Dynamic characteristic analysis of a high-speed small piezoelectric turntable

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Abstract. Fast motion of piezoelectric turntable is an important guarantee for fast target locking and tracking of imaging system. Vibration of piezoelectric turntable in fast motion will seriously affect imaging quality and even damage imaging system. Therefore, the three-dimensional model of high-speed small piezoelectric turntable is built by SolidWorks software, and the finite element model is established by ANSYS software to analyze the dynamic characteristics of the piezoelectric turntable. The natural frequencies and modal modes of the turntable are obtained by modal analysis. On this basis, the harmonic response analysis is carried out, and the amplitude-frequency characteristic curve of the piezoelectric platform is obtained. The analysis results show that the dynamic characteristics of the designed high-speed small piezoelectric turntable meet the design requirements, and there will be no resonance.

Keywords. Piezoelectric turntable, modal analysis, harmonic response analysis

1. Introduction
With the rapid development of information and communication technology in the new era, various airborne photoelectric turntables play an increasingly important role in the field of reconnaissance [1, 2]. The difficulty lies in enabling the imaging system to move quickly to lock and track targets, acquire key information, and avoid the detection of other detection devices. Therefore, how to reduce the volume and mass of the airborne photoelectric turntable with imaging system, and how to rotate at 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, and the dynamic characteristics are analyzed. The natural frequencies and modal modes of the turntable are obtained by modal analysis. On this basis, the harmonic response analysis is carried out, and the amplitude-frequency characteristic curve of the piezoelectric platform is obtained. The analysis results show that the dynamic characteristics of the designed high-speed small piezoelectric turntable meet the design requirements, and there will be no resonance.

2. Design of high speed small piezoelectric turntable
The piezoelectric turntable mainly includes control board, connecting plate, frame of piezoelectric turntable, piezoelectric driving part and imaging sphere part. The imaging sphere part is the key part of
the piezoelectric turntable, which integrates optical scanning camera and optical measurement equipment. SolidWorks software is used to build the three-dimensional digital model of piezoelectric turntable, and the shape and structure of piezoelectric turntable is obtained as shown in Fig. 1.

**Figure 1.** Schematic diagram of piezoelectric turntable configuration.

3. Dynamic characteristics analysis of high speed small piezoelectric turntable

3.1. Establishment of finite element model

In order to satisfy the requirement of calculation accuracy and moderate calculation time, it is necessary to simplify the model of piezoelectric turntable. In the software, the pins and circuits of the control board, chamfers, rounded corners and small holes are removed, and the parts without force such as gyroscope and counterweight block are simplified as a whole with the imaging sphere. The simplified model is obtained to ensure the better meshing quality [3, 4]. The resulting simplified model is shown in Fig. 2.

**Figure 2.** Schematic diagram of simplified model of piezoelectric turntable.

Aluminum alloy material is selected for the frame of piezoelectric turntable, PLA material is selected for the rest, and the material parameters are shown in Table 1.

| number | Youngmodulus E/GPa | Poissonratio μ | Density ρ/10^3mm³ |
|--------|--------------------|----------------|-------------------|
| AL-1   | 69.60              | 0.33           | 2.77              |
| PLA    | 3.50               | 0.35           | 1.20              |

Table 1. Parameters of the selected material.
After the material is given to the model, the mesh is generated. Finally, this paper uses the hexahedral mesh generation method, and fines the mesh by controlling the mesh size. The distortion is 0.46, as shown in Fig. 3.

![Hexahedral mesh generation method](image1)

![Mesh quality details](image2)

**Figure 3.** Hexahedral mesh generation method and the quality of the mesh.

### 3.2. Modal analysis

Modal analysis is the most basic dynamic characteristic analysis and the basis of other dynamic characteristics analysis. The natural frequency and mode shape of the structure can be determined by the modal analysis results, thus avoiding the resonance of the designed structure [5,6]. Fixing the connecting plate, the piezoelectric turntable modal is analyzed. The first six modes are obtained as shown in Fig. 4.

![First-order mode diagram](image3)

![Second-order mode diagram](image4)

(a)First-order mode diagram  (b)Second-order mode diagram
The results of modal analysis show that the first natural frequency of the piezoelectric turntable is 215.68 Hz. The working frequency of the main components of the piezoelectric turntable is generally between 80-160 Hz, which is also the environmental frequency range concerned in the design of the turntable. The frequencies of all modes of piezoelectric turntable are higher than those of environment, and resonance will not occur when it works, which shows that it meets the design requirements.

3.3. Harmonic response analysis
Harmonic response analysis is a kind of analysis in time domain. It can analyze the response of the structure under harmonic loads of different frequencies, so as to analyze the rigidity and strength of the structure [7, 8].

According to the classical mechanics theory, the dynamic model of the system is as follows:

\[
[M] \{\ddot{X}\} + [C] \{\dot{X}\} + [K] \{X\} = F_0 \sin(\theta t) \tag{1}
\]

The displacement response can be obtained as follows:
\[ |x| = |A| \sin (\theta t + \varphi) \]  

(2)

A 10N load is applied to the imaging sphere, and the frequency range is 0-1200 Hz. The harmonic response of the piezoelectric turntable is analyzed, and the amplitude-frequency characteristic curve of the frame of the piezoelectric turntable is obtained, as shown in Fig. 5.

Figure 5. Amplitude-frequency characteristic curve of piezoelectric turntable frame.

From the figure, it can be seen that the first resonance of the piezoelectric turntable occurs near 210 Hz, the deformation is 0.33 mm, which is basically consistent with the results of the modal analysis, and it can be seen that the turntable does not have resonance in the environmental frequency, and the displacement response meets the design requirements.

4. Conclusion

(1) The three-dimensional model of high-speed small piezoelectric turntable is built and the finite element model is established. The natural frequencies of the first to sixth order modes of the piezoelectric turntable are obtained by modal analysis. The results show that the first order natural frequencies of the piezoelectric turntable are much larger than its environmental frequencies, and there is no resonance, which meets the design requirements.

(2) Harmonic response analysis of high-speed small piezoelectric turntable is carried out, and the amplitude-frequency characteristic curve of the frame of the piezoelectric turntable is obtained, which corresponds to the modal analysis results. It shows that the piezoelectric turntable will not resonate in the environmental frequency, and the displacement response meets the design requirements.

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