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Kinematics error compensation for on-machine measurement

The Future Metrology Hub

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Introduction

In order to improve measurement availability for manufacturing applications, on-machine measurement (OMM) is integrated onto the machine tools. However, the inherent kinematics error will inevitably induce additional deviations onto OMM results. This paper presents a selective kinematics error model for OMM compensation. Using homogeneous transformation matrix (HTM), relationship between multi-coordinates can be established and spatially distributed single error components are consequently synthesized as a volumetric error model. For the machine tool configuration in the work, there are two kinematics error chains, as illustrated in Figure 1. One is from machine base to the machining surface, and the other is from the machine base to the DRI probe. Kinematics error modelling for multi-axis machine tools are based on multi-body system theory. Multi-body system theory offers a comprehensive description of general mechanical system utilizing lower order body topological structure.

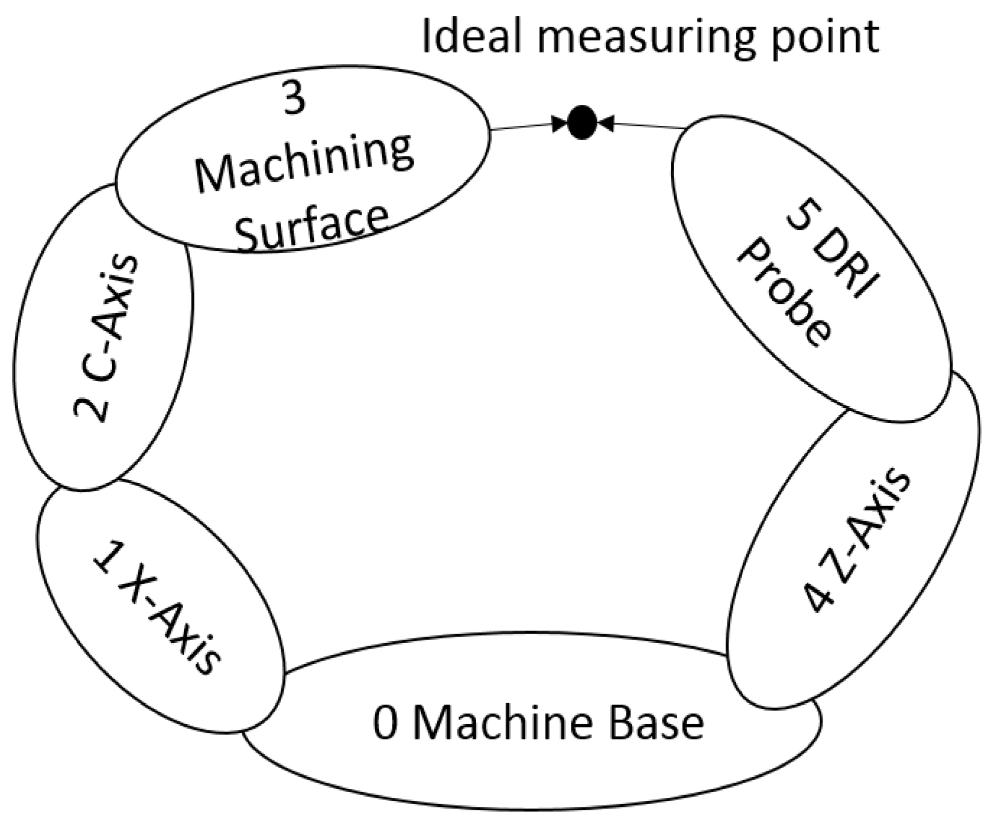

Figure 1: Kinematics error chain

Framework of kinematics error compensation

The flowchart of the proposed methodology is illustrated in Figure 2. According to the measurement task and machine tool configuration, a selective kinematics error modelling and measurement process will be carried out. The machine tool kinematics error in the scanning region is consequently mapped in order to compensate the OMSM result. To validate the proposed methodology, the OMSM result is compared with calibrated offline measurement result.

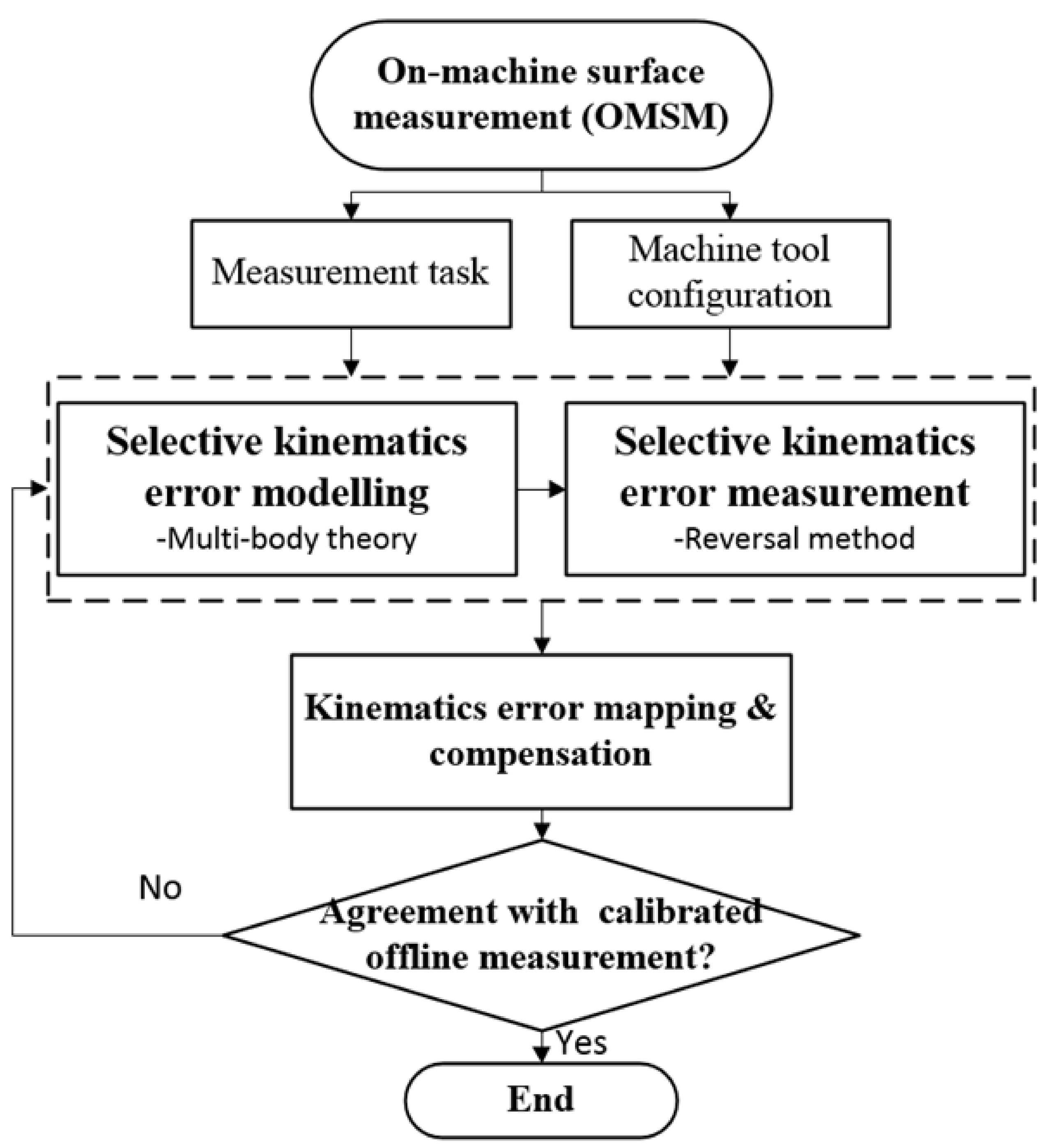

Figure 2: Flow chart of kinematics error compensation for OMM

Experiment and discussions

This section proposes a simple scheme for machine tool kinematics error measurement in nanometric level, with capacitance probes (Lion Precision C8) and a flat mirror artefact. The maximum sampling frequency of capacitance probes used is up to 1 kHz and the displacement measurement resolution is 0.08 nm. Furthermore, the 2 mm spot size also automatically filters out short wavelength errors on the target surface so that the artefact surface finish will not affect the measurement. In the following part, the measurement process for X axis straightness in the Z direction EZX, C axis axial error EZC, C axis tilt error EBC, and squareness error between X axis and C axis will be respectively described.

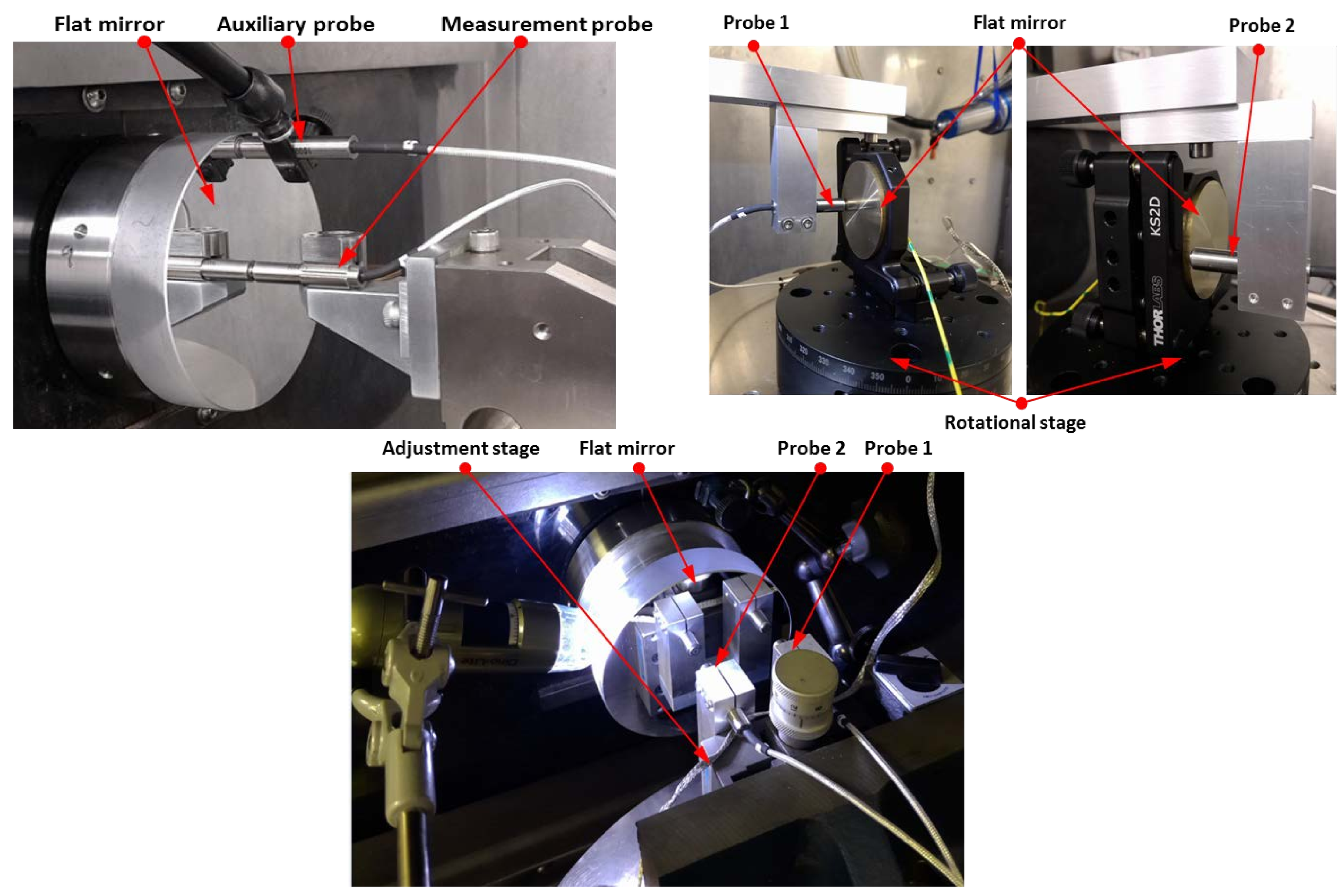

Figure 3: Kinematics error measurement (Reverse method)

To verify effectiveness of the proposed kinematics error modelling, measurement and compensation, OMM experiment of a standard flat mirror is performed. The results clearly indicate that DRI on-machine surface measurement result of the optical flat comprises machine tool kinematics error and the sample form error. With the aid of kinematics error mapping established above, the on-machine probing data was compensated. The result shows with the implementation of compensation, the accuracy of characterized flatness error from OMM improves 67%.

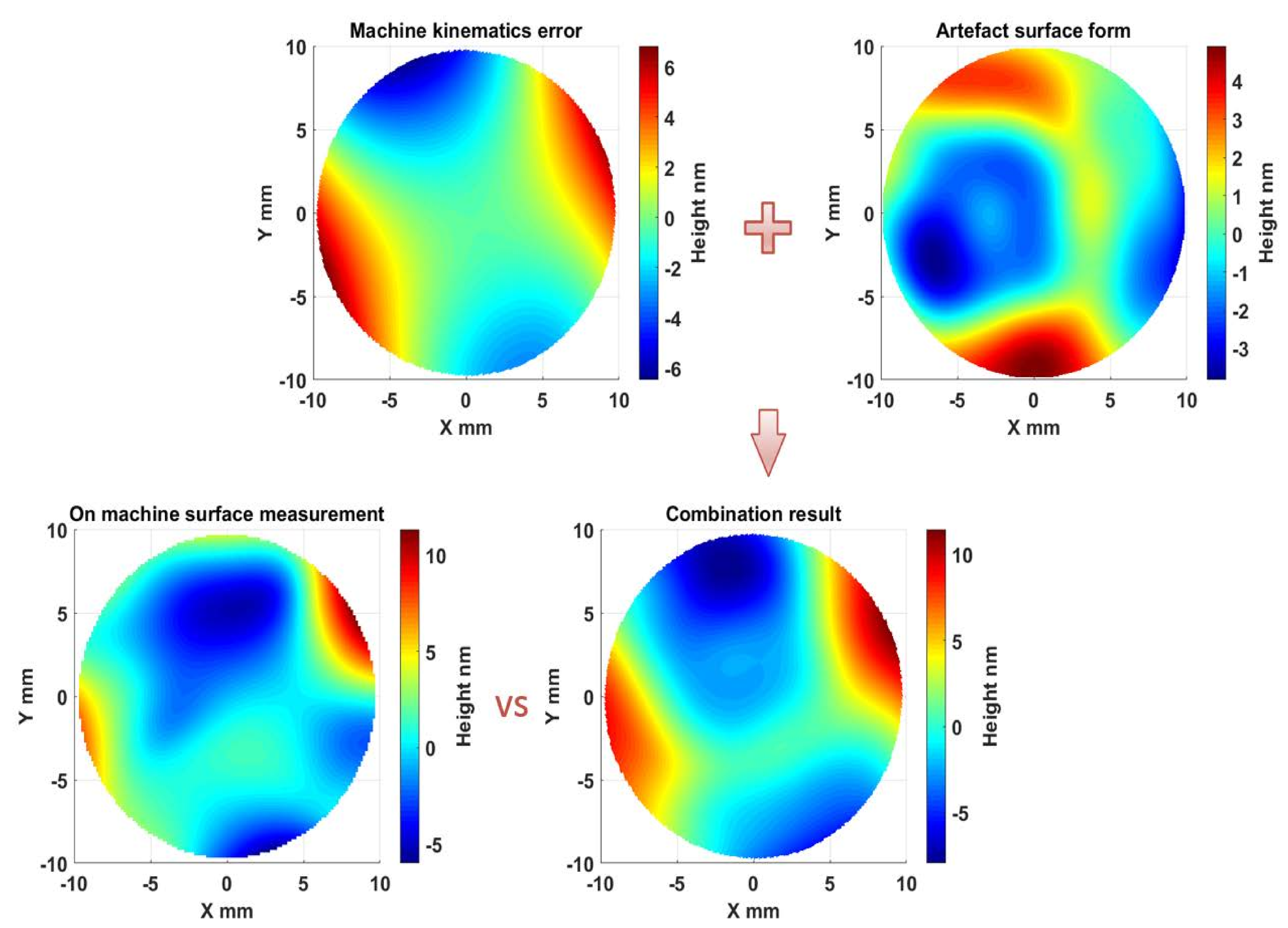

Figure 4: Error compensation results

Conclusions

The paper presents kinematics error modelling, measurement and compensation for on-machine surface measurement. Both theoretical and experimental work has been conducted to generate the machine tool kinematics error map for compensation of OMSM results.

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