Based on Bionic Optimization Design and Strength Analysis of The Tie Rod of Aircraft Landing Gear

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Abstract. Based on the three-dimensional model of the cross-type tie rod in the landing gear of an aircraft, the mechanical analysis and solution are carried out, and the stress nephogram as well as the maximum position are obtained. Based on the analysis of bamboo microstructure, two kinds of imitated bamboo tie rod has been designed, one is the imitated bamboo without knots, the other is added knots. The three-dimensional modeling is carried out. The static analysis of finite element is carried out under the same working condition, and the stress nephogram and the position of the maximum value are obtained. The results of two kinds of simulated bamboo tie rod and cross-type tie rod are compared and analyzed. The results show that the mechanical properties of the whole simulated bamboo tie rod are superior to the cross-type tie rod.

1. Introduction

As one of the most important means of transportation, aircraft plays an irreplaceable role in human production and life, and landing gear is an indispensable structural part of aircraft. In the process of taking off and landing, the landing gear is a very important force bearing part. In addition, the gliding and turning on the ground are also completed by the landing gear. At the same time, with the improvement of aircraft performance, in addition to the more stringent requirements on the structural stress, strength and service life of the aircraft landing gear, the higher requirements on the weight of the aircraft landing gear are also put forward. Aiming at the research of landing gear optimization and lightweight, the landing gear of a UAV is optimized based on the structural topology optimization method according to Yang et al[1], and make the structure achieve better results. For the problem of strength analysis of landing gear, Yuzhen Chen et al[2]. Studied the static strength simulation analysis of landing gear axle; Xueyu He et al[3]. Carried out the static structural optimization of landing gear strut. Because the brake rod in the landing gear is the key stress component when the aircraft brakes on the ground, its strength and structure will also have a key impact on the landing of the aircraft. Therefore, the paper studies and analyzes the existing cross-type tie rod. By observing the microstructure of bamboo, a new type of brake rod with bamboo like microstructure is proposed and designed, and its strength is analyzed. It is compared with the cross-type tie rod.

2. Establishment and Static Analysis of Cross-type Tie Rod

2.1. Cross-type tie rod and its establishment of three-dimensional model

As the key part of the brake after landing, the tie rod is mainly affected by the tension, with slight bending moment and torque. At present, the shape of the brake tie rod in use is a symmetrical shape...
model with the cross section of the middle cylinder with ears on both sides. Through the analysis, it can be seen that the contact position of the tie rod in the work at the ear hole. In order to make the analysis result reflect the real situation, the bolt is installed in the ear hole of the tie rod, in order to apply loads and boundary conditions, CATIA 3D model as presented in figure 1.

2.2. Static analysis
Firstly, the established three-dimensional model is imported into the ANSYS Workbench to generate the finite element model, and then 10 node tetrahedral element is used for automatic mesh generation. The mesh model as presented in figure 2.

According to the imported model coordinates and the stress analysis of the tie rod, it is concluded that the three coordinates of the bolt at one end of the tie rod should be constrained. The tension applied by the bolt at the other end is 300KN, the bending moment is 8KN, and the force and torque applied at the bolt is 2200N·m. Due to the different height of the ribbed plate in the middle of the tie rod, there are two directions when the bending moment is loaded. As seen in figure 3, the load is perpendicular to the ear bolt axis, as case B, and parallel to the ear bolt axis, as case A. The material property is 30CrMnSiNi2A high strength alloy steel, the modulus of elasticity is 211 GPa, the Poisson's ratio is 0.3, and the density is 7850 Kg/m³.

2.3. Analysis results
According to the statics analysis and solution of the cross-type tie rod after loading under the working conditions, it is concluded that the maximum stress of the tie rod under both loading conditions occurs at the joint between the outer side of the cylindrical ear and the rib plate. As seen in figure 4, the maximum stress under the case A is dangerous.

3. Design and Static Analysis of Bionic Tie Rod

3.1. Microstructure analysis of bamboo
Bamboo skin is the material basis of bamboo’s excellent mechanical properties, in which there are many kinds of cells with different morphological structures. From the mechanical point of view, these
cells can be divided into two categories: one is the basic tissue cells, which are the thin-walled structure that plays the role of load transfer; the other is the thick walled cells mainly vascular bundles, which are surrounded by the basic tissue cells and play a bearing role. At the same time, there are a large number of thicker tubular cells in the vascular bundle, which greatly enhance the mechanical properties of bamboo. As presented in figure 5, the density of this kind of cells in the outer layer is the highest, and then gradually becomes low to near the endothelial layer and slightly increases\textsuperscript{[6-8]}.

![Figure 5. Microstructure of bamboo cross section](image)

### 3.2 Design and modeling of bionic tie rod
According to the research and analysis of bamboo microstructure and mechanical properties, the tie rod was redesigned. In order to improve the mechanical properties, the thick walled cells of vascular bundle with load-bearing function were transformed into stiffeners. The stiffener and the wall thickness are connected to realize the function of load transfer of basic tissue cells. On this basis, imitated bamboo tie rod without knots (see figure 6) and the imitated bamboo tie rod with knots (see figure 7) are designed.

![Figure 6. Cross section of imitated bamboo tie rod without knots](image)

![Figure 7. A model of imitated bamboo tie rod with knots](image)

### 3.3 Static analysis of bionic tie rod
The redesigned two kinds of imitated bamboo tie rod models are introduced into the ANSYS Workbench, and the finite element analysis and solution are carried out according to the same mesh division mode, boundary constraints and loads as the cross-type tie rod. The solution results are shown in figure 8 and 9. Among them, in the case A, two kinds of bamboo imitation rods have stress concentration at the inner edge of the ear hole. However, this place is not a dangerous area by analyzing, the dangerous area is located at the hollow end of the interior to meet the actual situation, as shown in the figure. Top right picture of 8 and 9.
Figure 8. Stress cloud of imitated bamboo tie rod without knots in two case (The case A is above and the case B is below)

Figure 9. Stress cloud of imitated bamboo tie rod with knots in two case (The case A is above and the case B is below)

4. Comparative Analysis of Results
According to the static analysis of the cross-type tie rod, the imitated bamboo tie rod with bamboo joint and the imitated bamboo tie rod without bamboo joint, the stress nephogram is obtained, as presented in figure 10. For the convenience of comparing the results, the data summary of the corresponding stress nephogram is shown in table 1.

Figure 10. Data comparison line chart (Stress Value in the left and Overall deformation Value in the right)

Table 1. Comparison of statics results between cross-type tie rod and imitated bamboo tie rod.

|                     | Cross-type tie rod | Imitated bamboo rod without knots | Imitated bamboo rod with knots |
|---------------------|--------------------|-----------------------------------|-------------------------------|
| Maximum stress value in case A/MPa | 4283.1             | 918.7                             | 895.03                        |
| Maximum Overall deformation in case A/mm | 16.438             | 5.8283                            | 5.7321                        |
| Maximum stress value in case B/MPa | 1691.9             | 932.36                            | 931.1                         |
| Maximum Overall deformation in case B/mm | 5.1933             | 4.8452                            | 4.7529                        |
| Overall Quality/Kg | 6.9408915          | 6.2899695                         | 6.6958145                    |
From Table 1, the structural quality of the two imitated bamboo tie rods is slightly lower than that of the cross-type rods, which achieves a certain degree of lightweight structure. In the case A, the maximum stress value and the maximum overall deformation value of the imitating bamboo tie rod have greatly decreased. Both the strength and stiffness of the imitating bamboo tie rod have significantly improved. Specifically, the imitating bamboo tie rod without knots has a maximum stress value of 78.55% lower than the cross-type tie rod in the dangerous area, and the overall resistance to deformation is increased by 64.54%. The imitating bamboo tie rod with knots has a maximum stress value of 79.10% lower than the cross-type tie rod in the dangerous area, and the overall resistance to deformation is increased by 65.13%. In the case B, the maximum stress value and the maximum overall deformation value of the imitating bamboo tie rods have also decreased significantly. Specifically, the imitating bamboo tie rod without knots has a maximum stress value of 44.89% lower than the cross-type tie rod in the dangerous area, and the overall resistance to deformation is increased by 6.70%. The imitating bamboo tie rod with knots has a maximum stress value of 44.97% lower than the cross-type tie rod in the dangerous area, and the overall resistance to deformation is increased by 8.48%. Compared with the imitating bamboo tie rod without knots, the imitating bamboo tie rod with knots was slightly improved, but the quality increased by 6.06%.

5. Conclusions
In this paper, the three-dimensional model of the cross-type tie rod in the landing gear brake system of an aircraft is established by using CATIA software. The static analysis is carried out in the ANSYS Workbench finite element analysis software, and the stress nephogram of the cross-type tie rod is obtained. According to the relationship between the excellent mechanical properties and microstructure of bamboo, the cross-type tie rod was redesigned. The imitated bamboo tie rods with and without knots are obtained, and the comparison between them is made. At the same time, their stress nephogram and the position of the maximum value are obtained. Through the comparative analysis of the cross-type tie rod and two kinds of imitated bamboo tie rods under the same working condition, it is concluded that both the strength and the rigidity are greatly improved under the working condition of the case A and the case B. In general, the mechanical properties of the two kinds of imitated bamboo tie rods are superior to those of the cross-type tie rods. The redesigned bionic tie rod has a high reference value for improving the quality and mechanical properties of the cross-type tie rod in the landing gear brake system of the aircraft.

6. References
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