능동보정 압전소자 스테이지를 이용한 마이크로 밀링가공
Micro-milling with Active Piezoelectric Stage Error Compensator

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1. Introduction

The need for high-precision parts has recently become an important concern in the manufacturing industry. Such a machine is required to provide versatility, speed and workspace as well as high precision positioning [1]. The most common and popular drive system used in a machine tool is the linear stage system. Linear stages have several limitations such as transmission errors, dead zone, backlash, elasticity, large inertia and wear [2].

Positioning systems based on piezoelectric materials have received increased attention in many high-precision applications [1]. They have advantages that include: unlimited resolution, large force, fast expansion and no magnetic effects [3]. The disadvantages of piezoelectric actuators are their short travel range, hysteresis and creep.

The main goal of micro-milling with active piezoelectric error compensator in this work was to obtain overall system that has the travel range of linear stage and the accuracy of piezoelectric actuators which leads to improvements in machining results.

2. Experimental Setup

A piezoelectric stage with flexure-hinge-type lever mechanism was designed to increase the error compensation range. Piezoelectric actuators used in the stage were PI-830.20 made by Physik Instrumente. They had a travel range of 30 µm and a 1000 N pushing force with a voltage range of 0 to 100 V. The piezoelectric stage deformation simulations are shown in Fig. 1 and Fig. 2. With the help of the lever mechanism, simulation shows the maximum travel ranges of the piezoelectric stage become 106.90 µm and 84.85 µm for the *x*- and *y*- axes, respectively.

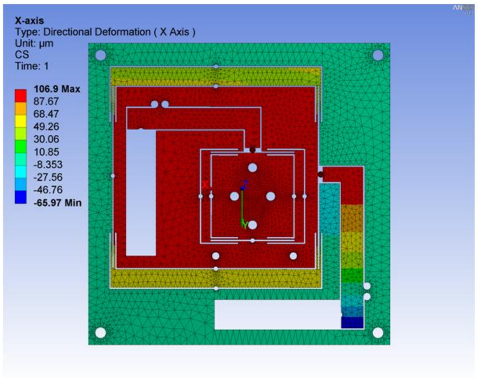

Fig. 1 Piezoelectric stage simulation for *x*-axis

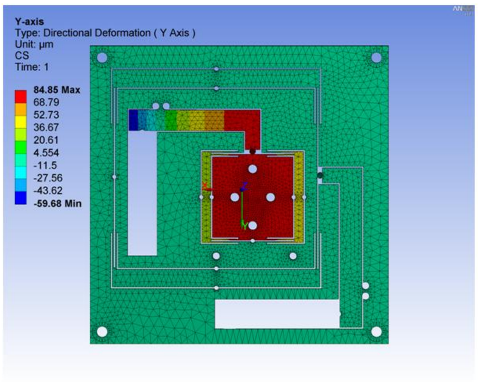

Fig. 2 Piezoelectric stage simulation for *y*-axis

A standard 3-axis milling machine was modified by stacking the piezoelectric stage on top of the *x*-*y* (horizontal) working table, as shown in Fig. 3. The linear stages used 50000 pulse/rev step motor, 8 mm ball screw lead and 0.1 µm linear encoder feedbacks. The piezoelectric stage used 0.05 µm resolution linear encoders as a feedback for each *x*- and *y*-axis. A 2-D grid encoder with 0.1 µm resolution monitored the positioning error of the overall system.

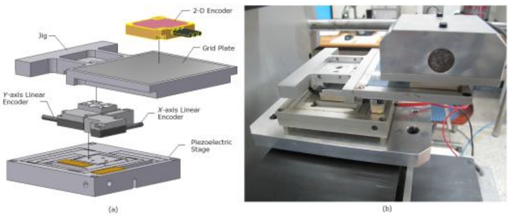

Fig. 3 Experimental setup; (a) sensor arrangement; (b) assembly on the milling machine

3. Control Strategy

The piezoelectric stage works as an error compensator for the linear stage which made the command for the piezoelectric stage is a deviation from commanded position and actual position of linear stage. The linear stage was controlled by PID (proportional-integral-derivative) controller, the piezoelectric stage was controlled by PI (proportional-integral) controller and the resulting control block diagram for the overall system is shown in Fig. 4.

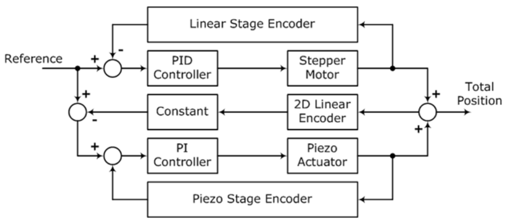

Fig. 4 Overall system control block diagram

4. Experiments on the Milling Machine

In our system we used x- and y-axes to generate circular motion in *x-y* plane. The interpolation command generated in the controller was to generate a circular motion with radius of 1 mm at 500 µm/s constant speed. Experimental results for circular motion with and without error compensation are shown on the commanded and actual position graph as shown on the next figures:

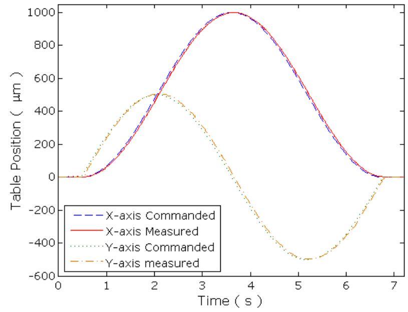

Fig. 5 Positioning graph without error compensation

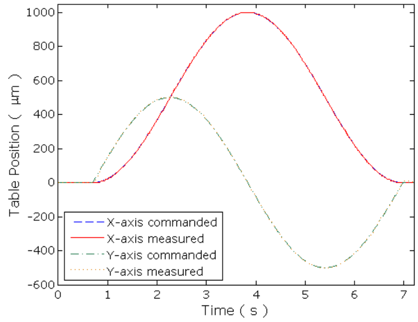

Fig. 6 Positioning graph with error compensation

5. Conclusion

There were significant improvements in machine accuracy by implementing active error compensation. The results were ensured by performing positioning performance experiments. Therefore, this technique can be applied to develop high-precision positioning in the manufacturing and machining systems.

References

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