# Evaluation of Thermal Drift of Nano-CMM

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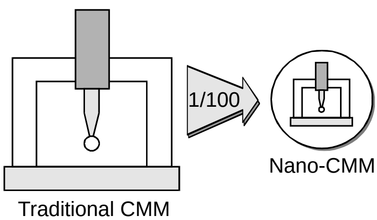
## Abstract

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 positions, orientations and parameters of three-dimensional features. For developing Nano-CMM, we established the specifications and the key elements of each factor. In this report, the thermal drift of X and Y stages of Nano-CMM were evaluated. Then we made the new prototype of Nano-CMM made of low thermal expansion iron steel to reduce the influence of thermal drift.

## Basic concept of Nano-CMM

Coordinate Measuring Machines (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 the year of the past 10. However, the limits and the drawbacks of the traditional CMMs are clearly such as the limit of the 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 positions, orientations and parameters of three-dimensional features (**Fig. 1**). For developing Nano-CMM, we established the specifications and the key elements of each factor, such as scales, actuators, tables and a probing system. Firstly, we decide that Nano-CMM has simple and the



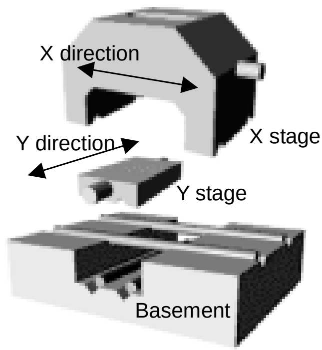




**Fig. 1:** Traditional CMM to Nano-CMM. **Fig. 2:** Basic construction of Nano-CMM.

symmetric constructions made of single material for the stability of measurements. Therefore, a conventional scale system (an optical glass scale) and a double Vee groove guide way mechanism are selected (**Fig. 2**).

The main items of each factor of Nano-CMM are listed as follows:

1. Scale: An optical glass scale with 10 mm of measuring range and 10 nm of resolution is selected for absolute accuracy, large measuring range and high stability,
2. Actuator: A friction drive system is selected for large moving range, high resolution and feedback control by scale.
3. Table: Symmetric construction of sliders with a scale and an actuator, and a double Vee groove with PTFE (Teflon) thin films is selected for stability.
4. Materials: Single material with high thermal conduction rate and low thermal expansion rate is considered.

## Thermal drift of Nano-CMM

**Fig. 3** shows the effects of drifts in the straightness evaluations (20 times measurements in 60 minutes). The maximum displacement of drifts is approximately 180 nm at each X position (**Fig. 4**). We install four thermometers in X stage and measure the variations of temperatures at four points, because these variations could be estimated to be the thermal drifts. The variations of the temperature at the four positions and the variation of the horizontal position at the center of X stage are measured. **Fig. 5** indicates the change of the temperatures and the change of the horizontal position correspond very well.

For reducing the thermal drifts, we make a small constant temperature box. The box is made of polystyrene foam and the inside of the box is wrapped in aluminum foil. The relationship between the temperature changes and the horizontal position changes of X stage without the box and in the box are observed. We conclude that the position change is in proportion to the temperature change and the constant temperature box is effective to reduce the thermal drifts. As for the thermal drifts are still bigger than our target specifications, good temperature control or low thermal expansion material should be necessary.

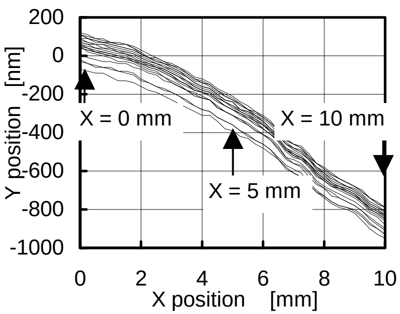



**Fig. 3:** Y position variations of X stage by thermal drifts: 20 measurements in 60 minutes.

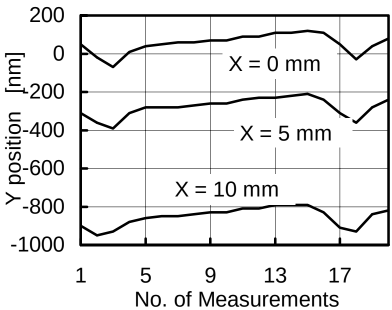



**Fig. 4:** Y position variations of X stage at X = 0 mm, 5 mm and 10 mm

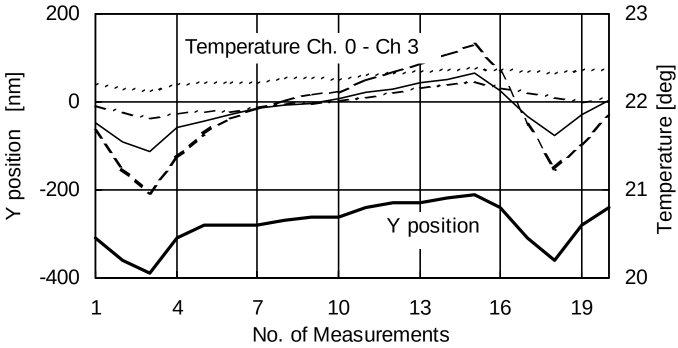



**Fig. 5**: Temperature changes and horizontal position changes of X stage.

## New prototype of Nano-CMM

### New X and Y stages and friction drive

For reducing the thermal drift, we make a new prototype of Nano-CMM using low thermal expansion cast steel. **Fig. 6** shows the constructions of the old and the new prototype of Nano-CMM. The new mechanisms of new prototype as follows (**Fig. 7**):

1. Change the style of X stage to allow bigger size of Z stage.
2. Change material from normal cast steel to low thermal expansion cast steel.
3. New friction drive system to increase the stabilities of X and Y stages.

### New Z stage

**Fig. 8** shows a new Z stage for Nano-CMM. The new Z stage has the double Vee grove guide way mechanism and the magnet attraction stage system.

## Conclusion

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

1. We introduce the basic concept of Nano-CMM.
2. Straightness of the prototype of Nano-CMM is approximately 40 nm and the repeatability is approximately 20 nm.
3. Thermal drifts of X stage are evaluated.
4. The new prototype of X and Y stages are made of low thermal expansion iron steel are made.
5. The new Z stage is made using the magnet attraction stage system.

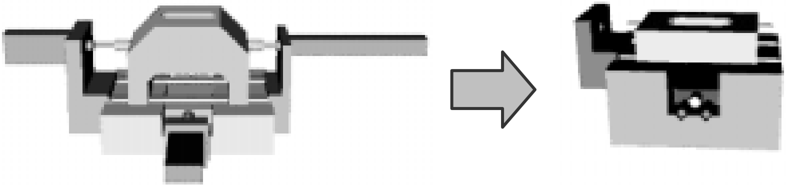


**Fig. 6:** Construction of old and new prototype.

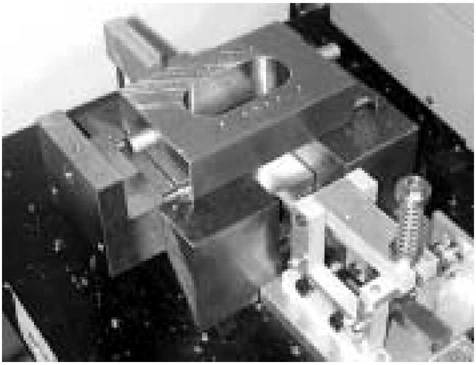


**Fig. 7**: Photograph of new prototype.

**Fig. 8**: New Z stage using magnet.

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