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Research on a lightweight x-precision object multi-blade rotating shaft system

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Abstract
This research mainly develops a new X-precision cutting machine for high precision parts. In the equipment, by analyzing the displacement degree of the rotating shaft of the original cutter system, the maximum displacement is 0.012 mm. For this, CFRP (Carbon Fiber Reinforced Plastics) is added to the rotating shaft, which reduces the weight of the rotating shaft by 4.5 times compared with the original. However, from the static analysis results, it is found that the blade deformation and maximum stress are reduced by 4.814 times and 4.425 times respectively. The results show that if the same way is used for lightweight improvement in cutting high-precision objects, not only the processing efficiency of the equipment will be doubled, the power will be reduced, but also the service life will be increased.

Multiple blades; Rotating shaft system; CFRP; Lightweight

1. Introduction

The cutting and splitting machine is mainly made of wool. However, the control of processing allowance for wool products will greatly pull down the wave rate of raw materials. There are many researches on cutting machines by university teachers or enterprise personnel [1-2]. Frederik Birk et al. [3] proposed a unique method to use CFRP in hybrid watches erected by machine tools, with emphasis on improving dynamic behavior, increasing ratio and making it easier. Yu Y H et al. [4] designed a machine tool worktable filled with BFPC (basalt fiber polymer concrete). The sensitivity histogram and response surface of each parameter are obtained through optimization design. Finally, the optimal width and height of the rectangular hole of BFPC filling worktable are determined. Li P Z et al. [5] made a new improvement on the structure of the machine tool by using the topology optimization results. The results show that the flexibility of the optimized structure decreases. The first-third order natural frequencies are improved. The structural quality was reduced by 5.55%. Similarly, some authors have used topology optimization theory to carry out optimization research on machine tool components [6]. This paper mainly studies the lightweight of the blade rotating shaft system of the cutting machine. By changing the material of the rotating shaft, the displacement of the rotating shaft system are reduced and the cutting stability is improved. Thereby reducing the waste rate of raw materials.

2. Structural analysis of high precision cutting machine

According to the requirement of X-precision object processing shape, a multi-blade cutting machine is designed. As shown in figure 1.

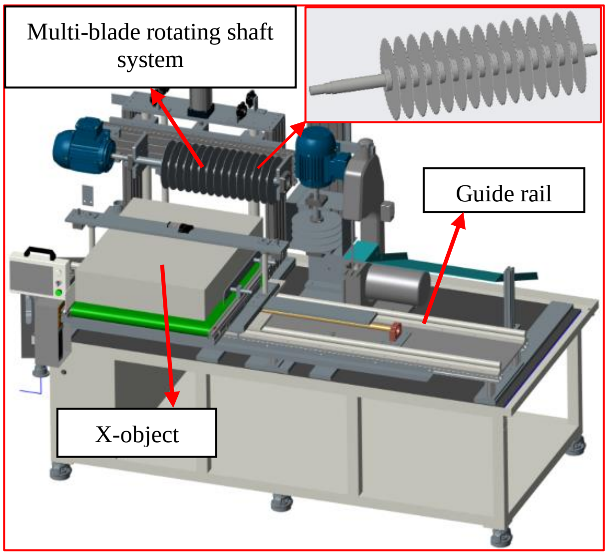


Figure 1. 3D Drawing of multi-blade cutting machine for X-precision objects.

According to figure 1, the rotating shaft system of the multi-blade mechanism is the main cutting component. Each blade and the rotating shaft are fixed by a brake. Rotation accuracy of rotating shaft and blade quality directly affect cutting accuracy. At the same time, it is considered that the cutting object may be liquid or solid. Therefore, the brake material is aluminum alloy, the rotating shaft is stainless steel, and the cutter is precision stainless steel.

3 Analysis of rotating shaft system of original blade.

In order to further obtain the comprehensive performance of the material collocation of the multi-blade rotating shaft system, ANSYS18.0 is used to simulate it. Because the blade rotating shaft system consists of blade, rotating shaft, chuck and many screws, it should be regarded as a whole in simulation. And parts such as screws are removed or the quality of the model is equivalent. Through grid division, boundary condition setting (limiting XYZ displacement of X precision object, setting different parts materials, setting the rotating shaft to rotate only around Y) and force application (given rotating speed is 1440r/min and torque is 2.2 N/m). Figure 2 is obtained. The simulation results are shown in figures 3, 4 and 5.

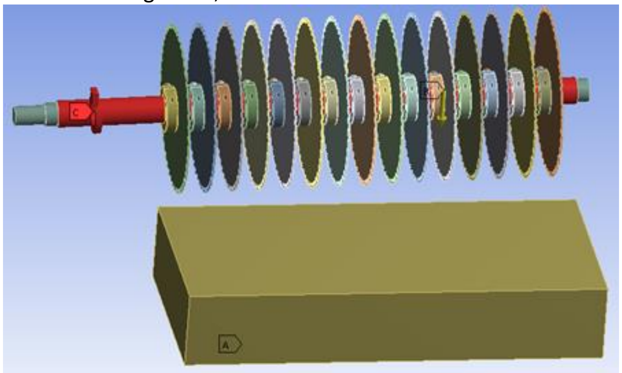


Figure 2. Boundary condition.

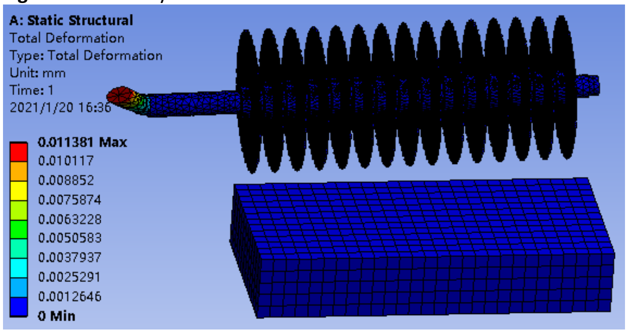


Figure 3. Maximum displacement.

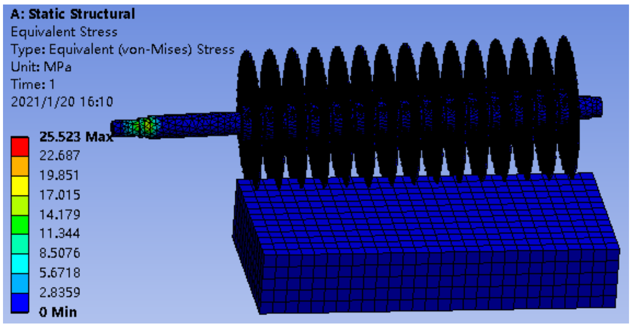
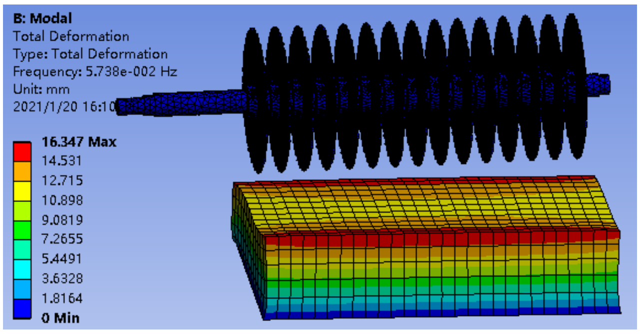
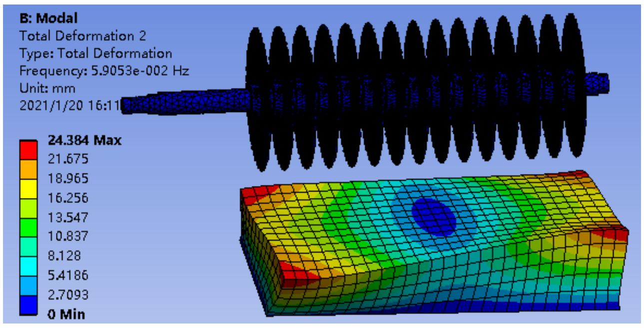


Figure 4. Maximum stress.



(A) First-order mode



(B) Second-order mode

Figure 5. The two modal.

As shown in figures 3, 4 and 5, the maximum displacement is 0.012 mm and the maximum stress is 25.52 MPa. At the same time, the first two modes are analyzed and obtained, and the first mode and the second mode are 5.738 e-002Hz and 5.9053 e-002Hz respectively. These values can basically meet the processing requirements. However, if more precise parts are processed, further optimization is needed. For this reason, the original structure and material are optimized, and CFRP is proposed to be applied to the rotating shaft system.

4 Comparative Analysis of CFRP Blade Rotating Shaft Structure

Through the above analysis, consider replacing the rotating shaft material. Replace the rotating shaft material with carbon fiber composite material. For this reason, combined with some previous studies, the sample stratification analysis of carbon fiber composites was carried out [7]. Carbon fibers and bisphenol A epoxy resin were blended in proportion to form the cross section of carbon fiber composites, such as figure 6. The yellow part was bisphenol A epoxy resin with a thickness of 0.62 mm. The black part was carbon fiber with a thickness of 0.45 mm. The carbon fiber composites are then heated and solidified as shown in figure 7. The temperature is 170 degrees and the heating time is 2 hours. Then the temperature is slowly cooled at room temperature. Then the lamination is homogeneous, as shown in figure 8. At the same time, load analysis of 100N, 500N, 1000N, 2000N and 5000N was carried out on the samples respectively, and the analysis results are shown in table 1.

Figure 6. Cross-section profiling of carbon fiber composites.

Figure 7. Heat solidification equipment for carbon.

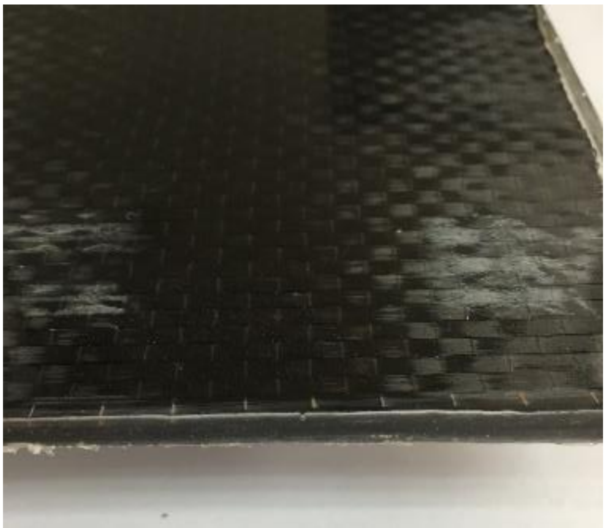


Figure 8. Sample completion of carbon fiber composites.

Table 1. Analysis results of CFRP samples bent in the same direction

Name / Variable	Displacement (mm)	Stress (MPa)	First order (Hz)	Second order (Hz)	Third order (Hz)	Fourth order (Hz)	Fifth order (Hz)	Sixth order (Hz)
100N	0.045837	150.1	131.6	216.6	493.23	848.61	999.51	1138.1
500N	0.22919	750.48	131.39	213.33	493.19	847.58	998.48	1137.8
1000N	0.45837	1501	131.06	208.95	493.13	846.17	997.07	1137.5
2000N	0.91675	3001.9	130.14	199.05	492.97	842.82	993.86	1136.7
5000N	2.2919	7504.8	126.17	155.77	492.31	832.35	979.41	1114.7

From table 1: When the sample is subjected to the same bending force in the same direction, the value of displacement and stress increases with the increase of load. In order to study the actual vibration frequency, we can analyze the first-order modal value. The first mode is when the excitation frequency of the external force is equal to the natural frequency of the object. The first mode of the object is called the first mode or the main mode of the vibration. So the first-order modal value decreases with the increase of load, which indicates that the vibration frequency in the experiment can not meet the requirement when the load is more and more large. Therefore, the result of such stratification is to meet the static requirements and can also be loaded into multiple rotating shafts. The analysis results are shown in figure 9 and 10.

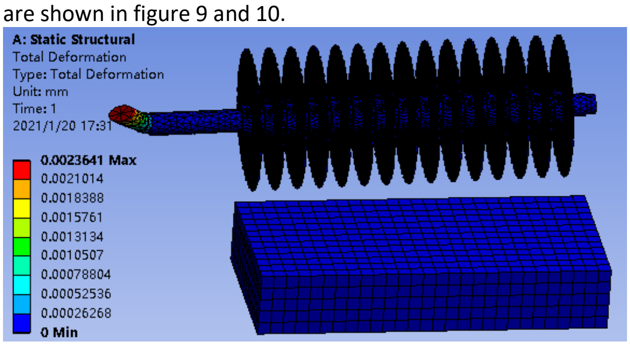


Figure 9 Maximum displacement of CFRP rotating shaft system.

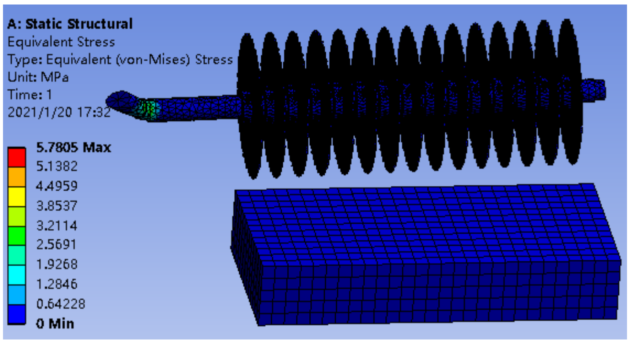


Figure 10 Maximum stress of CFRP rotating shaft system.

According to the analysis of figure 9 and 10, the maximum displacement and maximum stress are 0.002 mm and 5.78 MPa respectively, which are reduced by 4.81 times and 4.43 times. Through calculation, carbon fiber composite material is added to the rotating shaft, which reduces the weight of the rotating shaft by 4.5 times compared with the original. Such data greatly improve the machining accuracy and machining efficiency. For this reason, these data are used for multi-blade CFRP rotating shaft cutting machine processing and manufacturing. As shown in figure 11.

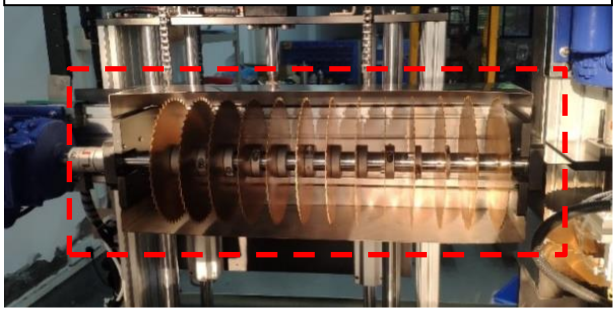


Figure 11 X-precision object multi-piece cutting machine.

5 Conclusion

This paper mainly studies the lightweight of the rotating shaft system in X precision object multi-blade cutting machine. Based on the analysis of the original structure, it is proposed to optimize the rotating shaft material by using carbon fiber composite materials. At the same time, the optimization results show that the maximum displacement and maximum stress are 0.002 mm and 5.78 Mpa respectively, which are reduced by 4.81 times and 4.43 times. Through calculation, carbon fiber composite material is added to the rotating shaft, which reduces the weight of the rotating shaft by 4.5 times compared with the original. This research method can be used in the future research of the rotation shaft. In the field of cutting, the waste rate of blank is reduced and the working efficiency is increased.

Acknowledgements

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