

Procedure Title: Multi-position Roundness Calibration (13020)
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Calibration of Roundness Standards using the Multi-Position Method (13020)

Scope: This document provides basic guidance for the calibration of a sphere or hemi-sphere style roundness standard using the multi-position method on the Talyrond 3 or Mitutoyo RA-H5000.

Equipment List: Either roundness instrument as specified in the scope, an indexing table for precise rotation between traces, a 1 mm diameter standard length probe, epoxy, appropriate cleaner and lint free towel, and dust puffer.

Environmental Constraints: For roundness work the absolute temperature relative to 20 °C is not important, however a stable environment is required. Changes in form features from trace-to-trace indicate changing temperature gradients within the part or machine thus degrading the repeatability. As such, calibration work should not be performed when the environmental controls are not working or if adequate trace-to-trace repeatability can not be achieved. Otherwise, environmental conditions do not need to be recorded as the uncertainty budget incorporates the every day lab environmental stability.

General:

Reference Documentation:

The following documents can be found in the “Roundness Calibration Documentation” three ring binder:

- NBSIR 79-1758, “The Calibration of a Roundness Standard”
- Users Manual for UNCC Roundness Calibration Program (for data collection only)
- ANSI B89.3.1-1972 (Reaffirmed 1988), “Measurement of Out-of-Roundness”
- ISO/DIS 12181-1 and 12181-2, “Roundness”
- ANSI/ASME B89.3.4M-1985, “Axes of Rotation”

The following documents will be with either the measuring instrument or in the equipment manual filing cabinet:

- Talyrond 3 Users Manual
- Mitutoyo RA-H5000 Users Manual

Scale Calibration:

Talyrond 3: The scale of the Talyrond is calibrated using cam style magnification standards. The actual value of the cam is obtained by measuring the diameter difference between two specific diameters. The difference is between minimum diameter (referred to as the 0 – 180 ° diameter), which is obtained by scanning between two contacts of a bench style micrometer, and the diameter 90° from the minimum diameter (referred to as the 90 - 270° diameter). The uncertainty of this difference measurement on the micrometer is limited to the uncertainty contribution due to the scale calibration, repeatability, and contact geometry. These cam standards are calibrated upon use and the data should be recorded in the “roundness documentation” binder for historical purposes. Equipment should be chosen so that the uncertainty of the difference measurement is less than 2% of the cam’s nominal value. For the calibration of the Talyrond scale on the 20,000 magnification range, it is recommended to use Cam #11 because it is the largest magnification standard that can be measured on this range of the Talryond. Once an actual value is determined for the cam, it can then be measured on the Talyrond. The first step should be to ensure the cylindrical axis of the cam is aligned to the axis of the spindle by way of the leveling adjustment. Ignoring the larger radius area (or depression zone), the cam should be centered as well as possible. A least-squares

fit is not done to the data, thus any miscentering of the part causes distortion thus contributing to the error of scale calibration results. The data should be collected and saved using the UNCC software with the filter set to a cutoff of 50 upr. The data can then be analyzed in Excel by identifying the data position corresponding to the minimum radius (referred to as the 0° position) and the radius positions corresponding to the 90, 180, and 270° orientations. Three degrees of radius data should be average at each location. The following calculation can then be performed with these averages to obtain the scale calibration factor: Scale Factor = Actual Value of the Cam / (ABS((0 + 180) - (90 + 270))) = nm/unit. Historically, this value has been approximately 0.765 nm/unit ± 0.025 nm/unit.

Mitutoyo RA-H5000:

The Mitutoyo scale is calibrated using a nominal 3.810 um step created by wringing two gage blocks to a platen. The actual value of the step is determined by static interferometry. This step has been made and is kept with the machine. Refer to the “roundness documentation” binder for the latest actual value for the step. The step standard should be placed on the rotary table and the wrung gage blocks positioned manually so that they are centered with respect to a trace path on the platen around them. Next, the platen surface should be leveled to within 1 division on the 100,000 range. This is done with the probe oriented for circular flatness measurement. Once leveled, the stylus should be moved so that it contacts one of the gage blocks at the gage point and when rotated it contacts the other gage block at approximately the gage point as well. Select the 1.00 “Init” scale calibration factor from the available scale calibrations in the software. Using the software perform the static calibration, according to the manual ten times. Average the ten results compare the average with historical results in the “roundness documentation” binder and record the value along with the standard deviation of the ten measurements, if the results are acceptable. Finally, register the average in the scale calibration log in the software and make sure that it is selected.

Setup:

Whichever instrument is used, a maximum of a 1 mm diameter probe should be used and the instrument should be set up to filter the data using a 2RC filter with a 50 upr cutoff. The Mitutoyo RA-H5000 should be set to collect 7200 data points.

Either Type Roundness Standard:

- (1) Center indexing table to rotation axis of instrument.
- (2) Level top of indexing table so that it is perpendicular to the rotation axis.
- (3) Manually center roundness standard so that it is centered in relation to the axis of the indexing table previously centered. Do not use the automatic centering function on the Mitutoyo or the centering knobs on the Talyrond 3, this must be done physically. This procedure is done to minimize centering between each rotation of the indexing table.

Hemisphere Type:

- (4) Probe should contact the hemisphere 3 millimeters above the base and probe angle should be adjusted so that the deflection is normal to the surface. If the probe is kept vertical then a cosine correction must be made to the results.

Sphere Type:

- (4) With the probe vertical the probe should contact the ball at the equator; this can be done by scanning vertically near the equator for a maximum reading.

Measurement:

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Twelve traces are to be collected, one every thirty degrees. Between traces the roundness standard should be rotated clockwise using the indexing table and centered.

Talyrond 3: The UNCC Software (C:\reeve\round) should be used to collect the data (file name can not exceed 6 characters). Only trace data that visually closes at the start and end location (zero degrees) on the graphical display of the trace data should be saved, otherwise repeat the measurement until this condition is satisfied.

Mitutoyo RA-H5000: The Mitutoyo software "Roundpak" is used to operate the machine and to collect and store the data. The data file used for evaluation in Excel is the CSV file. To ensure that the stored data is filtered according to the settings in the software, the registry entry for "Evaluation Curve ON" in the "Text Out" folder located on the desktop should be set (refer to Mitutoyo "Roundpak" instruction manual section 13.3 for details). It is recommended that at least three traces be taken at each position and the first trace discarded. The following two traces should repeat with regards to shape and magnitude of features, otherwise the measurements should be repeated until traces 2 and 3 repeat.

Data Analysis:

The data analysis is exactly the same regardless of which machine the measurements are made on, with the exception of the number of data points the file is set up to analyze.

The following blank Excel spread sheets should be used to analyze the data:

Talyrond 3: Talyrond 3 Multi-Position.xls
Mitutoyo RA-H5000: RA-H500 Multi-Position.xls

These blank Excel spread sheets are included on the CD contained in the "roundness documentation" binder.

The populated data sheet should be saved with the internal control number (M####) as the file name and this file should be attached (archived) with the calibration record for that item in the ISSC database upon "technical" log out.

The machine error obtained should be compared to the historical machine error for that particular machine. The machine error to be test is inserted into the Excel file and the T-test formula column is copied to the next available column. This new T-test column should be labeled and all values in the column should be less than 3.00, otherwise check your setup and redo the measurements. The T-test compares the difference between the result to be tested and the historical average for that position to long term reproducibility (~1.8 nm for the Talyrond and ~ 2.0 nm for the Mitutoyo RA-H5000). After the Excel file is revised it should be save on the appropriate disk and placed back in the roundness documentation binder.

The instrument error files are:

Mitutoyo Error History.xls
Talyrond 3 Error History.xls

As one final check the results obtained for the roundness standard should be compared with history. If history is available the new results should agree with historical values to within the root-sum-square of the uncertainties corresponding to the results to be compared. Most customer history dated back to 1996 is archived on the CD-RW in the roundness documentation binder. New and revised history files should be archived to this CD.

Report:

See attached pages for sample reports, noting that there are two different reports corresponding to the two different style roundness standards. These sample reports are also included on the CD contained in the

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“Roundness Calibration Documentation” three ring binder. The polar plot can be produced using the NIST developed “ROUND” software in the METLAB directory by inputting the results, otherwise they can be produced using another software package and a cubic spline algorithm.

Data Sheets:

There are no data sheets for this measurement process, only data files which are transferred and imported into the Excel spreadsheet to analyze the data. The spreadsheet with the raw data and analysis is archived in the ISSC database upon completion of the calibration.