EURAMET

Measurement of roundness errors on roller machines and determination of their uncertainties

Björn Hemming, Pasi Laukkanen, Veli-Pekka Esala (VTT-MIKES)

Thomas Widmaier, Petri Kuosmanen (Aalto University)

Measurement of roundness errors on roller machines and determination of their uncertainties

- What is roundness, how it is measured
- Roundness for rollers
- Traceability
- Uncertainty evaluation

ISO 1101 – Geometrical tolerances Roundness

ISO 1101:2012(E)

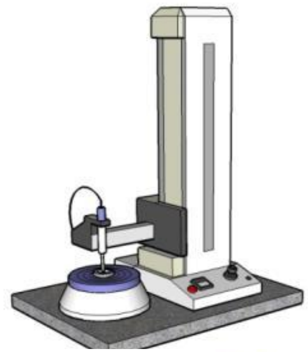
5 Symbols

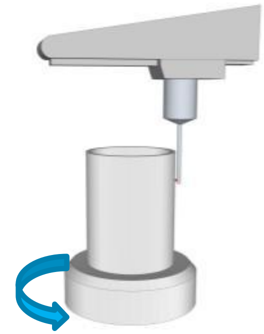
See Tables 1 and 2.

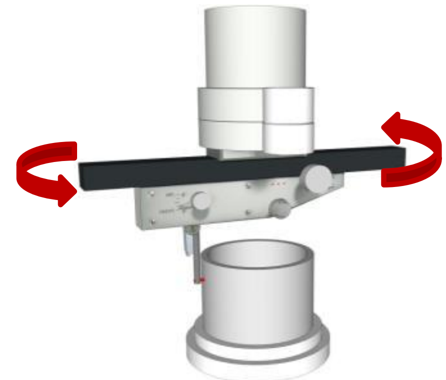
Table 1 — Symbols for geometrical characteristics

Tolerances	Characteristics	Symbol	Datum needed	Subclause
Form	Straightness	—	no	18.1
	Flatness	▱	no	18.2
	Roundness	○	no	18.3
	Cylindricity	⌭	no	18.4
	Profile any line	⌒	no	18.5
	Profile any surface	⌓	no	18.7
	Parallelism	//	yes	18.9

Measurement of roundness

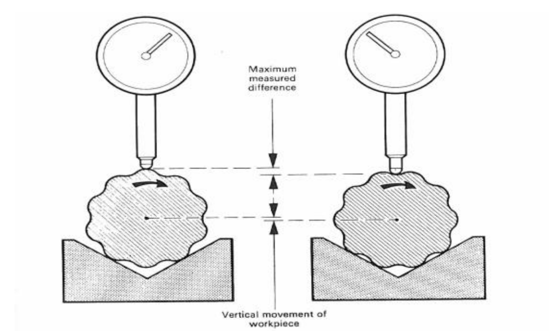






Roundness instrument, best
Uncertainty U = 0,1 µm

CMM, reasonable
Uncertainty U = 5 µm
You also get diameter
Number of points affect result



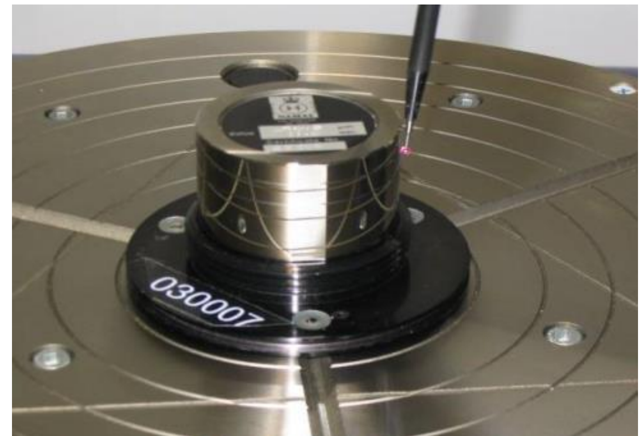
Dial gauge and rotation of part is cheap and easy
Uncertainty U = 10 µm
Difficult to see shape of your part

Source: H Dagnall . Let's talk roundness. Rank Taylor Hobson Ltd Leicester 1976

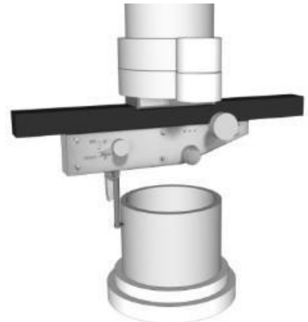
Roundness material standards for laboratory

Cylinder with a flat part, Flick standards
- Calibration of gauge

Almost perfectly round sphere
- Calibration of rotation



Roundness in roller measurements

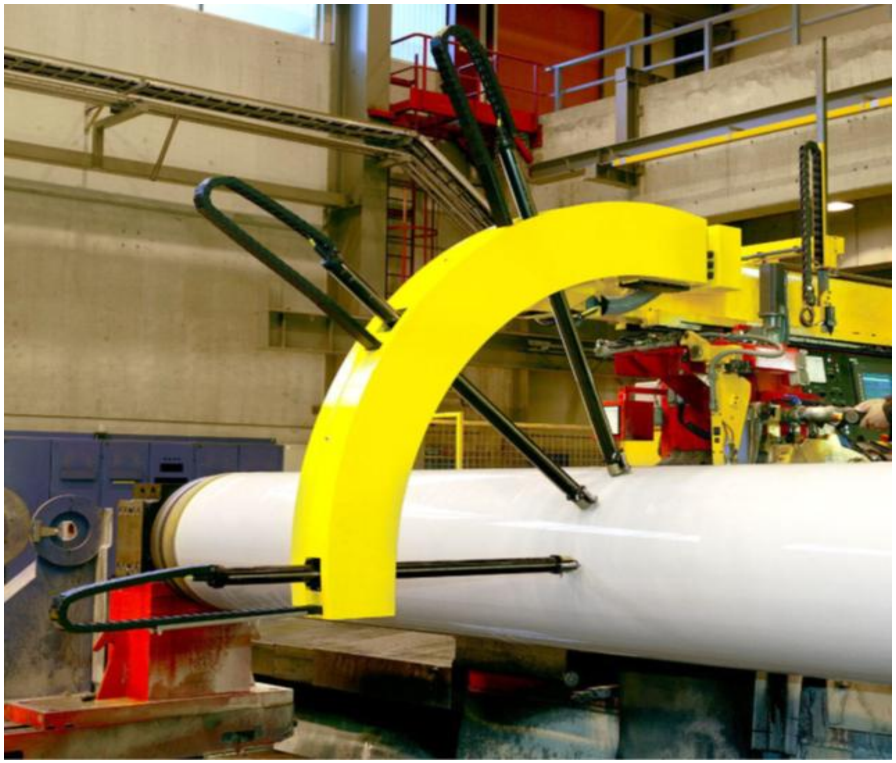


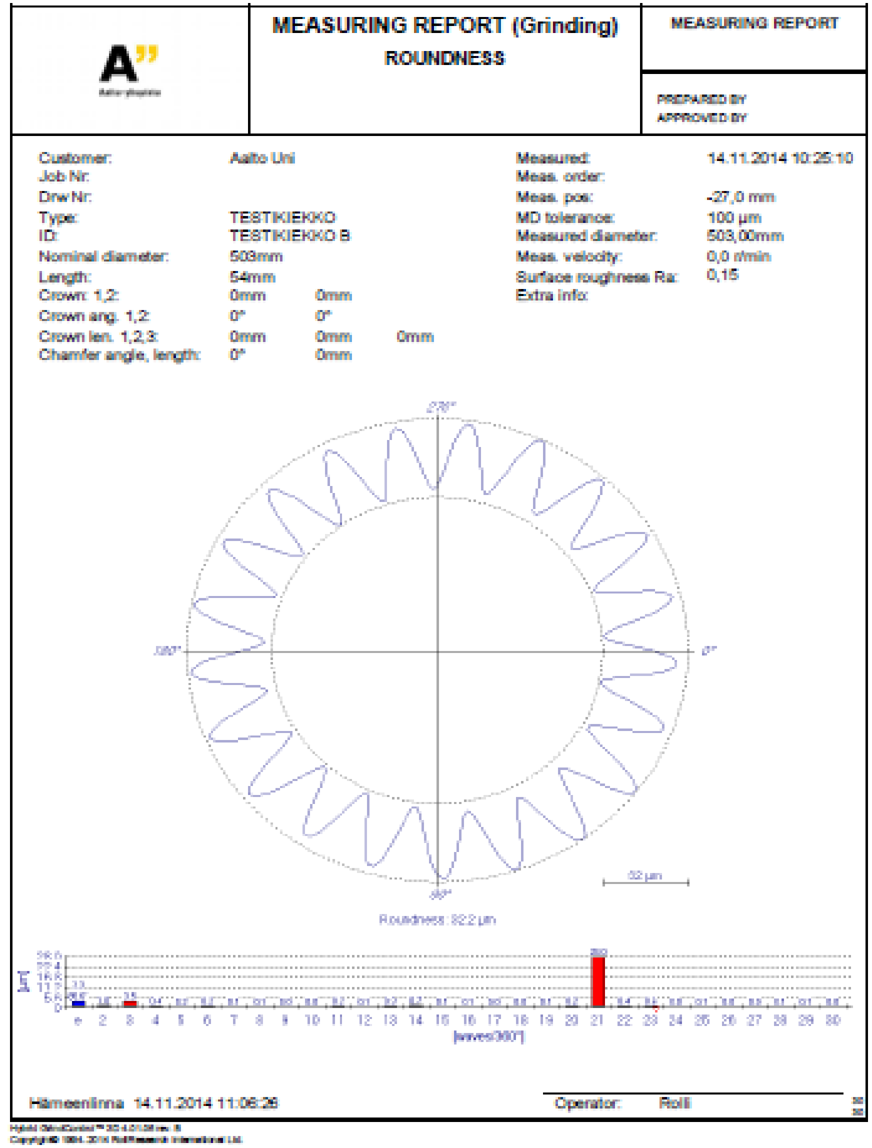
Roundness is an important feature when thickness and flatness of the end product is needed, such as paper machines, rolling mills for steel strips or sheets, printing machines

Uncertainty of roundness is roughly 0.5 µm to 50 µm

Three R-MS developed in WP2

Roundness measurement with 4-point instrument





MEASURING REPORT (Grinding)
ROUNDNESS

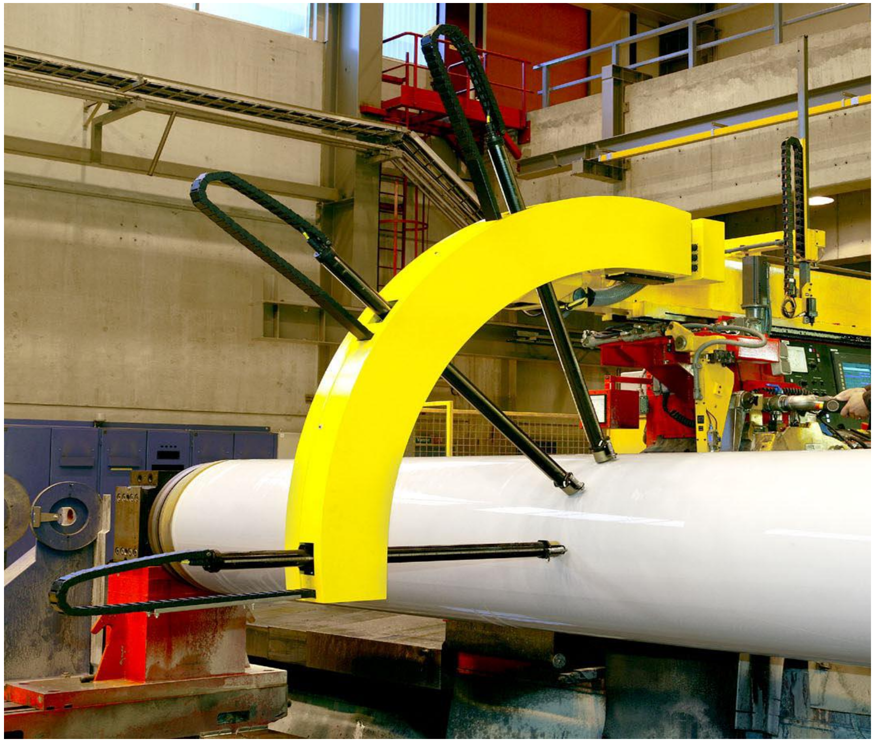
MEASURING REPORT

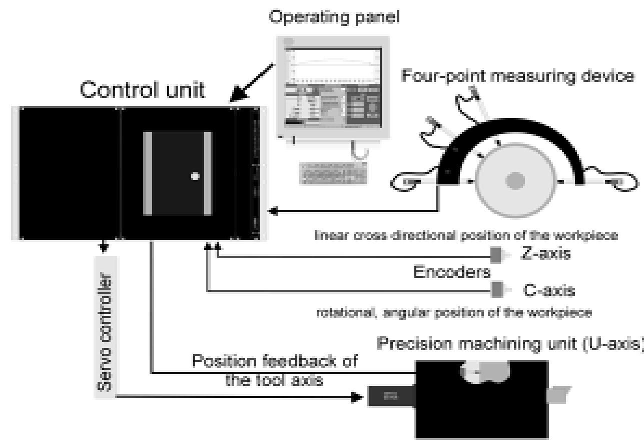
PREPARED BY
APPROVED BY

Customer:	Aalto Uni			Measured:	14.11.2014 10:25:10
Job Nr:				Meas. order:	
Drw Nr:				Meas. pos:	-27,0 mm
Type:	TESTIKIEKKO			MD tolerance:	100 µm
ID:	TESTIKIEKKO B			Measured diameter:	503,00mm
Nominal diameter:	503mm			Meas. velocity:	0,0 r/min
Length:	54mm			Surface roughness Ra:	0,15
Crown: 1,2:	0mm	0mm		Extra info:	
Crown ang. 1,2:	0°	0°			
Crown len. 1,2,3:	0mm	0mm	0mm		
Chamfer angle, length:	0°	0mm			

Hämeenlinna 14.11.2014 11:06:26   Operator: Rolli

In-process measurement Roll Geometry & Machining

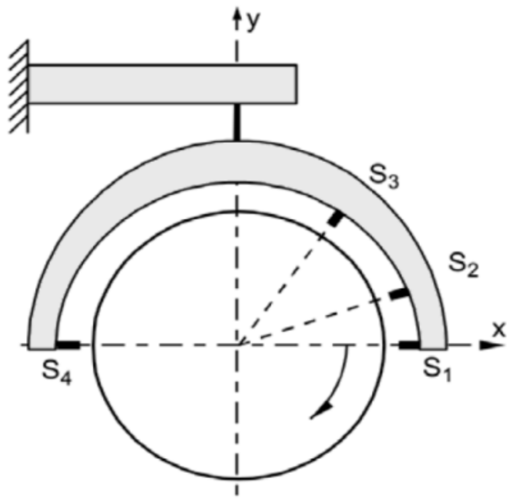




Modernised roll grinding machine at a Paper Mill. The control system includes 3D grinding control technology. The fully-automatic 3D measuring device is based on the fourpoint measuring method.

From: Kuosmanen, P.: Predictive 3D Roll Grinding method for Reducing Paper Quality Variations in Coating Machines. Ph.D. Dissertation, Helsinki University of Technology, 2004.

Multi point systems and the Ozono method

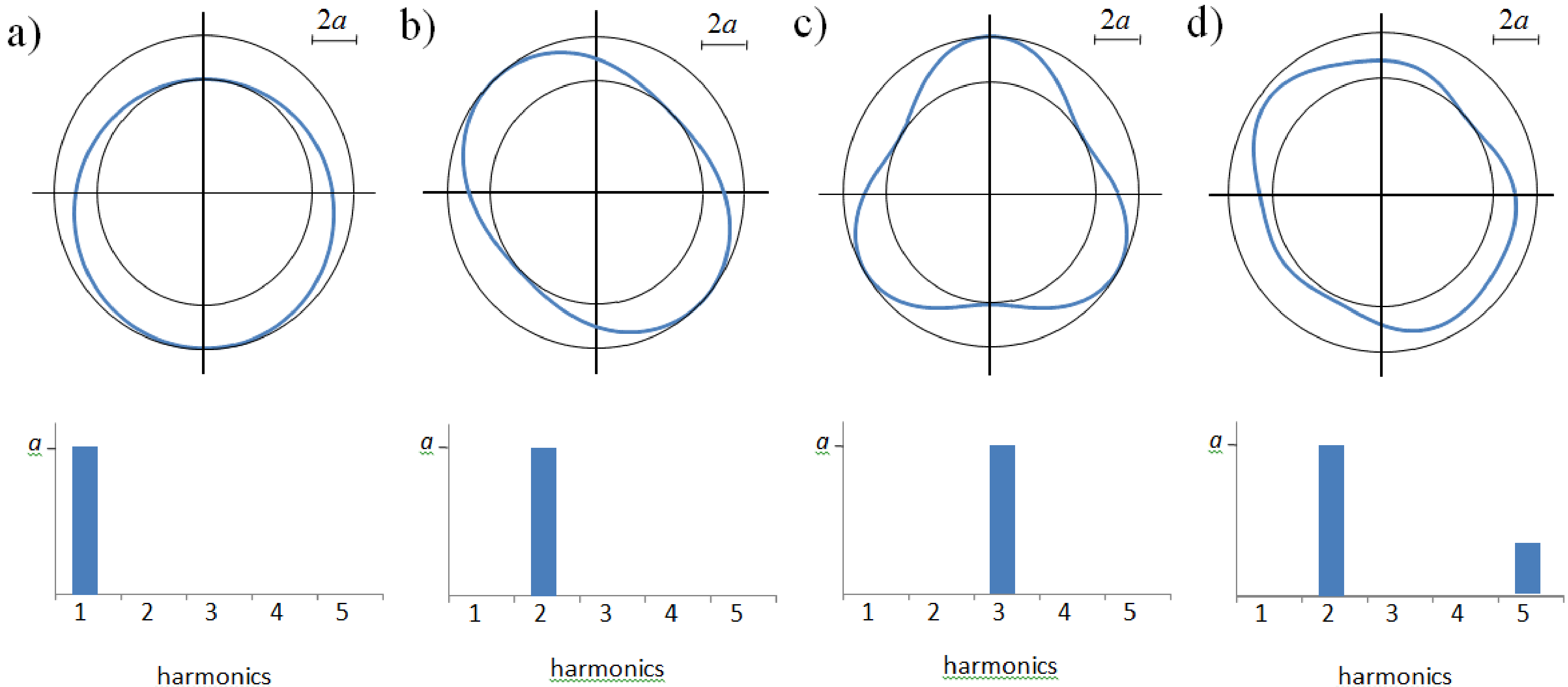


Using Ozono algorithm transducer readings are combined to exclude the errors in rotation

The method is commonly used, but often the traceability and measurement uncertainty are not known

Ozono, S. (1974). On A New Method Of Roundness Measurement On The Three Point Method, Proceeding of the ICPE, pp 457-462, Tokyo, Japan, 1974.

Harmonic amplitudes in roundness



Examples of run-out profiles and their harmonic amplitudes

Roundness standards

Name	Nominal Form	Deviation from nominal form / µm	Surface texture /µm	Diameter /mm	Thickness /mm
Type A	round	2 µm filtered 1-500 UPR	Ra 0.2 Rz 0.9	503	30
Type B	21 UPR with 20 µm amplitude	1 µm	Ra 0.4 Rz 1.2	503	54
Type C	asymmetric multi-wave, 2 to 30 UPR 10 µm / undulation	2 µm	Ra 0.4 Rz 1.2	503+/-1	54

Function of each standard

The type A standard is almost perfectly round.

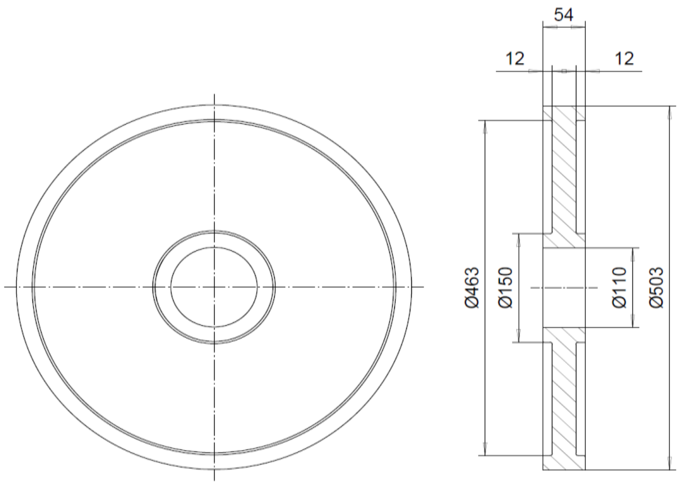
With a roundness error below 2 µm this standard helps to reveal errors like noise and thermal drift

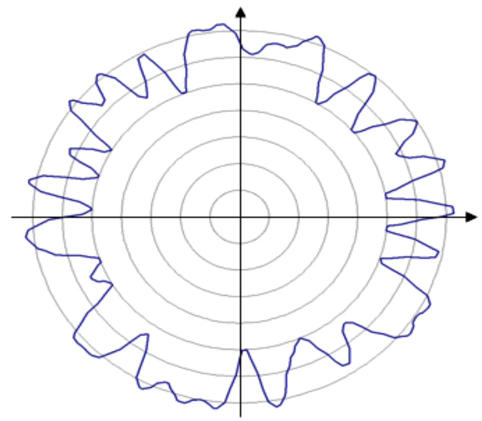
Type B has characteristic form of a 21 UPR wave.

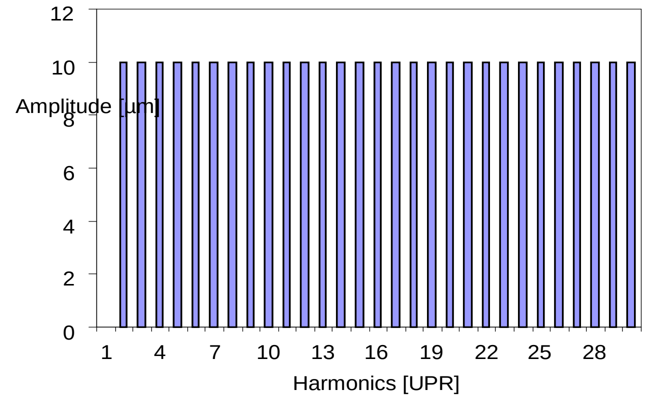
The hypothesis is that the characterisation of a single probe of a multi-point measurement system is straightforward with a disc with single harmonic content.

The harmonic amplitude from the calibration certificate of the disc will be compared with the harmonic measured by a single sensor.

Roundness standard, type C







The type C, asymmetric multi wave, consists of several waves.

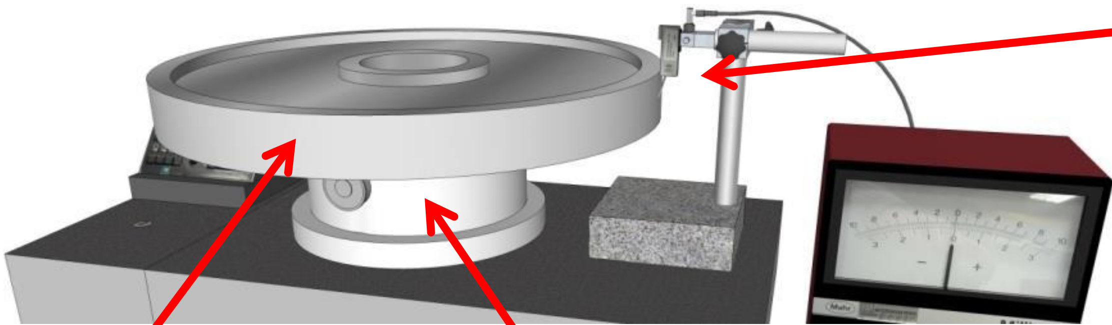
Are expected to work as overall test standard.

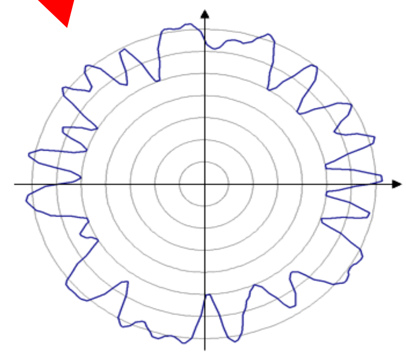
Previously only type C discs have been used in the calibration.

Calibration of the roundness standards

Readings from an inductive sensor gives run-out

Roundness analysis is done by software (centering, FFT)





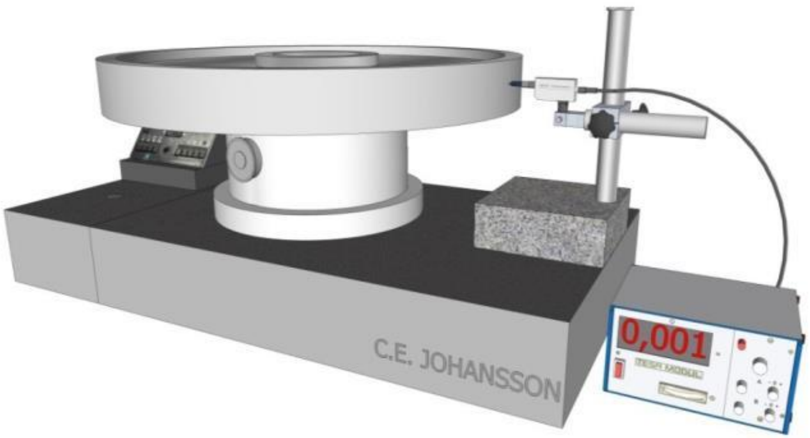
Disc is centered on a rotary table

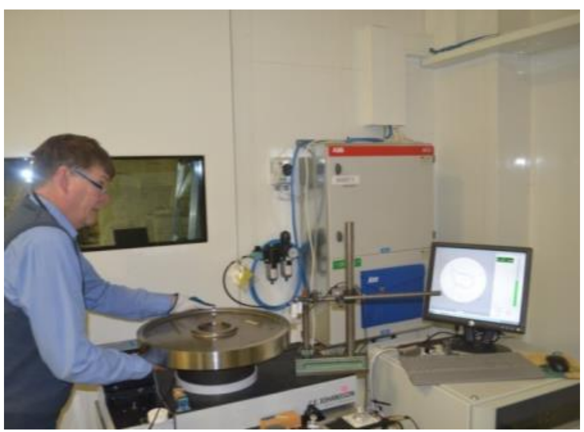
Traceability

Sensor is calibrated against laser interferometer

Radial run-out of rotary table is checked using a very round glass hemisphere (calibrated using error-separation on a separate roundness instrument)

Roundness measurement with modernized roundness instrument





VTT-MIKES Roundness analysis

MIKES METROLOGY

Roundness Analysis

Configuration:

Instrument	C.E. Johansson
Author	AR
Object	B
Serial number	B_27um
Averaging	50 Rounds
Reference circle	Least squares
Filtering	Gaussian 500UPR
Drift correction	No

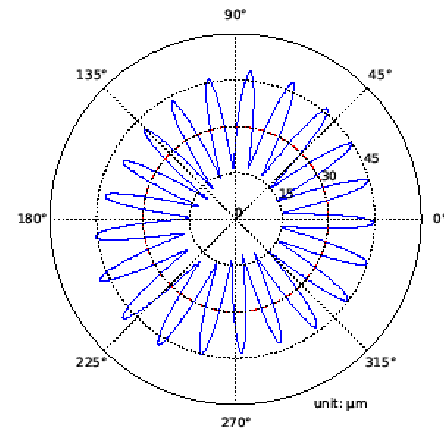
Results:

Roundness error
- RONt 37.0241 µm
- RONv 18.5168 µm
- RONp 18.5074 µm

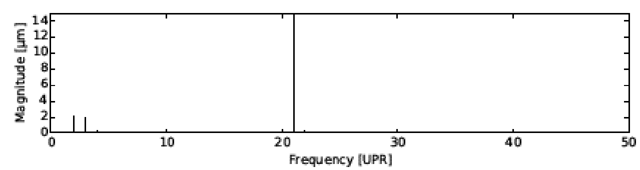
Eccentricity
- Ecc_x -0.474 µm
- Ecc_y -0.055 µm
- Ecc_r 0.478 µm
- Ecc_phi -173.3°

Miscellaneous
- Runout 37.93 µm

Polar plot:

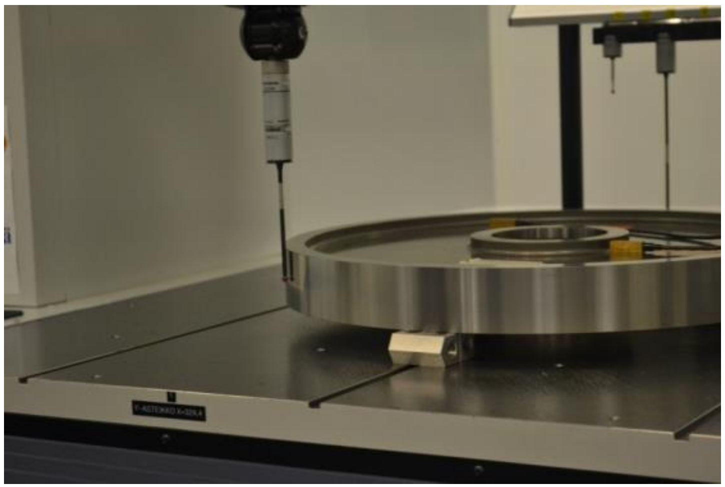


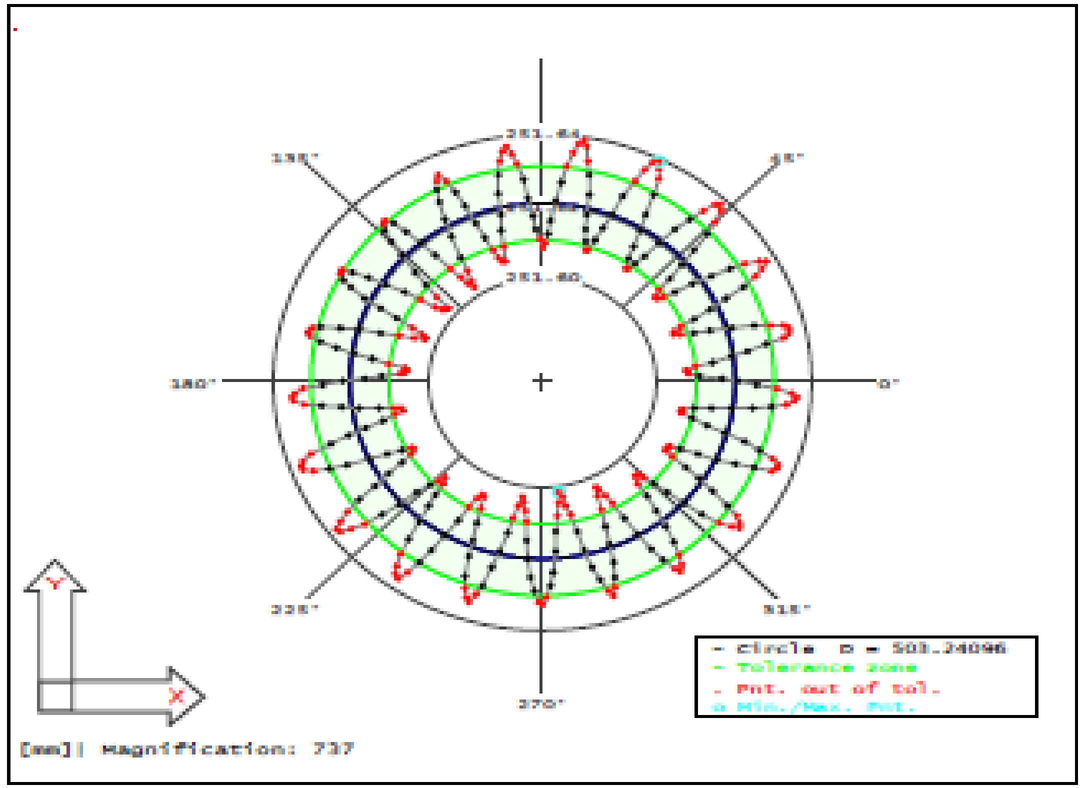
Spectral content:



May 22, 2015

Verification of roundness with a CMM

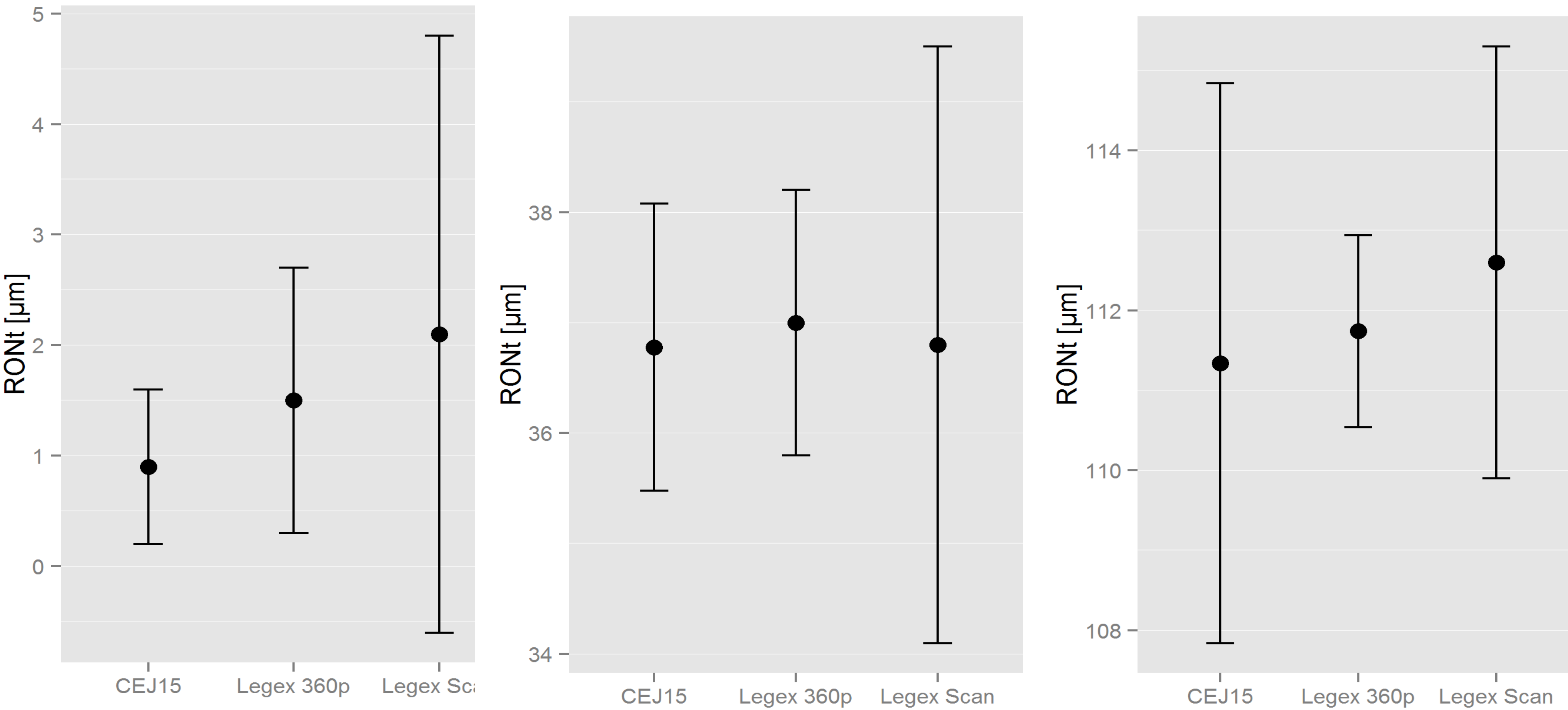




Tolerance zone	Upper tol.	Lower tol.	No. of pts.
0.02000	0.01000	-0.01000	360
Circularity			Min./Max. Pnt.
0.03704			279 / 65

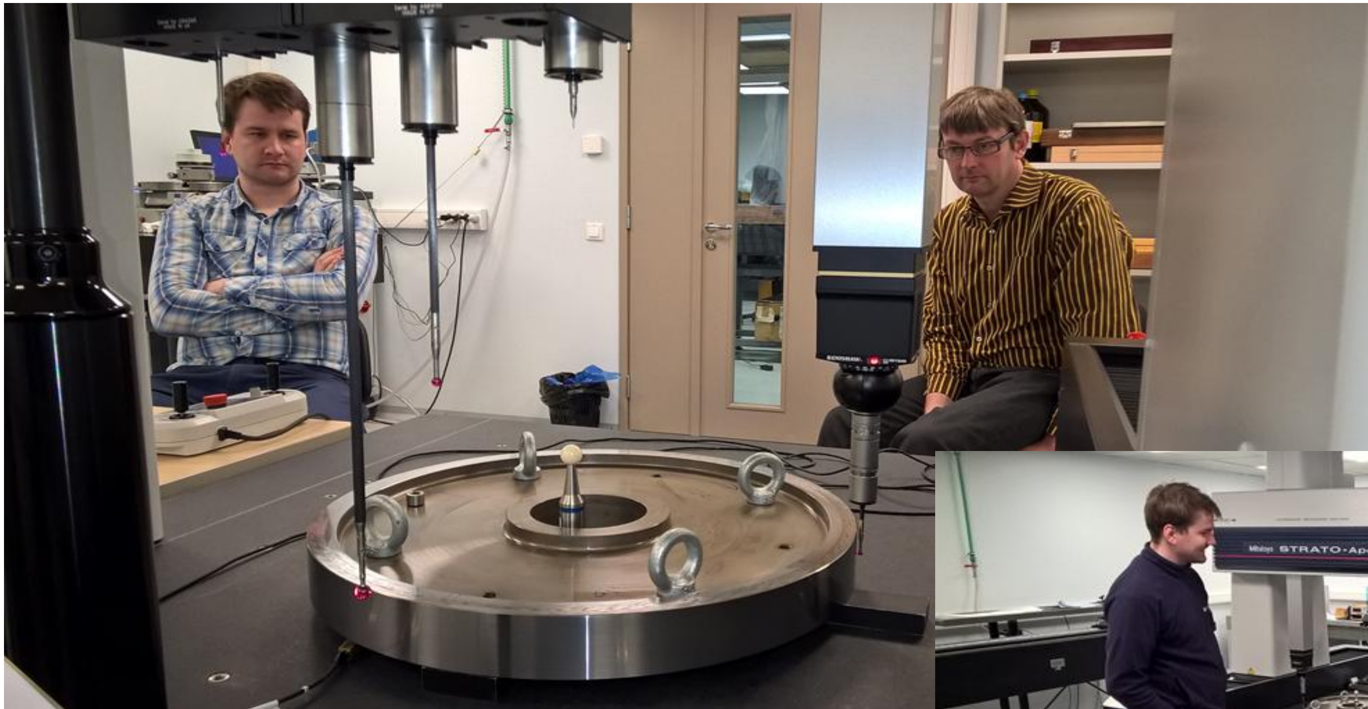
Measurements of the R-MS comparison to CMM

- Disc A   Disc B   Disc C



Measurements of the R-MS

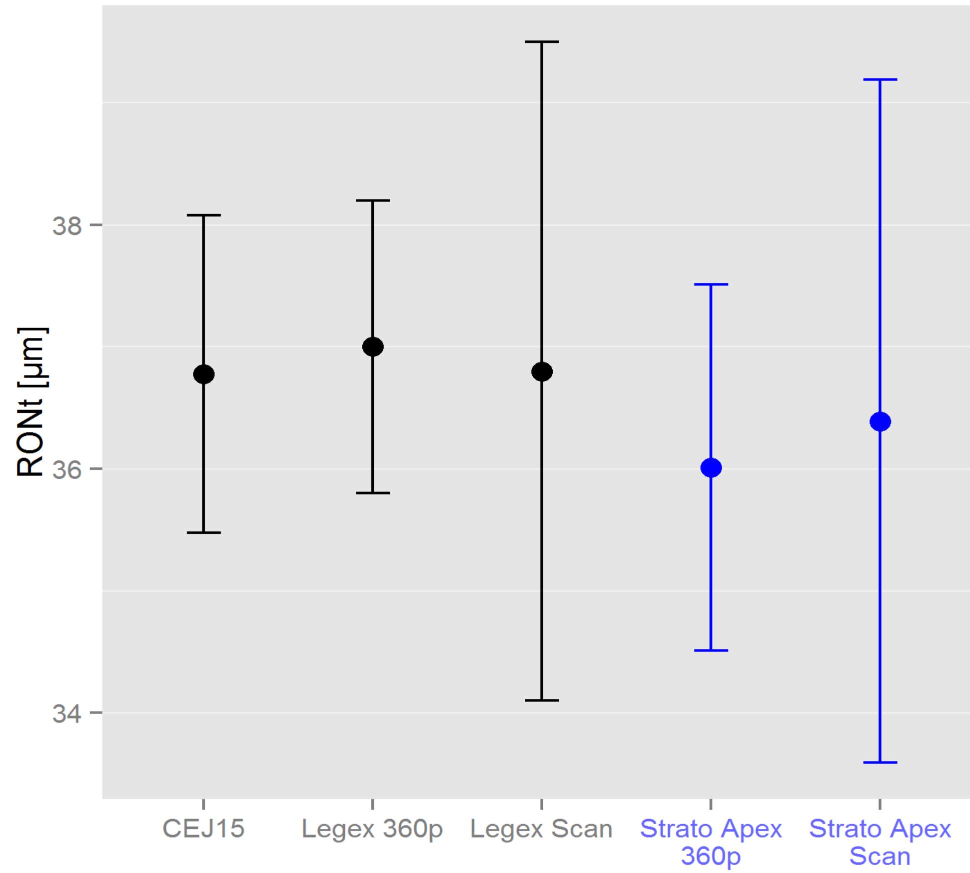
Disc B also measured at Metrosert



Measurements of the R-MS comparison to two CMM's

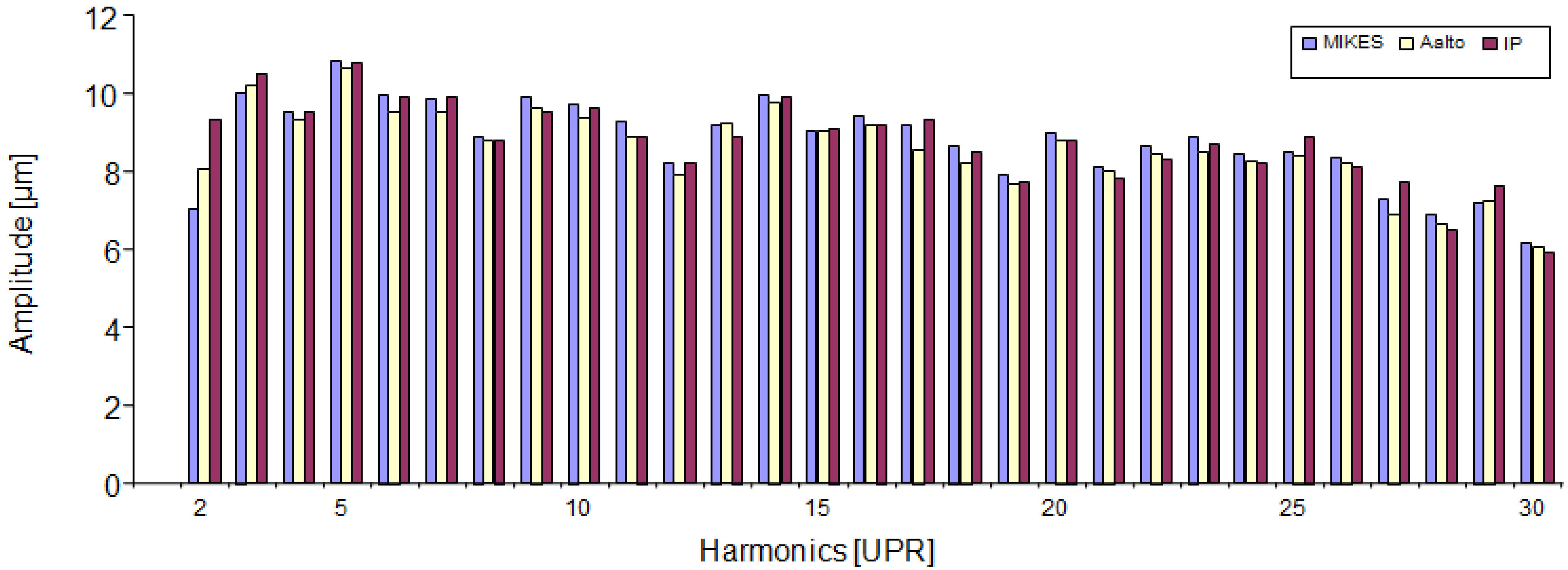
- Disc B
- Also measured at Metrosert
- Variation of results within +/- 0.5 µm

- Conclusion
- Disc B is a robust material standard



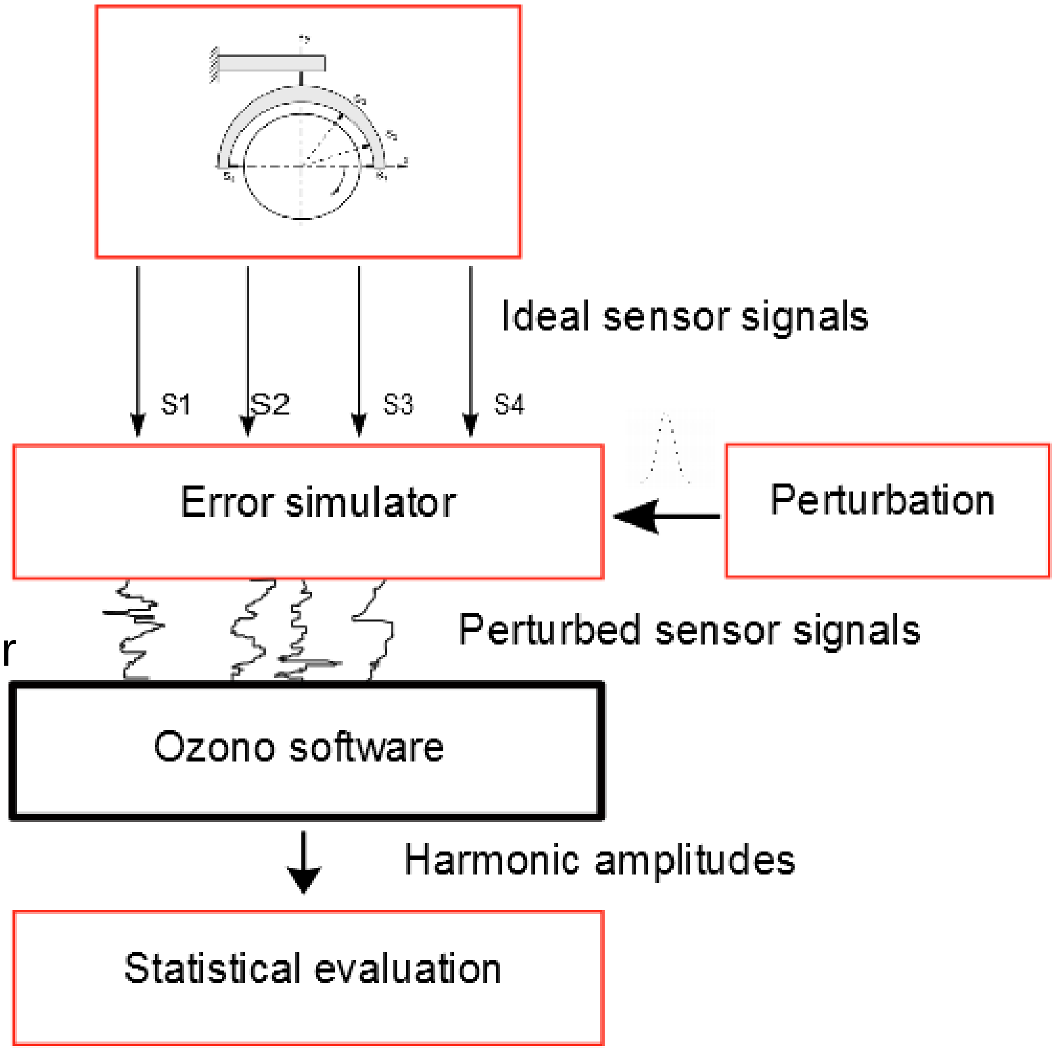
R-MS, type C

Measurements at MIKES, Aalto and industrial partner (IP)



Task specific uncertainty for harmonic amplitudes

A script written in Python and generates a large number of input data files (synthetic data representing a roundness measurement, distorted with suitable distributions for error contributions),

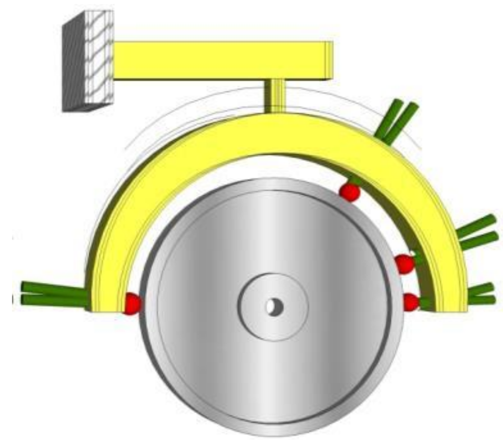


The Ozono algorithm doing the calculations for the four point method was acquired from Rollresearch as a executable program.

Output file is read by a Python script and after many runs the standard deviation and other statistical properties are evaluated

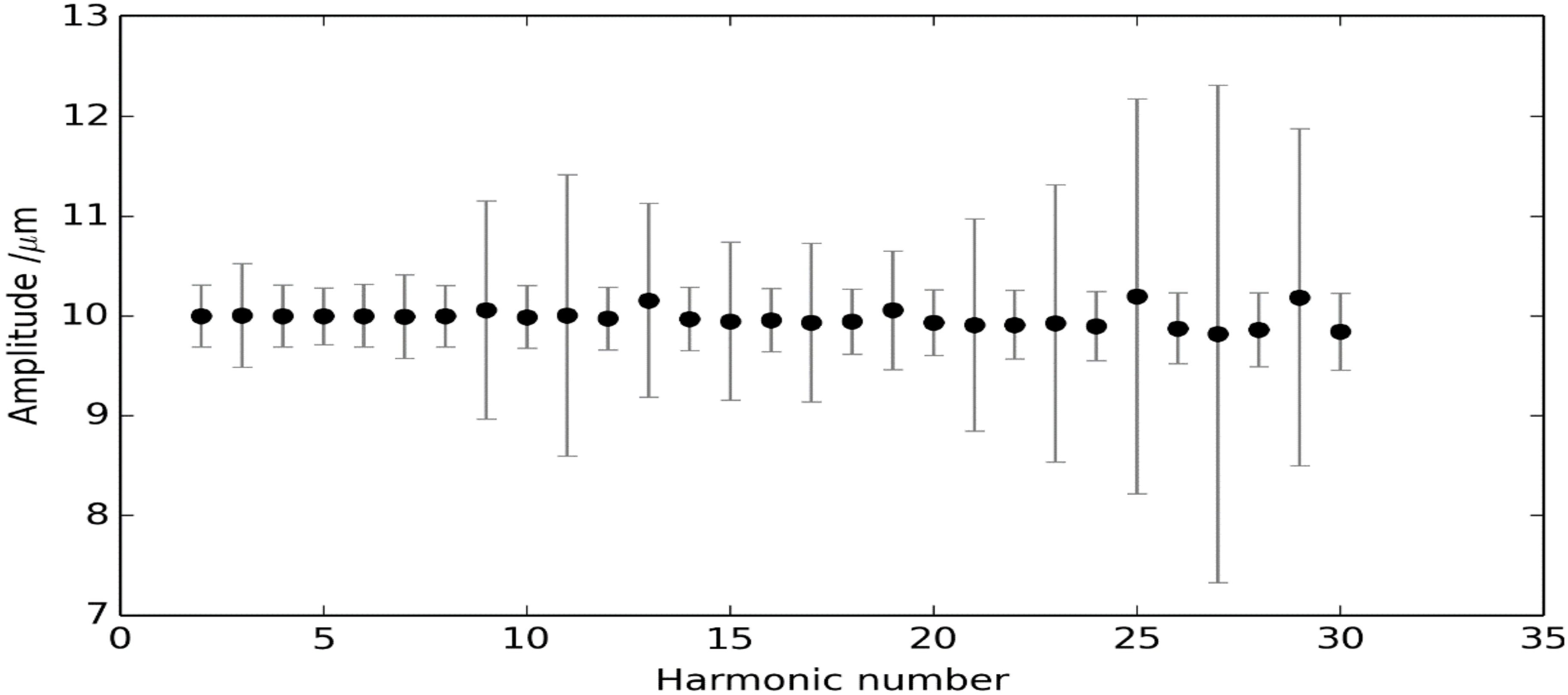
Task-specific uncertainties for measurements of rollers, preliminar uncertainty contributions

- The assumed errors are alignment error of one degree for length transducers.



- Scale error of +/- 0.5 µm for length transducers
- temperature change of 0.5 °C are assumed
- Note: it is impossible to do a single uncertainty estimate that works for all conditions, situations and users around the world

Result of Monte Carlo simulation



Output from Monte Carlo simulation (N = 10 000) where standard uncertainties are shown as error bars.

Mean values noted as ball deviates from the true value of 10 µm mainly because of limitations in the four point algorithm.

Conclusion

- New traceable material standards
- Procedure developed for task specific uncertainties
- Values for uncertainty components show reasonable agreement with measurements of R-MS
- No knowledge of previous published work on uncertainty evaluation for industrial roller measurements