

## Simple calibration artifact for use on roundness testers

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### Abstract

Roundness testers are very useful tools on the manufacturing floor and are an important part of Professional Instruments Company's continuing efforts to produce the most accurate air bearing spindles possible. In order to build spindles that have less than 12 nanometer error motions, we need to make shafts and housings with roundness, flatness and squareness errors better than 0.20 micrometers. To hold such tight geometry tolerances, we have put roundness testers at every one of our grinders and diamond turning machines, which has created a new issue of how to make sure that those roundness testers are functioning properly. This work describes a simple calibration artifact useful for ensuring accurate roundness measurements as shown in Figure 1. We use a 100 mm diameter x 25 mm cylinder, which has been purposely ground and lapped out of flat 1 micrometer. We produce low frequency errors in the face of the artifact by selectively torquing screws that are used in the lapping process.



Figure 1: Lapped flatness artifact

### Motivation

With almost 20 roundness testers in use in our manufacturing facilities we are very concerned that they are functioning properly. Standard procedure for calibrating an electronic indicator involves measuring across 2 gage blocks that differ in size by 20 micrometers [1]. However, we are concerned with magnitudes of less than 0.1 micrometers, and when electronic indicators get sticky they don't register small

motions (even though they might look perfectly fine when measuring two blocks 20 micrometers apart). Furthermore we wanted a convenient test that would mimic as closely as possible the parts we measure.

### Design

Our flatness artifact has a narrow raised section just outside a 12 counter-bored hole pattern as shown in Figure 2. We use that hole pattern to elastically deform the metal around the screw heads while we lap the raised surface as shown in Figure 3. When we remove the screws we have a smooth surface with a small wave, ideal for our measuring.



Figure 2: Artifact with screws torqued to backing plate, ready for lapping

### Manufacture

The artifact is ground flat on the top and bottom sides and then torqued up to a disk with 5 of the 12 screw holes available. It is then lapped flat and smooth on the raised section and finally it is removed from the disk and calibrated for circular flatness.

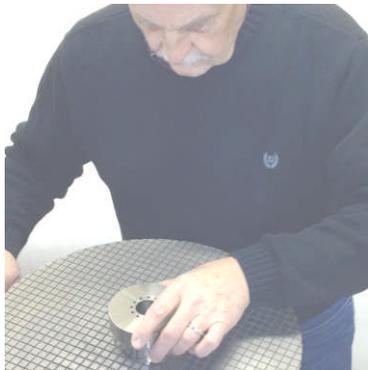


Figure 3: Lapping the artifact

## Calibration

We calibrated the artifact with our Lion C-LVDT based roundness tester shown in Figure 4. The C-LVDT is manufactured by Lion Precision and is calibrated yearly.

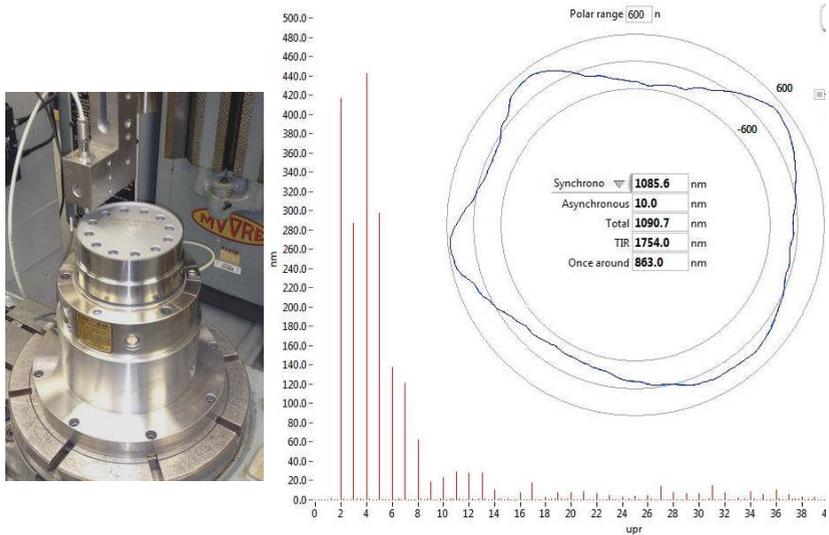


Figure 4: Flatness artifact checked in roundness tester with Lion air bearing C-LVDT

We were curious whether we could also calibrate our artifact optically, so we checked it on our Tropel Flatmaster grazing incidence interferometer shown in Figure 5. We were pleased when it showed almost identical results.

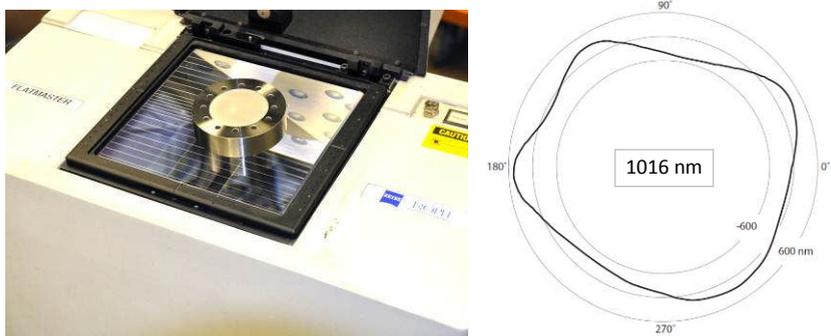


Figure 5: Tropel Flatmaster measurement of the artifact

## Conclusion

A roundness tester is only of value when it is actually giving you correct measurements. Electronic indicators are notorious for giving erroneous results, so they need to be verified regularly. The shape of a polar plot and the magnitudes of an FFT give the operator a quick and powerful indication when there is a problem with the instrument. This test also has the advantage of testing the whole roundness tester, including the structural loop and will show problems that might not be apparent just by checking the gage alone. The artifact itself can be calibrated on a roundness tester or an interferometer at an independent laboratory and so can be made traceable.



Figure 6: Calibrating a roundness tester on the shop floor

## References:

- [1] Mahr Federal, Series 830 Amplifier User's Manual, March 25, 2009.
- [2] Vigliano, V. Design and experimentation of a roundness tester. The Pennsylvania State University, Master's Thesis, Spring 1999. <http://mdrl.mne.psu.edu/theses/vcvdoc.pdf>. Accessed January 31, 2012.