Analysis of a Parallel-Axis Flatness Measuring Instrument

Research Objectives
- To analyze the performance of a flatness inspection instrument that measures workpieces with up to one millimeter departure from flatness.
- Use a complete homogeneous transformation matrix analysis of the propagation of errors into the measurement.
- Carry out sample measurements on diamond-turned workpieces.
- Use the measurement data to provide a scan of the workpiece in rings of data that are digitized and subsequently post-processed in software with synchronization provided by rotary encoders on each air bearing spindle.

Motivation
- This work seeks to characterize an instrument for measuring flatness that bridges the performance gap between the CMM and interferometry in range, resolution, and surface finish requirement.
- We can evaluate the instrument accuracy using a homogeneous transformation matrix (HTM) model incorporating instrument geometry, alignment and spindle errors, and angular position of the two spindles.
- The flatness measurement may be simulated by repeated evaluation of the HTM model, post processing to remove piston and tilt (using a least-squares fit plane), and examination and interpretation of the remaining error.

Conclusions
- In tests with a high sensitivity probe, the instrument demonstrates measurement repeatability of 25 nanometers on a Ø75 mm workpiece.
- A calibration technique is available to remove the largest source of instrument error by a reversal-type procedure.
- The dual spindle layout is scalable to measure larger workpieces.

Experimental Setup
- Two air bearing spindles with parallel axes simultaneously rotate a workpiece and slowly pass a capacitance probe over the spinning surface.
- The resolution and range of the capacitance probe is selectable for different workpieces.
- Nonconductive workpieces can be measured with capacitance probes using a diamond stylus on an air bearing movement.

Face and Axial Errors

Contributors to Measurement Error
- Workpiece spindle error motion
- Spindle alignment (parallelism)
- Swingarm spindle error motion

HTM model
- Displacement indicator
- Indicator on axis
- Indicator off axis

Future Work
- The instrument’s size can be expanded to allow larger workpieces.
- Further analysis will be carried out to determine if additional components of the instrument error can be made self-checking.
- Workpiece surface figure will be compared to interferometric measurements.

Separate Cone from Wedge

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