

Characteristic Study of Large Torque Micro-Nano Platform Based on Piezoelectric Stack

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Abstract. With the development of precision engineering and precision instruments, the micro-nano platform becomes the important carrier in the precision positioning technology, which provides large torque and high precision. The platform's performance is tested by using laser displacement meter. Four kinds of testing are applied in this paper, including static displacement output test, repeated precision test, stability test, and dynamic state characteristic test. The testing data shows that the micro-nano platform can provide large output displacement stably and quickly, and it has very strong practicality. In the same time, the testing conclusions show the bad influence from the hysteresis and creep deformation of piezoelectric material and mechanism. So the closed-loop control is used to control the platform, and the control result shows the closed-loop control reduce the influence of creep deformation, but it is acquired by sacrificing the quickly response. The conclusion shows that the next step is necessary to research the drive and control of this platform for amplifying its practicability in the future.

1. Introduction

Piezoelectric ceramic actuator is widely used in micro-nano positioning system. However, piezoelectric actuator also has a small displacement, hysteresis, non-linear, creep and other shortcomings [1]. In order to enlarge the displacement, which is currently enlarged by using hinge form [2~4], but the output torque decreases. In order to solve this problem, an amplification mechanism based on piezoelectric stack and triangular amplification principle is designed to realize the driving of micro-nano positioning system. And on the basis of this theory, a kind of micro-nano platform is designed, which not only owns higher displacement accuracy and output torque, but also owns larger output displacement. This paper uses the various test method on the micro-nano platform to study its practicality.

2. Structure and Principle of Large Torque Micro-Nano Platform based on Piezoelectric Stack

The micro-nano platform composed of piezoelectric stack and triangular amplification principle is shown in Fig.1. (1,1': Piezoelectric stack, 2,2': stack Amplifying mechanism; 3: platform; 4,4': Fixed hinge; 5,5': Connected hinges; 6,6': Auxiliary hinge). The working principle of this micro-nano platform is that the amplification mechanism deforms after applying the forward voltage on the piezoelectric stack, the deformation produced by the magnifying mechanism is realized by connecting the hinge to drive the platform to realize the corresponding displacement, when one end of the magnifying mechanism is fixed to the platen by a fixed hinge. The auxiliary hinge only assists the platform in moving smoothly and evenly.

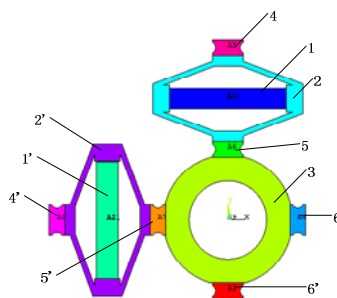


Fig.1 The structure diagram of micro-nano platform

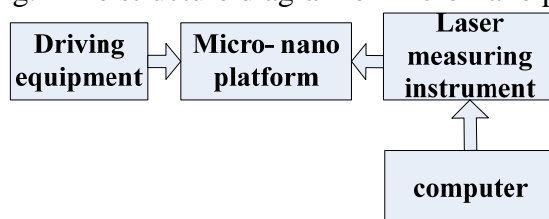


Fig.2 The system diagram of laser tester about micro-nano platform

3. Experimental Measurement of the Characteristics of the Large Torque Micro-Nano Platform based on the Piezoelectric Stack

In order to study the work characteristics of the micro-nano platform in this paper, the static and dynamic testing of the platform is carried out by using the high speed and high precision laser testing.

3.1 Experimental Testing Device and Method

The system diagram of this test is shown in Figure 2. In order to test the micro-nano platform, firstly a positive voltage is applied to the piezoelectric stack in the micro-nano amplification mechanism through a waveform generator and a power amplifier to make it output the corresponding displacement. Secondly, the displacement of the micro-nano platform was measured by a laser tester connected with a computer.

The test system consists of signal generator that is AFG320 Tektronix, oscilloscope that is Tektronix TDS1012, power amplifier that is Japan NF high speed quad quadrant broadband bipolar power amplifier HSA4052, laser tester that is KEYENCE high-speed high-precision laser displacement sensor (LK-H020 sensor, LK-HD 500 controller, MS2_H50 source).

3.2 Test Results Analysis

Due to the symmetrical structure of the micro - nano platform, the following test system is used to test and analyze one direction of the existing micro-nano platform from two aspects: static and dynamic.

Static Displacement Output Test

In the test, the voltage of a piezoelectric stack is applied in the case of fixed hinge fixing, and then the corresponding displacement of the platform is tested by the laser tester. Drive voltage range is 0~100V. At the first, the voltage gradually rises from 0V to 100V, and then gradually reduce the voltage to zero. Every 5V record a displacement. After repeated testing, data collection and processing, the voltage displacement curve of the platform is obtained as shown in Figure 3.

It can be seen from the experimental data that the displacement output characteristic of this platform is better. In the input voltage 100V, the output displacement can reach about 63μm and basically is a linear state, which can meet the requirements of the use. However, affected by the hysteresis characteristics of the piezoelectric materials, the micro-nano platform also has a typical hysteresis phenomenon, and this phenomenon will limit the accuracy of positioning.

Repeat Accuracy Test

Repeat accuracy test is used to test the platform to determine whether multiple sets of test data are the same under the same voltage. In the process of applying voltage, every 15V takes one point, a

total of 8 points. Carry out 5 times repeated positive pressure zero test, record the displacement of each voltage point, and the displacement curve is shown in Figure 4.

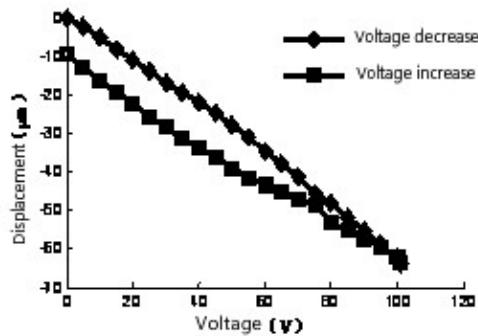


Figure 3. Static displacement output curve
Stability Test

Stability test is used to test the creep property of micro-nano platform. During the test, take 7 kinds of voltage value. After applying a certain voltage, every 30s record the corresponding displacement of the platform, and the displacement characteristic curve is shown in Figure 5. From the experimental data, the stability of the micro-nano platform is very good. However the creep properties also exist at the same time (especially in the full 50s of power).

Dynamic Characteristic Test

Dynamic characteristic test is used to test the response speed of the platform. In the test, different step voltage signals are applied to the piezoelectric stack in the platform to test the displacement with the change of time. After the step voltage of 50V are applied respectively, the displacement time curve of the platform is shown in Figure 11.

From the experimental data, the platform achieves the corresponding displacement in a short time ($<0.08s$), and then the platform achieves stability after a short period of time ($<0.4s$) of the small fluctuations. Therefore, this platform has a better step response characteristic.

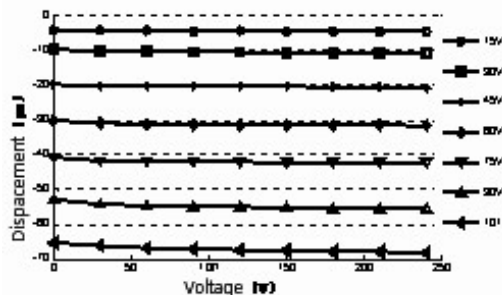


Figure 5. Stability test curve

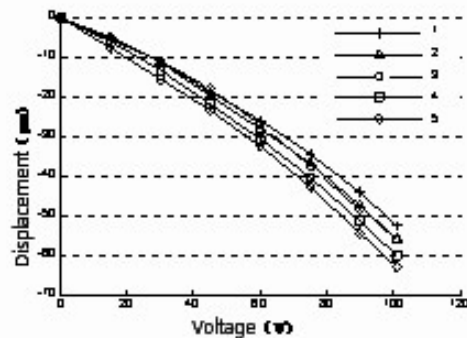


Figure 4. The test curve of the precision

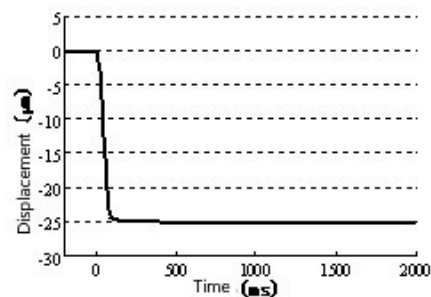


Figure 6. Dynamic characteristic test curve

4. PID Closed Loop Control

The above research shows that the platform has better response characteristics. But there are inevitable lag and creep characteristics, which need to use a certain way to eliminate their impact. In order to achieve the requirements to improve its stability and repeatability. The paper based on the LabVIEW platform uses the incremental PID control principle to realize the closed-loop control of the platform. The control system composition diagram is shown in Figure 7. The test results are shown in figure 8.

From the results, it can be known that using closed-loop control can effectively improve the Creep property, but this control method sacrifices the quick reaction, and needs to be further improved.

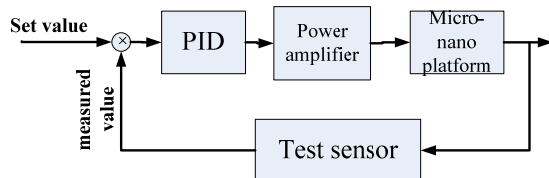


Figure 7. The composition of PID closed loop control system

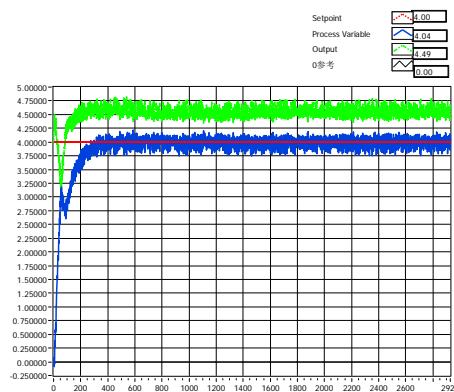


Figure 8. Test results

5. Conclusion

In this paper, we design and manufacture a micro-nano platform with a high torque by using the principle of piezoelectric stack and triangular amplification. The characteristics of this platform are tested by means of laser testing. By static displacement output test, repeated precision test, stability test and dynamic characteristic test, it can be seen that the micro-nano platform can stably and quickly output large displacement, and has strong practicability. However, in performance testing, the ineluctable hysteresis and creep characteristics of piezoelectric materials also bring some influence to the application of this platform. At the same time, using LabVIEW to carry on the close-loop control on the platform can be regard as effectively improving its creep characteristic. But the method also sacrifices its certain fast response characteristics. In the subsequent use of the process, the further analysis research is needed to conduct in drive control to reduce the impact of adverse factors, and further improve the platform practicality.

References

- [1]. SUN Bao-yu. Experimental Research on Dynamic Charateristic of Flexible Micro-displacement Mechanism Based on Piezoelectric Actuator[J]. Micro Fabrication Technology, 2008(2): 33-36.
- [2]. DU Xi-bo, CHEN Xi-ping, ZHANG Bin, et al. Design and Analysis of Micro-displacement Mechanism for Motion Position with Piezo-actuator Based on Triangle Prinple[J]. Aviation Precision Manufacturing Technology, 2009(6): 10-12.
- [3]. LIU Deng-yun, YANG Zhi-gang, CHENG Guang-ming, ZENG Ping. Study on a Micro-displacement Magnifying Mechanism Used on Piezo-stack Pump[J]. Machinery & Electronics, 2007, 3:75-77.
- [4]. Li Wanquan, Gao Changyin. Design and Modeling of Micro-displacement Amplifying Mechanism Using Revolute Joints and Flexible Hinges[C]. 2010 International Conference on Intelligent Computation Technology and Automation, 2010:1147~1150.