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EVALUATION OF STAGES OF NANO-CMM

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Abstract

The Coordinate Measuring Machines (CMMs) are widely used for the three-dimensional measurements of workpieces. For solving the limits and the drawbacks of the traditional CMMs, we have started developing nano-CMM that measures three dimensional parts in nanometer resolution. In this article, we evaluate the repeatability and the straightness of stages of nano-CMM.

Keywords

CMM (coordinate measuring machine),nano meter measurement, friction drive

1. INTRODUCTION

Coordinate Measuring Machine (CMMs) have been developed and widely used to measure quickly and complex shapes with high accuracy as improving precision of industrial workpieces. The system and the key technology of traditional CMMs come to maturity in this 10 years. However, the limits and the drawbacks of the traditional CMMs are clearly such as the limit of accuracy, measuring range, measuring speed and so on.

Therefore, we have started developing novel systems and key technology as “nano-CMM project”. in this project, our intention is developing the CMM with nanometer resolution to measure three dimensional position, orientations and parameters of three-dimensional features.

2. BASIC CONCEPT OF NANO-CMM

Figure 1 shows the basic construction of prototype nano-CMM. Almost all specifications of nano-CMM are 1/100 of the specifications of traditional CMMs. For developing nano-CMM, we established the specifications and key points of each factor, such as scales, actuators, tables and a probing system. Firstly, we decide that nano-CMM has simple and the symmetric constructions made of single material for the stability of measurements.

scale : an optical glass scale for abstract accuracy, large measuring range and high stability.

Actuator : A friction drive system for large moving range, high resolution and feedback control by scale.

Table : Symmetric construction of sliders with a scale and an actuator, and a double Vee groove with Teflon films for stability.

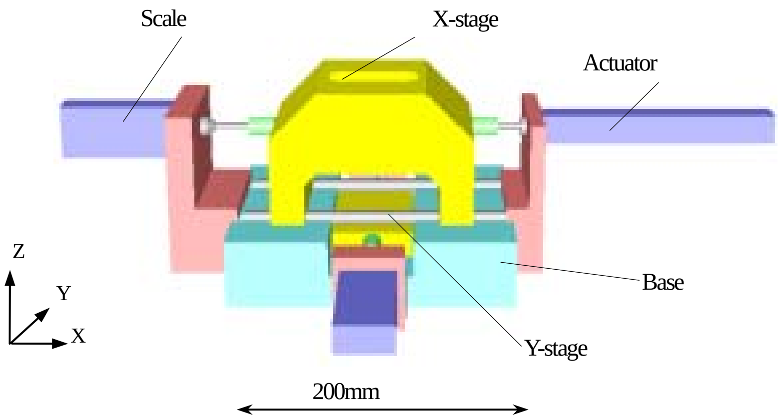


Figure 1. Basic construction of nano-CMM

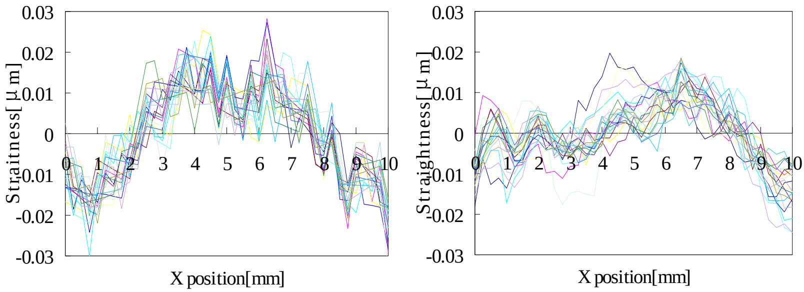
3. EVALUATION USING ELECTROSTATIC CAPACITY DISPLACEMENT METER

The straightness and the repeatability of stages of the prototype are evaluated using the measurements on a surface of a gauge block. A optical glass scale has been used as the scale to measure a gauge block. However, the straightness of nano-CMM is so small that the glass scale can’t evaluate it exactly. Therefore electrostatic capacity displacement meter is used for measuring. Table 1 shows specifications of the optical glass scale and the electrostatic capacity displacement meter. Figure 2 (a) illustrates the straightness of X-stage measured with the optical glass scale and Figure 2 (b) illustrates the straightness of X-stage measured with the electrostatic capacity displacement meter.

From these evaluations, the straightness measured with a optical glass scale shows approximately the actual condition of the stages.

Table 1. Specifications of the optical glass scale and the electrostatic capacity displacement meter

	optical glass scale	electrostatic capacity displacement meter
accuracy	100 nm	4 nm~40 nm
resolution	10 nm	0.1 nm~1 nm
measuring renege	10 mm	±1μm~±10 μm
	in contact	without contact



(a) Optical glass scale (b) Electrostatic capacity displacement

Figure 2. Straightness of X-stage

Table 2. Straightness and repeatability measured with the optical glass scale and the electrostatic capacity displacement meter

	optical glass scale	electrostatic capacity displacement meter
straightness	30 ~ 40 nm	30 nm
repeatability	20 nm	16 nm

4. MEASURING A TILT ANGLE OF THE STAGE

We measured straightness in order to evaluate precision of stages till now. However, we realize only 1 dimension of length by measuring straightness. Therefore we measure a tilt angle of the stage in order to realize three-dimensional behavior of the stage. Two glass scales are used for this measurement. Figure 3 illustrates constitution of the experiment, and figure 4 illustrates the difference of measurement value of two glass scales and the tilt angle of X-stage.

From these evaluations, we recognize, when the stage changes direction, the tilt angle changes in discontinuity. It is because the contact state between the stage and guide shifts.

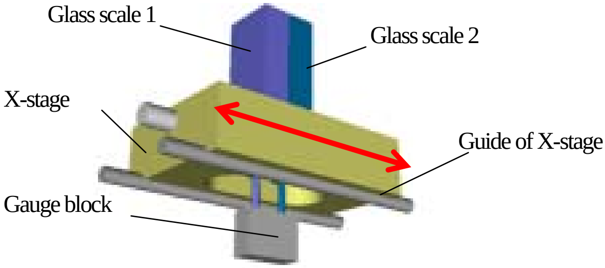
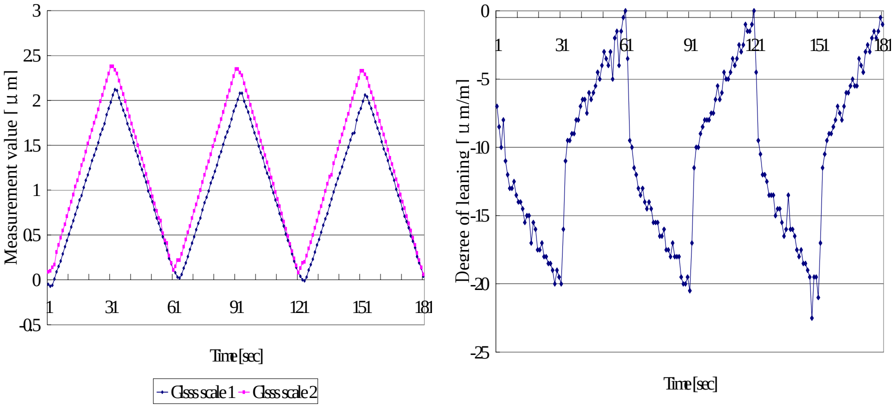


Figure 3. Constitution of the experiment to measure a tilt angle of X-stage



(a) Measurement values of glass scale 1 and 2 (b) Tilt angle of X-stage

Figure 4. Result of the experiment to measure a tilt angle of X-stage

5. DEVELOPMENT OF NEW STYLE STAGES OF NANO-CMM

we develop the new prototype to solve the problems of our prototype. The main improvements are listed as follows:

- material : low thermal expansion cast iron.
- shape : more simple and symmetric shape.
- actuator : adapt friction drive to Z-stage.

Figure 5 illustrates the construction of X-stage and Y-stage of new prototype. In this construction, X-stage is simplified and downsized and the center of gravity of X-stage move into the lower part. Figure 6 illustrates the overview of the new prototype.

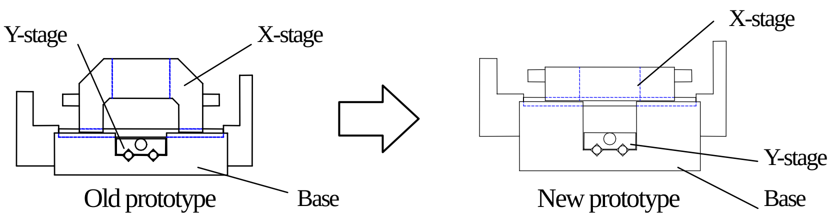


Figure 5. Construction of X-stage and Y-stage of new prototype and old prototype

Figure 6. Overview of new prototype

6. CONCLUSION

In this article, we introduced our developing projects “nano-CMM project” carried out in the University of Tokyo. We reached the following conclusion from the developments and the series of experiments of nano-CMM :

- We introduce the basic concept of nano-CMM.
- The prototype of nano-CMM are made and tested using a optical glass scale and a electrostatic capacity displacement meter.
- Straightness of the prototype of nano-CMM measured with a optical glass scale is similar to straightness with a electrostatic capacity displacement meter.
- We measure a tilt angle of the stage, and recognize, when the stage changes direction, the contact state between the stage and guide shifts.
- We develop the new prototype with low thermal expansion cast iron.

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