Multi-body dynamics analysis of a small piezoelectric turntable with high speed

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Abstract. Piezoelectric turntable is a new type of real-time image reconnaissance equipment. The fast movement of piezoelectric turntable is an important guarantee for fast target locking and tracking of imaging system. Therefore, the multi-body dynamic analysis of the piezoelectric turntable designed by virtual prototyping technology is needed to verify whether its function meets the requirements. SolidWorks software is used to build a three-dimensional model of a high-speed small piezoelectric turntable. Then, the three-dimensional model of piezoelectric turntable is simplified and introduced into Adams software for multi-body dynamics analysis. The analysis results show that the piezoelectric turntable can rotate around the azimuth axis and pitch axis at high speed, which meets the design requirements. The virtual prototyping technology improves the design efficiency and provides a theoretical basis for the design of similar turntables.

Key words. piezoelectric turntable, virtual prototype, multibody dynamics analysis

1. Introduction
With the rapid development of information and communication technology in the new era, people pay more attention to the acquisition of information. Piezoelectric turntable has attracted the attention of many researchers because of its small size and low cost. It has become a new type of real-time image detection equipment, which is widely used in the fields of investigation, search and rescue, surveying and mapping [1,2]. Fast motion of piezoelectric turntable is an important guarantee for fast target locking and tracking of imaging system. With the development of virtual prototyping technology, how to verify whether the structural motion can meet the requirements at the design stage has become a research hotspot.

Therefore, a three-dimensional model of a high-speed small piezoelectric turntable is built by using SolidWorks software in this paper. Then the three-dimensional model of the piezoelectric turntable is simplified and introduced into Adams software for multi-body dynamics analysis to verify whether the piezoelectric turntable can satisfy the function. The analysis results show that the piezoelectric turntable can rotate around the azimuth axis and pitch axis at high speed, which meets the design requirements.

2. Design of high speed small piezoelectric turntable
The piezoelectric turntable mainly consists of 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.](image)

3. Multi-body dynamics analysis of high-speed small piezoelectric turntable

3.1. Model simplification
In order to make the results of Adams simulation more accurate, it is necessary to simplify the model of piezoelectric turntable. In the software, the pins and circuits of the control board are deleted, and the fixed parts such as gyroscope and counterweight block are simplified as a whole with the imaging sphere. The simplified model is obtained to facilitate the addition of constraints and reduce the complexity of the analysis [3,4]. The resulting simplified model is shown in Fig. 2.

![Figure 2. Schematic diagram of simplified model of piezoelectric turntable.](image)

3.2. Multibody dynamics analysis
The simplified piezoelectric turntable is imported into Adams software, and the correctness of the model is verified. Then a series of pretreatments of the model are carried out [5,6]. Firstly, the quality attributes are given to each part of the model. Among them, the aluminium alloy material is chosen for the piezoelectric turntable frame, and the density is 2.77 *10^3 g/mm^3. The PLA material is chosen for the rest, and the density is 1.2 *10^3 g/mm^3. In order to distinguish assembly and motion relations conveniently, different coloring is needed for each part [7]. Constraints and corresponding motion pairs are added between parts. Fixed constraints are added to the control board, connection board, piezoelectric turntable frame and ground, relatively fixed constraints are added between the imaging spheres, and corresponding pairs are added to the four piezoelectric parts and the imaging sphere parts, respectively, as shown in Fig. 3.
3.3. Analysis of simulation results

(1) The simulation of a piezoelectric turntable rotating independently around the pitch axis is carried out. The motion state diagram of the imaging sphere rotating around the pitch axis ± 60 degrees is shown in Fig. 4, the velocity detection diagram is shown in Fig. 5, and the force diagram of the contact point between the driving foot and the driven sphere is shown in Fig. 6.

(a) Initial state diagram of sphere rotation around pitch axis

(b) Motion state diagram of sphere rotating around pitch axis + 60 degrees

(c) Motion state diagram of a sphere rotating - 60 degrees around the pitch axis

Figure 4. Rotation of imaging sphere around pitch axis.
The analysis shows that the imaging sphere of a piezoelectric turntable can rotate around the pitch axis ± 60 degrees independently, which meets the design requirements.

(2) A piezoelectric turntable is simulated to rotate around both pitch and azimuth axes. The motion state diagram of the imaging sphere rotating 60 degrees around the azimuth axis and pitch axis at the same time is shown in Fig. 7, the velocity detection diagram is shown in Fig. 8, and the contact force diagram is shown in Fig. 9.
Figure 7. Compound rotation diagram of imaging sphere.

Figure 8. Compound rotation velocity detection diagram of imaging sphere.

Figure 9. Stress diagram of compound rotating contact point of imaging sphere.
From the analysis of Fig. 7 to Fig. 9, it can be concluded that the imaging sphere of a piezoelectric turntable can rotate around the pitch axis and the azimuth axis at the same time, which meets the functional design requirements.

4. Conclusion
The three-dimensional model of high-speed small piezoelectric turntable is built, and the model is simplified by using virtual prototyping technology and then imported into software Adams for multi-body dynamics analysis. The analysis results show that the imaging sphere of the high-speed small piezoelectric turntable can rotate independently around the azimuth axis and the pitch axis, as well as around the azimuth axis and the pitch axis at the same time, which meets the design requirements.

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