Multi-probe Evaluation Study on an Ultra-precision Eight-axis Positioning Stage

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Abstract

This abstract presents results from development of a controller for an ultra-precision, eight-axis motion control stage. This represents an extension of previous work to develop controller strategies in individual freedoms that demonstrated an ability to keep the peak to valley controller error to within 5 nm linear and 1 nrad angular. Early results from a study of newly developed mechanical probes for dimensional metrology of small components are also included. A one dimensional capacitance base probe has been developed and has been used to measure a common reference artifact. Currently, three other probes are to be included in the study, these being; the Triskelion IBS, PTB ACP and Insitutec SWAT. An update of the results from these tests will be presented at the conference.

1 Positioning Stage System

The 8-axis positioning stage is comprised of a two-axes (*XY*), long-range stage and a 6 degree-of-freedom (DOF) short-range stage and, in combination, provides a working volume of 50 mm × 50 mm × 17 µm [1]. Figure 1 shows the assembled stage system with the 1D integrated

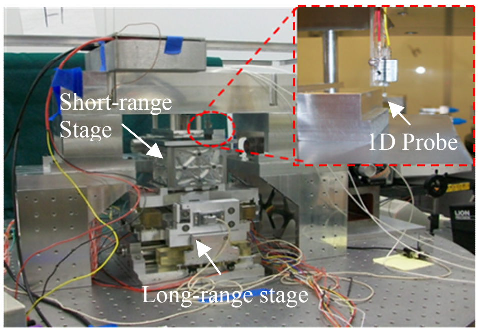


Figure 1. Complete assembly of stage with 1D probe. Inset shows probe in-situ.

probe. Previous strategies for single axis control have now been combined to achieve a full 8-axes control of the stage [2].

As a measure of full 8-axes controller capability, a 'hold' demand is applied to the controller and monitored over extended periods. Figure 2 shows a 20 second long

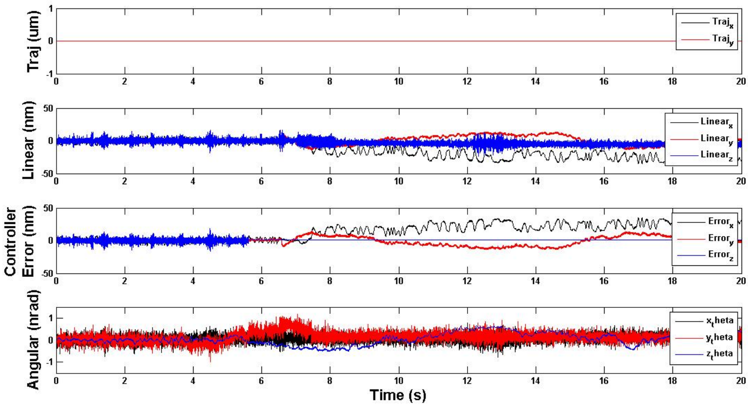


Figure 2. Graphs show demand (top), displacement readings, linear controller error and angular measurement (bottom).

sample of six axes coordinate measurements of the upper stage platform with a 'hold' demand being turned off after 5 seconds. Note that the controller under full 8-axes control can achieve 5 nm linear and 1 nrad angular as shown in 2^{nd} and 4^{th} graphs of the above figure.

2 Probe Systems

As of writing, three probes have been selected for the study and will be used to measure nominally similar geomteric parameters on a common artifact. It is envisaged that these probe systems after testing on the current stage can be integrated into other fine motion measuring machines, such as the SAMM stage (UNCC), and used to measure the same artifact for comparison. Selection criteria for these probes include; integration, procurement and availability. As a first step to integrate these probe systems to the stage, a 1D capacitance-based probe has been developed in-house and used for systems testing. Figure 3 shows a solid model of the 1D probe

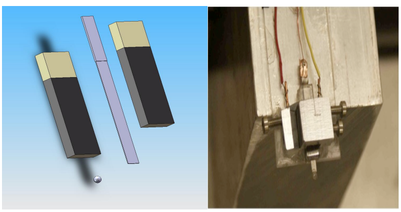


Figure 3. (left) Exploded solid model of 1D probe (right) Photo of 1D probe

and a photograph of the probe mount. Other probes such as the IBS Triskelion and PTB assembled cantilever probe (ACP) have been loaned to the project and are currently being integrated prior to testing.

3 Reference Artifact

An artifact constructed from three Mitutoyo gage blocks Grade 0 will be used. The triple gage block artifact is produced by wringing together and stacking in which the center block is offset as shown in Figures 4 and 5. It is envisaged that all the probes will measure this aritifact using the same scan alogrithm to generate measurement data from which comparable parametric measures can be extracted. From the data of the scan, information can be extracted to provide the separation of surfaces around this artifact as shown in Figure 5. Currently, the first artifact used in this study would be too large for some of the positioning systems envisaged to participate in this study. An effort to produce a smaller artifact is in progress. This smaller artifact will comprise three, 5 mm gage blocks of half the length again wrung together in the same configuration as before.

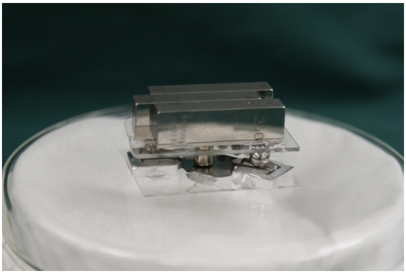
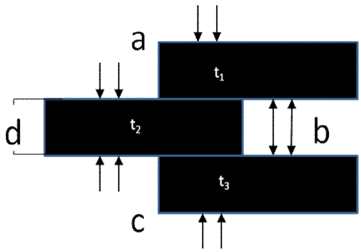


Figure 4. Triple stacked gage block artifact.



$a = t_1 + t_{w12}$
$c = t_3 + t_{w23}$
$d = t_2 + D_p$
$b = t_2 - D_p + t_{w12} + t_{w23}$

Figure 5. Targeted information from the measurement

4 Initial measurements

Following the controller development, trajectory path algorithms are required to move the probe in defined paths around the artifact. An example of one implementation and resulting measurements is shown in Figure 6. In this measurement, the specimen has been moved toward the probe in the x direction while the probe is stationary. After contact and retraction, the specimen surface is

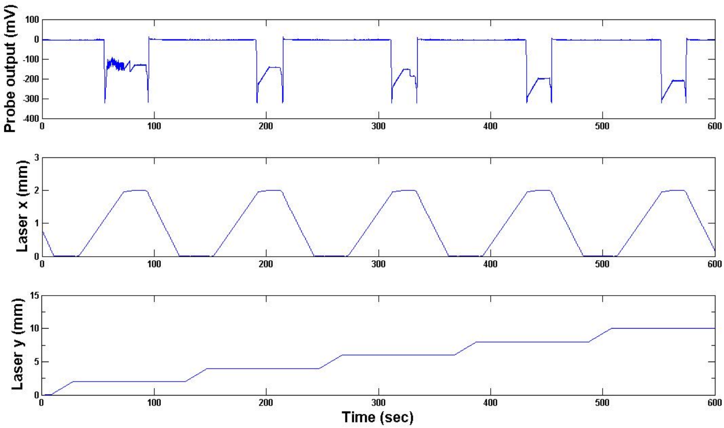


Figure 6. Line trajectory in y of 10 mm while probing surface at 2 mm intervals. Top: output of probe, middle: laser reading of x, bottom: laser reading of y.

then translated (y = 2 mm) parallel to the probe direction and the cycle repeated. Figure 6 shows the measurment of 5 contacts on a gage block surface over a length of 10 mm.

A scan algorithm to obtain data points of the artifact will be standardized and the results then processed in a common algorithm for parameter extraction relevant to this specific artifact. This algorithm will then be transfered with the artifact to the other measuring machines participating in this study.

References:

[1] Eric S. Buice, Implementation of a dynamic positioning machine for nano-scale engineering, PH.D thesis dissertation, University of North Carolina at Charlotte

[2] Teo C.S., Yang H., Smith S.T., Hocken R.J., Buice E.S. and Otten D., 2009, Controller strategies for an Ultra-high Precision Stage, Proc. EUSPEN, P2.13-220 Vol[1].