Design and research of a high speed small piezoelectric turntable

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Abstract. In order to achieve fast target locking and tracking in imaging system, a high-speed small piezoelectric turntable is designed. The piezoelectric turntable is driven directly by piezoelectric motor and has compact structure, which can realize high-speed rotation of imaging system. According to the index, the structure of piezoelectric turntable is designed, and the three-dimensional model is built by SolidWorks software. After simplifying the model, the finite element model is built by ANSYS software, and the static analysis of the turntable is carried out. Different materials were used to design the turntable, and their mass is compared. It is determined that the mass of the turntable with new materials is the lowest. The static analysis of the turntable with new materials shows that the designed turntable meets the design requirements of stiffness and strength, which provides a reference for the design optimization of similar turntables.

Keywords. Piezoelectric turntable; finite element analysis; static analysis.

1. Introduction
With the rapid development of information and communication technology in the new era, UAV plays a more and more important role in the field of reconnaissance because of its small size, flexibility and other advantages [1, 2]. The difficulty lies in enabling the imaging system to lock and track targets quickly, acquire key information and avoid detection by other detection devices in reconnaissance, which necessitates that UAV becomes smaller, and the imaging system can move quickly. Therefore, how to reduce the volume, reduce the mass and rotate the turntable with high speed has become a research hotspot.

A high-speed small piezoelectric turntable is designed to meet the requirements. It is driven directly by piezoelectric motors. It has compact structure and meets the function of fast action. The digital and finite element models of the designed turntable are established. Different materials were used to design the turntable, and their quality is compared. It is determined that the quality of the turntable with new materials is the lowest. The static characteristics of piezoelectric turntable with new materials are analyzed to verify whether the designed turntable meets the design requirements of stiffness and strength.

2. Design of high speed small piezoelectric turntable
The designed piezoelectric turntable mainly includes control board, connecting plate, frame of piezoelectric turntable, piezoelectric driving part and imaging sphere part. The piezoelectric turntable is
digitally modeled by SolidWorks software, and the shape structure of the turntable is obtained as shown in Fig. 1. The imaging sphere is the key part of piezoelectric turntable, which mainly includes azimuth axis gyroscope, pitch axis gyroscope, optical scanning camera equipment, optical measuring equipment and corresponding counterweight. The internal structure diagram of the piezoelectric turntable is shown in Fig. 2.

The piezoelectric turntable drives the imaging sphere simultaneously through four symmetrically arranged piezoelectric driving parts, so that the imaging sphere can rotate around the azimuth axis and pitch axis at the same time, which meets the design functional requirements of the piezoelectric turntable. Moreover, because four symmetrical piezoelectric driving parts are driven at the same time, the transmission link is reduced and the volume of the turntable is greatly reduced.

![Figure 1. Schematic diagram of piezoelectric turntable configuration.](image1)

![Figure 2. Schematic diagram of internal structure of piezoelectric turntable.](image2)

1-control panel 2-connecting plate 3-piezoelectric turntable frame 4-azimuth axis gyroscope 5-pitch axis weight 6-pitch axis gyroscope 7-infrared camera equipment 8-azimuth axis weight 9-pitch axis weight 10-pitch axis weight 11-measuring optical equipment 12-drive 13-imaging sphere part

3. Establishment of finite element model for high speed small piezoelectric turntable

3.1. Simplified model
In order to reduce the volume of piezoelectric turntable, small connection structures are designed between parts. These connection structures are relatively complicated, which will increase computing time. Therefore, the model is simplified in order to reduce the calculation time within the scope of
meeting the calculation accuracy requirements. The simplified model directly affects the results of calculation [3, 4]. The pins and circuits of the control board, chamfers, rounded corners and small holes are removed in the software, and the force-free parts such as gyroscope and counterweight block are simplified as a whole with the imaging sphere. The simplified model is obtained, as shown in Fig. 3.

![Schematic diagram of simplified model of piezoelectric turntable.](image)

3.2. Material selection
Aluminum alloy material is selected for the piezoelectric turntable, and the material of control board and connecting plate is kept unchanged after improvement. A new PLA material is used for the frame and imaging sphere of the piezoelectric turntable. The material parameters are shown in Table 1.

| number | Youngmodulus E/GPa | Poissonratio μ | Density $\rho/10^3$mm$^3$ |
|--------|---------------------|----------------|-----------------------------|
| AL-1   | 69.60               | 0.33           | 2.77                        |
| PLA    | 3.50                | 0.35           | 1.20                        |

The mass of piezoelectric turntable is calculated by software. The mass of piezoelectric turntable with PLA material and aluminium alloy in frame and imaging sphere parts is 0.092 kg and 0.137 kg respectively. The results show that the mass of piezoelectric turntable made of PLA material is 32.8% less than that of aluminium alloy.

3.3. Mesh generation
After the material is given to the model, the mesh is generated. Mesh generation is the premise of finite element analysis, and the quality of mesh generation will directly affect the accuracy of calculation results [5]. There are many methods of mesh generation, including tetrahedral mesh and hexahedral mesh. On this basis, the mesh size can be controlled and the mesh can be refined to change the quality of the mesh. Theoretically, the finer the mesh is, the more accurate the result will be. However, when the mesh is too small, the stress singularity will occur, so the refinement of the mesh should be moderate. An important parameter for evaluating mesh quality is the distortion of mesh. The smaller the distortion is, the better the mesh quality will be. Finally, the hexahedral mesh generation method is used to refine the mesh by controlling mesh size. The distortion is 0.46, as shown in Fig. 4.
4. Static analysis of high speed small piezoelectric turntable

Static analysis is the most commonly and widely used analysis method in engineering. Static analysis is also one of the most basic analysis of the characteristics of turntable [6, 7]. The piezoelectric turntable is subject to its own gravity during the flight of the aircraft, and is also affected by the centrifugal inertia force produced by the rotation of the imaging sphere at an angular velocity. In the static analysis of piezoelectric turntable, gravity is applied and 1.4 rad/s angular velocity is applied to the imaging sphere. The PLA material is given to the turntable, and the load diagram, deformation cloud diagram and stress cloud diagram of the piezoelectric turntable under stress are obtained by simulation as shown in Fig. 5 to Fig. 9, respectively.
Figure 6. Deformation diagram of turntable

Figure 7. Deformation diagram of turntable frame

Figure 8. Deformation diagram of imaging sphere
From Fig. 5 to Fig. 9, it can be seen that the total deformation and maximum stress of the piezoelectric turntable are 0.06 mm and 0.34 MPa respectively; the deformation is less than 1 mm, and the stiffness meets the design requirements; the maximum stress is far less than the allowable stress of the PLA material, which indicates that the strength of the piezoelectric turntable using PLA material meets the design requirements.

5. Conclusion
A high-speed small piezoelectric turntable is designed, which is driven by a piezoelectric motor to reduce the volume of the turntable. SolidWorks software is used to build three-dimensional model. Aluminum alloy and new PLA materials are used to compare the mass of turntable using two materials. The mass of turntable with new material PLA has been reduced by 32.8%.

The finite element model of high-speed small piezoelectric turntable is established. Static analysis of high-speed small piezoelectric turntable with new materials is carried out. The results show that the rigidity and strength of the designed high-speed small piezoelectric turntable meet the design requirements, which provides a reference for similar design.

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