is reached in the fifty-third step when the moisture regain is 5.5%. The stress distribution of cotton fiber bundles, which are mainly affected by the saw tooth, is mostly light blue, and the very small part is dark blue and green, and the stress varies between 159 MPa and 318 MPa. From the strain nephogram, most areas of the fiber bundle subjected to serration are light blue. The strain of cotton is between 9.59% and 19.17%. Compared with the analysis when the moisture regain is 7.8%, the main stress and strain change trend of cotton is approximately the same when the moisture regain is 5.5%. In addition, in other cases of moisture regain, the stress of cotton reaches the maximum in the last step, the same as with strain.

Longitudinal contrast, under the same other conditions, when the moisture regain changes, the variation of cotton stress condition is not very large. Li and Chen (2015b) tested the breaking strength of cotton seed under different moisture regain rates and ginning speeds. The data are shown in Table 7. The stress values under different moisture regain rate and ginning speed can be obtained by numerical transformation of Appendix II. The breaking strength is multiplied by the density of the cotton fiber to obtain the stress, and the data are shown in Table 8. From its numerical analysis, the stress of cotton under different moisture regain rate is not regular. Comparing the simulation data with the literature, it can be seen that the value of stress obtained by the simulation are correct and there is no regularity in the change. But when the moisture regain is 8.5%, the stress and strain of cotton are relatively high. That is, at the same time, the effects of serration and cotton are more intense.

Analyses of the impact of speed on ginning process

In order to analyze the stress of the cotton under different conditions, 435 r/min, 507 r/min, 580 r/min, 652 r/min and 725 r/min were selected as the rotation speed of serration and the moisture regain of cotton as 5.5%, 6.5%, 7.5%, 8.5%, and 10%. The above simulation was repeated and 25 sets of orthogonal results were obtained. The results of the stress and strain of cotton under the serration are summarized in Tables 4 and 5. The rotating speed is the X-axis, the moisture regain is the Y-axis and the stress is the Z-axis. The three-dimensional curved surface of stress is drawn in Figure 10a. Similarly, the three-dimensional curved surface of strain is drawn in Figure 10b.

There are two curved surfaces in Figure 10. Since the stress and strain distributions are a range value, the upper curved surface represents the maximum stress value/strain value, and the lower curved surface represents the minimum stress value/strain value. Combined with the charts, it can be seen that the stress

Table 4. The stress of cotton at different moisture regain and speed, in MPa.

Moisture regain	435 r/min	507 r/min	580 r/min	652 r/min	725 r/min
5.5%	159–318	162–323	168–337	183–366	203–405
6.5%	151–303	158–315	167–333	197–395	206–413
7.5%	154–309	157–314	178–356	188–375	195–390
8.5%	160–319	167–334	179–358	206–411	220–441
10%	154–308	155–310	162–324	188–376	213–427

Table 5. The strain of cotton at different moisture regain and speed, in %.

Moisture regain	435 r/min	507 r/min	580 r/min	652 r/min	725 r/min
5.5%	9.59–19.17	9.76–19.52	10.20–20.40	11.41–22.83	12.60–25.19
6.5%	9.26–18.51	9.52–19.04	10.10–20.20	11.99–23.98	12.63–25.26
7.5%	9.32–18.63	9.48–18.96	10.77–21.55	11.43–22.85	11.92–23.85
8.5%	9.64–19.29	10.09–20.18	10.86–21.71	13.84–27.68	13.90–27.79
10%	9.29–18.58	9.37–18.74	10.51–21.02	11.46–22.93	13.01–26.02

Table 6. Experimental data of cotton ginning.

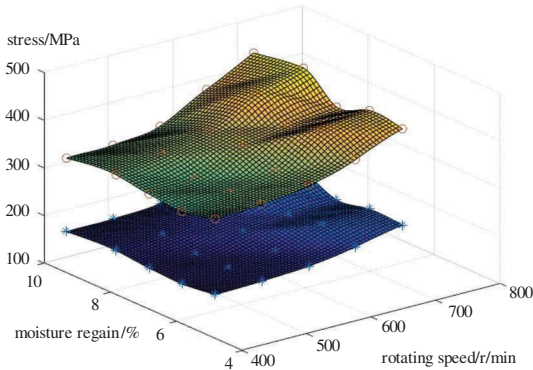
	The weight of sandbag (g)			Average (g)
153.56	177.95	148.40	167.07	175.399
179.94	177.62	170.05	179.16	
201.61	191.82	177.71	179.90	

Table 7. Breaking strength of cotton seed under different moisture regain rate and ginning speed, in cN/tex.

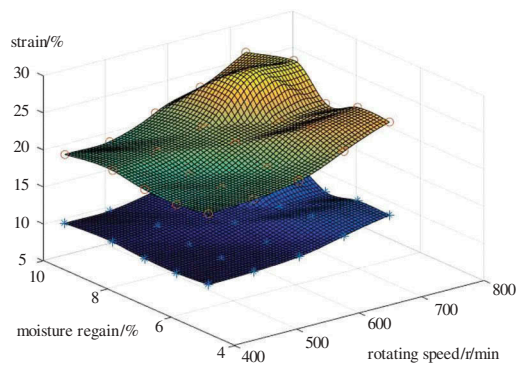
Moisture regain	435 r/min	507 r/min	580 r/min	652 r/min	725 r/min
5%	21.1	20.8	20.9	20.7	20.6
7%	20.7	21.0	22.1	21.5	21.7
8%	21.1	21.1	21.0	21.3	20.7
9%	20.8	20.6	20.6	20.9	20.5
11%	22.0	22.3	21.8	21.9	21.9

Table 8. Stress of cotton seed under different moisture regain rate and ginning speed, in MPa.

Moisture regain	435 r/min	507 r/min	580 r/min	652 r/min	725 r/min
5%	316.5	312.0	313.5	310.5	309.0
7%	310.5	315.0	331.5	322.5	325.5
8%	316.5	316.5	315.0	319.5	310.5
9%	312.0	309.0	319.0	313.5	307.5
11%	330.0	334.5	327.0	328.5	328.5



(a) Three-dimensional curved surface of stress



(b) Three-dimensional curved surface of strain

Figure 10. Three-dimensional curved surface. (a) Three-dimensional curved surface of stress. (b) Three-dimensional curved surface of strain.

and strain of cotton are distributed between the two surfaces. The force of the serration during the ginning process is the power of the lap to rotate, which produces a rotational moment on the lap. The force of the serration tip is F and the tip mass is m , then $F = mv^2/r$. When the speed of serration is larger, the linear velocity v is increased, and F is also increased. In the finite-element analysis, it is assumed that the central node of the cotton is fixed. The greater the force F of the serration tip, the greater

the stress on the cotton. Therefore, according to theoretical analysis, under certain conditions, the higher the speed of the saw tooth, the greater the stress on the cotton.

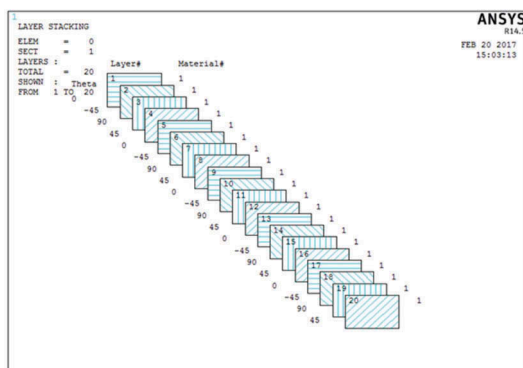
At the same speed, when the moisture regain of cotton is 8.5%, the stress and strain curves are higher, indicating that the effect of ginning is the most intense. The stress and strain curves are from low to high, indicating that under the same moisture regain, the higher the speed of serration is, the more intense the effect of ginning is. Therefore, the ginning yield can be increased by increasing the ginning speed. However, due to the increase of ginning speed, the effect of cotton will be aggravated, which will cause some damage to the cotton fibers and reduce the quality of cotton.

Comparison of two cotton models

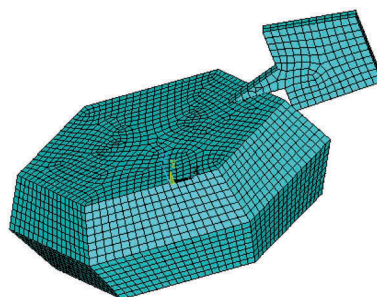
In the model of the laminated cotton model proposed by Chen et al. (2019), the cotton mass is made up of a certain number of cotton fibers, each of which has a different arrangement angle. The three-dimensional braided cotton model is presented based on the laminated cotton model and the idea of three-dimensional braided composites. The model consists of cotton fiber bundles arranged according to the unit cell structure of a three-dimensional four-directional braided composite material. The fiber bundle has a circular section and the shape of the cross section remains unchanged along the axial direction.

In terms of model structure, the three-dimensional braided cotton model is closer to the actual situation of cotton than the existing laminated cotton model. The laminated cotton model is an entity, which is bonded together by multiple layers of single-layer panels at different angles. The laminated model is not perfect because it uses a two-dimensional laminated structure to describe a three-dimensional distribution of cotton fibers in a cotton ball. The three-dimensional braided cotton model takes into account the intertwining of fibers and has a certain gap. However, both the three-dimensional braided cotton model and the laminated cotton model does not consider the actual distribution of cottonseed. It uses the method of controlling node to constrain the center in the finite-element simulation and assumes the existence of cottonseed. By comparison, the three-dimensional braided cotton model is closer to the actual situation of the cotton in terms of structure. The structure of the laminated cotton model is shown in Figure 11a.

In terms of finite-element analysis, the stability of the three-dimensional braided cotton model is better than the laminated cotton model. When using the laminated cotton model for finite-element analysis, the state of the model is unstable. In different working conditions, finite-element analysis needs to be adjusted for specific situations. But when using the three-dimensional braided cotton



(a) The laminated cotton model structure



(b) Cotton and single serration finite element model

Figure 11. The structure of two cotton models. (a) The laminated cotton model structure. (b) Cotton and single serration finite-element model.

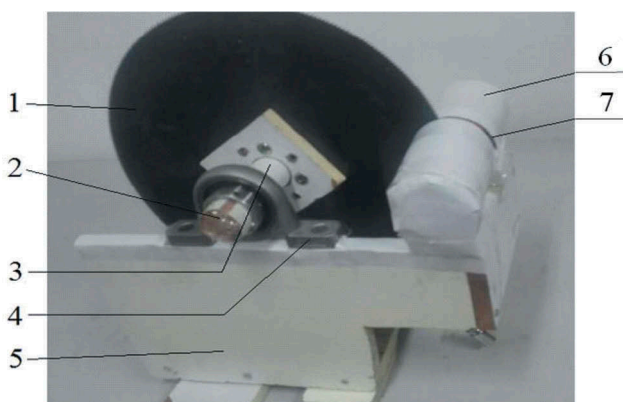


Figure 12. Ginning experiment device. 1—saw blade, 2—shaft, 3—axle sleeve, 4—roller bearing, 5—bracket, 6—cylinder, 7—cylinder gap.

model for different working conditions, the model state is relatively stable and the data changes are obvious.

Compared with the laminated cotton model, the three-dimensional braided model has a relatively obvious improvement. However, the actual structure of cotton is very complicated. The cotton fibers are randomly interlaced, their distribution is not regular, and the distribution of cottonseed is not known. Therefore, the model of cotton can be further studied and improved, and the model can be used in further practical application research.

Conclusions

Through the above analysis, the following conclusions can be drawn:

- (1) On the basis of the existing model of laminated cotton model and the idea of three-dimensional braided composite materials, a three-dimensional braided cotton model is proposed. Combining with ANSYS, the finite-element simulation on the three-dimensional braided cotton model successfully describes the working status in the ginning process. It obtains reasonable results and verifies the rationality of the model.
- (2) By simulating the effect of different moisture regain and speed on the ginning process, it can be concluded that when the moisture regain of the cotton is 8.5%, the effect of ginning is the most intense. The higher the speed of serration is, the more intense the effect of ginning is. However, the effect of cotton is also aggravated and the quality of cotton may be damaged to a certain extent. For the improvement of lint quality, the results of finite-element simulation have certain reference values for the selection of the ginning work conditions and the determination of parameters in the actual production.
- (3) Compared with the laminated cotton model, the three-dimensional braided model has a relatively obvious improvement in all aspects. However, the three-dimensional braided cotton model does not consider the distribution of cottonseed, which will be the focus of future research. The intertwining of cotton fibers is complex, and the connection between cottonseed and fibers is also complex. At present, there is no perfect model to reflect these two points at the same time. We will consider the connection between cottonseed and fibers on the basis of three-dimensional braided cotton model. The actual structure of cotton is very complicated. The cotton fibers are randomly interlaced and their distribution is not regular. Therefore, the model of cotton can be further studied and improved.

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