대면적 미세가공을 위한 고주파 Fast Tool Servo 개발
High Frequency Fast Tool Servo Developed for Large Area Micro Feature Machining

*여굉[1], 이승준[2], 이상민[1], 하양협[3], 박천홍[4], #이득우[5]
*Hong Lu[1], S. J. Lee[2], S. M. Lee[1] , Y. H. Ha[3], C. H. Park[4], #D. W. Lee(dwoolee@pusan.ac.kr)[5]
[1]한국대 나노융합기술학과, [2]부산대 천단정밀공학과, [3]부산대 정밀기계공학과,[4]한국기계연구원,[5]부산대 나노메카트로닉스공학과

Key words : Fast tool servo, piezoelectric actuator, frequency response

1. Introduction

The fast tool servo (FTS) technique is applied widely in the field of precise manufacturing, thus generating non-axisymmetric surface, manufacturing metal moulds for light enhancing films or correcting for errors. Flexure hinges are implemented in the structure of these micro-positioning stages to offer a FTS system with no backlash, negligible friction, no lubrication and free of thermal heat generation. Therefore, PZT-driven micro positioning stages represent the best choice to provide precision feed capability and compensate for ultra precision FTS machining. The stroke range of a stacked piezoelectric actuator is proportional to the number of stacked ceramic elements (or the length of the actuator). Utilizing an actuator to produce a desired large output range requires the use of a long (or big volume) actuator which could interfere with a tight workspace.

Nowadays, a significant amount of research effort has been directed towards FTS design. T. A. Dow et al [1] designed a FTS utilized a piezoelectric ring type attack actuator (25 mm OD, 18 mm long, 20 µm free stroke) and a pair of high-bandwidth capacitive sensor. Their unit produced approximately 5 µm of full stroke at 1 kHz with a usable bandwidth of over 2 kHz. This research also revealed that the dynamic thrust forces caused by cutting had little effect on the quality of the finished surface. O. Sosnicki et al [2] published the design for a FTS of 86 µm strokes, 600 Hz bandwidth, and 2% error using piezoelectric actuator. Rasmussen et al [3] reported a piezo-driven cutting tool system, which can produce 52 µm of stroke with a bandwidth of 200 Hz. Tool motion error less than 0.5 µm was achieved using a repetitive controller. Most of these FTS, which are designed for special machine tools and special tasks, do not satisfy our demands for machining microstructure surface. It is because these FTS only can provide either long stroke with low driving frequency (< 1 kHz) or high bandwidth with small travel range (< 10 µm).

This paper presents the design and test of a high frequency FTS, which used a set of leafspring to transform the extension and shrink of the piezoelectric actuator to the diamond tool. The two kinds of the materials were used to the leafspring, aluminum alloy and steel respectively. According to the finite element analysis, the stiffness of the leafspring witch was made by steel is greater than that was made by aluminum alloy. And the two material leafsprings provide the similar first nature frequency. The test results point out that the steel leafspring can provide greater first nature frequency than the aluminum leafspring, and output displacement can reach up to 12.1 µm with the driving frequency of 2000 Hz.

2. Experiments and Discussions

Two kinds of leafspring were shown in the Fig. 1, steel and aluminium respectively. To evaluate the performance of the FTS, a series of tests are carried

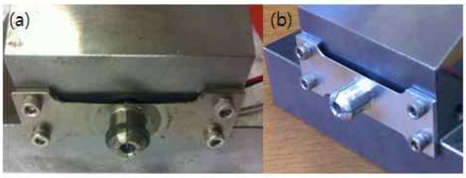

Fig. 1 Leafspring of FTS made by different materials (a) steel, (b) aluminum

out. A capacitance displacement sensor is used for position measurement. Typically, the displacement signal ranges from -250 μm to +250 μm with a resolution of about 2.9 nm. Also, the bandwidth of the capacitive displacement sensor is set at 5 kHz, considering the maximum frequency required for fast tracking performance of the FTS. The piezoelectric actuator, can generate displacement of up to 30 μm, has an axial stiffness of 68 N/μm and can deliver a maximum driving force of 2100 N, is preload by a bolt that mounted to the main body of the FTS. And the high voltage amplifier provides the complete voltage range from +3 to +1100 V with an average output power amounting to 110 W. It is capable of supplying a maximum peak output current of 500 mA for fast expansion of the piezoelectric actuator that behaves like a capacitive load. The labview software is used to analysis the data. From the experimental data, it is noted that the primary natural frequency of FTS is greater than 2500 Hz, as shown in Fig. 2.

The response of FTS for a command input signal of 50 V, 150 V, 250 V voltages respectively and a 50 Hz sinusoidal frequency is illustrated in Fig. 3. Through the feedback of the signal from the capacitive displacement sensor, the end tip of the tool holder in the FTS is made to follow the command sinusoidal signal more accurately. It is indicated that the response is good over a wide amplitude range without any gain change or stick-slip behavior.

3. Conclusions

Utilizing a piezoelectric actuator and flexure leafspring guide mechanism, a novel FTS used for machining microstructure surface is developed. The test results point out that the steel leafspring can provide

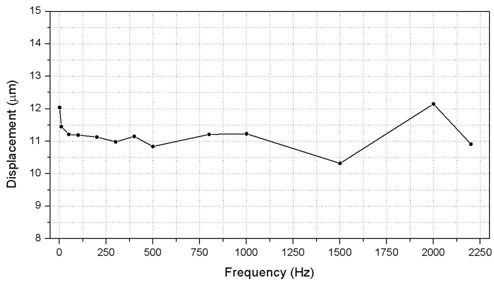

Fig. 2 Frequency response of the FTS

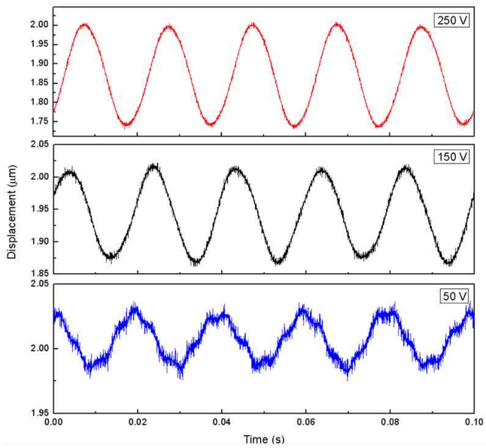

Fig. 3 Sinusoidal response (open loop) of the FTS

greater first nature frequency than the aluminum leafspring, and the output displacement can reach up to 12.1 μm with the driving frequency of 2000 Hz.

Acknowledgement

This work was supported by NCRC (National Core Research Center) program of the Ministry of Education, Science and Technology (2010-0008-277) and "Development of Micro Feature Machining System on Large Surface and Core Technologies for Measurement & Inspection" project of ministry of knowledge economy.

Reference

1. T. A. Dow, M. H. Miller, P. J. Falter, "Application of a fast tool servo for diamond turning of nonrotationally symmetric surface," Precision Engineering, 13 (4) 243-250, 1991.
2. O. Sosnicki, A. Pages, C. Pacheco, T. Maillard, "Servo piezo tool SPT400MML for the fast and precise machining of free forms," International Journal of Machine Tool & Manufacture, 47, 903-910, 2010.
3. J. D. Rasmussen, T. C. Tsao, R. D.Hanson, S. G. Kapoor, "Dynamic variable depth of cut machining using piezoelectric actuator," International Journal of Machine Tool & Manufacture, 34 (3), 379-392, 1994.