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Implementation and Experiment of an Active Vibration Reduction Strategy for Macro-Micro Positioning System

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Highlights

- We focus on the stage with high-speed, large-stroke with high positioning accuracy.
- An adaptive vibration reduction action method for a macro-micro stage is proposed.
- The start-up condition and extension of the piezoelectric device are finalized.
- The stage settling time is greatly reduced without sacrificing positioning accuracy.

Abstract—In microelectronics manufacturing, the macro-micro precision positioning system is often utilized to achieve a high-precision positioning motion with high-velocity and large-stroke. The working efficiency of the stage is affected by the inertial vibration of the macromotion which will cause more time to settle. This paper adopts an active vibration reduction method through a piezoelectric (PZT) device to quickly reduce the designed vibration amplitude of the macro-micro positioning stage. In the paper, we propose a dynamic adaptive vibration reduction strategy to work against the motion of the macro-stage through the PZT to settle the stage with much less time. The start-up condition and extension principle of the piezoelectric element used in the vibration reduction action are designed and finalized. The method can therefore dynamically start up the actuation of the PZT to act on the macromotion at right moment and determine the effect of the vibration reduction through the extension length of the PZT. A dynamic model, a force analysis, and an amplitude reduction analysis are performed to understand the vibration reduction action applied in the macro-micro stage and a dynamic simulation is conducted to examine the effect of the method. The experimental tests are carried out on the stage through the exploration of different extensions and waveform types of the piezoelectric device. The experimental results indicate that the settling time of the macromotion can be greatly reduced with the proposed method without decreasing its positioning accuracy for motion with high velocity and large stroke. This novel method is useful for applications of the electronic manufacturing equipment with high-velocity and high-accuracy requirements.

Index Terms—Dynamic model, Force analysis, Precision positioning stage, Piezoelectric element, Settling time reduction.

1. Introduction

The macro-micro precision positioning concept has become popular in precision engineering, microelectronic manufacturing engineering, semiconductor-based manufacturing industries, micro-nano manufacturing, and optical engineering, among others [1–4]. A macro-micro positioning system has been developed to combine the micromotion actuator with linear motor to realize large-stroke, high-velocity and high precision positioning [5, 6]. Specifically, a micromotion actuator, such as piezoelectric element (PZT), possesses the advantages of high-precision, large-thrust and high-frequency response, but it usually has difficulty achieving large stroke movement [7]. A linear motor, or a voice coil motor (VCM), has large-stroke and high-velocity characteristics, but its positioning accuracy is still limited [8]. Combining of the characteristics of a PZT actuator and a linear motor in macro-micro composite actuation can help solve the contradiction problem of high-velocity, large-stroke motion with high-precision positioning, which currently has been applied in related industrial fields [9, 10]. In the hard disk drives (HDD)

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