Structural Design of Long Range Sub-Nanometer Positioning System

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Abstract

Demands for ultraprecision positioning systems with a long travel range have increased in industrial fields. In order to realize sub-nanometer positioning over a long range, a new structural design concept for high performance positioning is proposed. The positioning table system is developed based on the proposed design concept, and the performance evaluation results confirm that the developed system has capability to position with a sub-nanometer resolution over a hundred millimeter.

1 Introduction

The demands for realizing high accurate positioning systems have increased in many industrial and advanced scientific fields. A lot of researches on precision positioning have been reported, hardware and software of positioning systems have progressed. However there are few researches that realize both a long range motion and a nanometer positioning resolution simultaneously. Because it is necessary to consider all error factors in the system structure for achieving such superior positioning performance.

This paper presents a structural design concept for a sub-nanometer positioning system with a long travel range. After developing a positioning system based on the concept, the positioning performance is evaluated through actual positioning experiments.

2 Structural design of the long range sub-nanometer positioning system

2.1 Structural design of the positioning system

Figure 1 shows main design concept for a long range sub-nanometer positioning table system. In order to realize such superior performance, it is required to realize ideal condition for positioning from the view points of mechanical, thermal, and kinematics.

In consequence, principal components such as guiding, driving, control systems are required to have less undesirable characteristics for precision positioning. Furthermore, these main components should be arranged to minimize error factors caused by structural design.

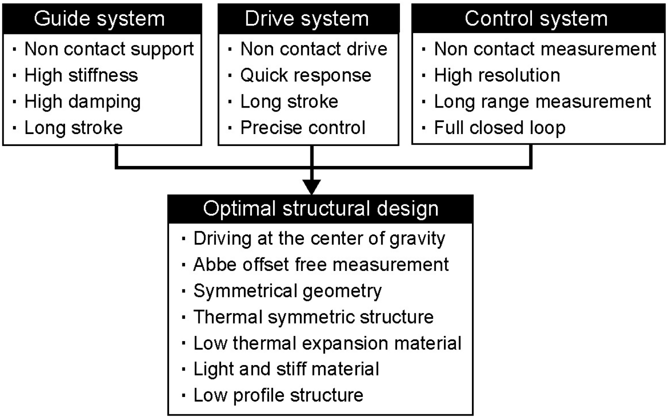


Figure 1: Design concept of the long range sub-nanometer positioning system

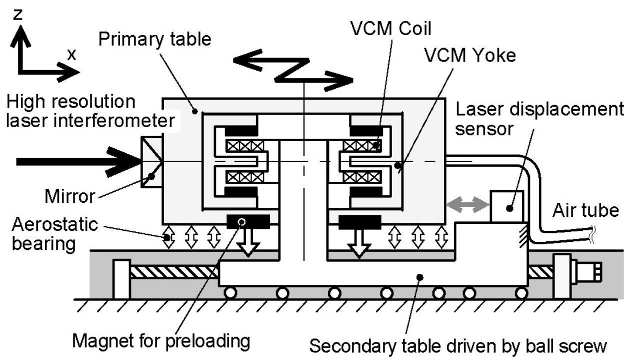


Figure 2: Structural design of the system

Figure 2 shows structural design of the newly developed positioning system. The system has two moving tables: a primary table for fine positioning and a secondary table for extending effective moving stroke. The primary table is driven by a voice coil motor(VCM) at the center of gravity on aerostatic guideway, and its position is measured at the center of gravity with a high resolution laser interferometer to minimize abbe offset. The secondary table has coils of VCM and is driven by a ball screw mechanism in a long range. The secondary table has a relative displacement sensor, and is controlled to follow the primary table motion.

2.2 The developed positioning system based

Figure 3 shows an exterior view of the positioning system developed based on the proposed structural concept. Main structural parts were made of aluminum ceramics for achieving high stiffness, light weight, and low thermal deformation. The entire system was mounted on a pneumatic vibration isolation system and installed in temperature-controlled enclosure to eliminate mechanical and thermal disturbance from environment. Principal specifications of the system are listed in Table 1. The primary table position was measured with a modified laser interferometer[1] which provide higher resolution less than sub-nanometer.

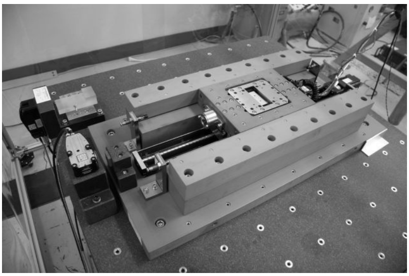


Figure 3: Exterior view of the developed system

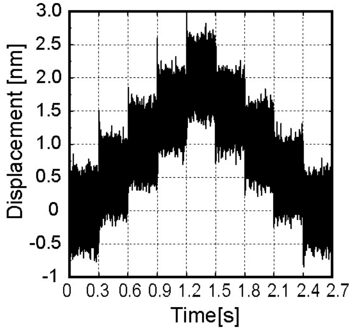
Table 1: Specification of the system

Full stroke	300mm
VCM stroke	±2.5mm
Mass of primary table	7.8kg
Sensor resolution	9.7pm
Control frequency	33kHz

3 Performance evaluation of the developed positioning system

In order to evaluate positioning performance of the developed positioning system based on the structural design, some positioning experiments were performed.

Figure 4 shows a stepwise response of 0.5nm. Clear stepwise motion can be observed in the positioning result. Because the primary table is driven and supported in non-contact condition, and hence there is no friction between the primary table and other components. This structural feature enables accurate motion control in micro region.



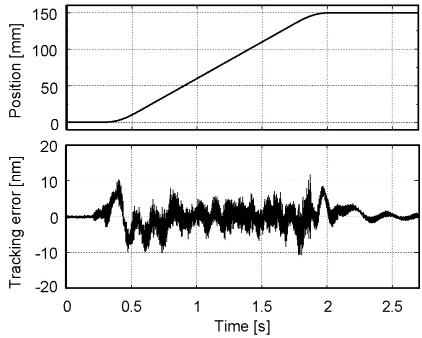


Figure 4: 0.5nm stepwise response

Figure 5: 150nm driving(100mm/s)

Figure 5 shows a measured position and tracking error of the primary table during a long stroke motion of 150mm with high speed of 100mm/s. Because this traveling displacement was much larger than a stroke of VCM, it is necessary to drive not only the primary table but also the secondary table. As shown in Fig. 5, the tracking error during a high speed driving was less than ±10nm even in acceleration and deceleration periods.

4 Conclusions

A structural design concept for a long range sub-nanometer positioning table system was proposed, and then a table system was newly developed based on the proposed concept. The evaluation results confirmed that the table system developed has sub-nanometer positioning capability over a hundred millimeters.

Acknowledgement:

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References:

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