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TRACEABILITY FOR ROUNDNESS MEASUREMENTS OF ROLLS - European Metrology Research Programme, project No. IND62

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Abstract: *The roundness of rolls is critical for the operation of the paper machines and for the rolling mills in the steel industry. Therefore the rolls are periodically reground and roundness measurements are made throughout the grinding process. During the last decades several manufacturers have developed measurement systems for large rolls of diameter 500 to 2000 mm. The multi-point measurement algorithms of the systems are typically based on measurement algorithm by Ozono. The advantage of this method is that it can separate the movement and the geometry of the measured rotor, i.e., roll. From a metrological and quality perspective every serious measurement should be traceable and every measurement result reported together with an estimation of measurement uncertainty. Therefore, calibration discs are developed and traceable calibrated in laboratories of MIKES and Metrosert with a known measurement uncertainty. By measuring these standards by multi-point roundness instruments in industry new procedures to get traceability for roundness measurements of rolls, will be developed.*

Keywords: metrology, roll, roundness, calibration

1. INTRODUCTION

Roundness is an important feature for all rotating machines where smooth rotation of the rotors or even surface quality and even thickness of the end product is needed, such as paper machines, printing machines, engines and generators etc. In length measurements diameter is often measured as a two point measurement which is affected by out of roundness of the part. Therefore measurements of roundness are also useful when the specific diameter is critical or important.

In paper mills the roundness measurements are commonly carried out when the roll is located on a lathe or on a grinding machine (Fig. 1). There the heavy rolls are rotating with their own bearings or they are supported by sliding pads. With this measurement setup it is difficult to avoid a rotational error of the centreline of the roll, and thus one or two point measurement methods cannot separate the rotational error movement of the workpiece from its geometry. This is the reason for the usage of multi point measurement devices in the paper industry [1]. Most of them are based on the Ozono[2] method.

In the steel industry the roundness tolerances of the rolls are not as tight as in the paper industry, and thus the common measurement device there is a two point measurement device. [3-6].

The reliability of a measurement instrument is ensured by calibration. Ideally the calibration is performed using traceable calibrated measurement standards with a stated calibration uncertainty for the given reference values.

Fig. 1. Four point roll measuring device of a grinding machine.[1]

This gives the possibility for the end user to make traceable measurements with a known measurement uncertainty. As a part of an EMRP project “Traceable in-process dimensional measurement” calibration discs are developed and manufactured. The design of these discs is presented in this paper. The evaluation of measurement uncertainty will be presented in a future paper.

2. MATERIAL ROUNDNESS STANDARDS

Roundness material standards are needed when calibrating a roundness measuring device. There are two main categories of standards:

- standards with nearly zero roundness error
- sensitivity standards or magnification standards with intended form error

Typically the size of parts which need to be measured at high accuracy have diameters in the range 1 to 500 mm. This means that most measurement equipment are built for this range and as a result from this is that roundness standards have nominal diameters in the range 20 to 100 mm. In Fig. 2 a typical laboratory roundness measurement setup is shown. The standards used in metrology laboratories are too small to be used to calibrate large roundness instrument intended for diameters at several meters. Therefore the needs of industry are not met by existing roundness standards.

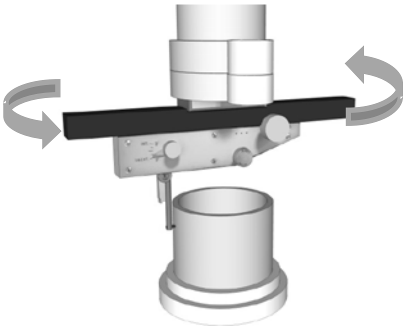

Fig. 2. Measurement of roundness.

2.1. Hemispheres

In roundness metrology glass hemispheres are manufactured to be as round as possible (Fig. 3). Typically they have roundness errors in the range of some tens of nanometres. They reveal radial errors in the rotation or axial reference for the roundness measurement.

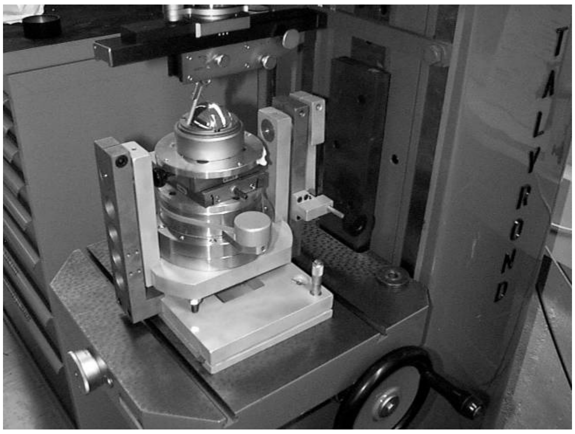

Fig. 3. A hemisphere at a roundness measurement instrument.

2.2. Flick standards

Flick standards are cylinders with a flat part (Fig. 4). The flat feature of the otherwise round cylinder makes an inward out of roundness. The magnification error or sensitivity of a roundness instrument can be calibrated by measuring the Flick standard. Flick standards can be compared to gauge blocks. Similarly to the typical use of gauge blocks, one or two standards are not

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[1] RollResearch Int. Ltd.

enough and quite a large set of Flick standards is needed to check the magnification error of a roundness instrument. Although the geometry of a Flick looks simple it is non-trivial to calibrate [7].

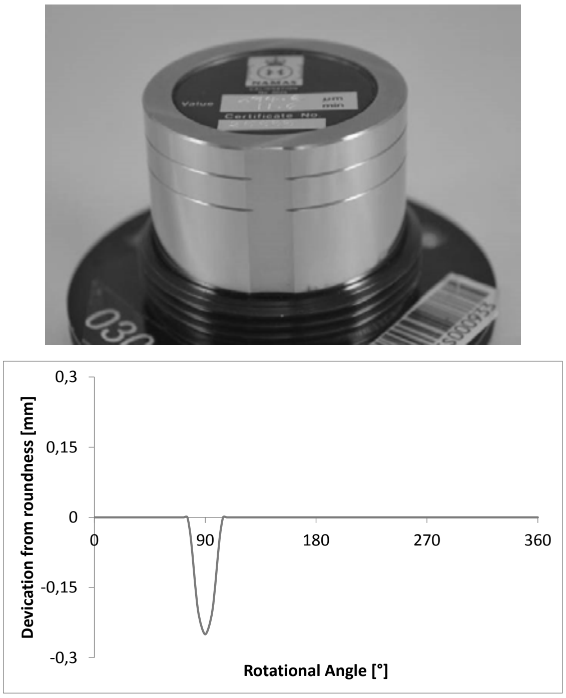

Fig. 4. Flick standard[2] above and below deviation from roundness.

All Flick standards are of plug-type intended for external measurement. In all roundness measurements the selection of filter affects the results and this is especially true for Flicks. As roundness is a measurement of form, short-wave roughness is usually filtered out. In a roundness plot the Flick area appears as a deep valley and is therefore reduced by any filtering. The frequency content of a Flick makes it not ideal for equipment relying on the Ozono method where analysis is done in frequency domain.

2.3 Ellipse standards, single wave

The ellipse standard is a cylinder with an elliptical form error. This form error linearly depends on the height (Fig. 5). At MIKES two standards are used. One with roundness error in range 5 to 30 µm and another with roundness error in range 35 to 300 µm. If the roundness instrument is able to measure at different heights automatically, a large amount of roundness results can be plotted quickly.

A drawback is the critical dependence between position (height) and magnitude of elliptical form. The uncertainty in the height produces an uncertainty in the reference value

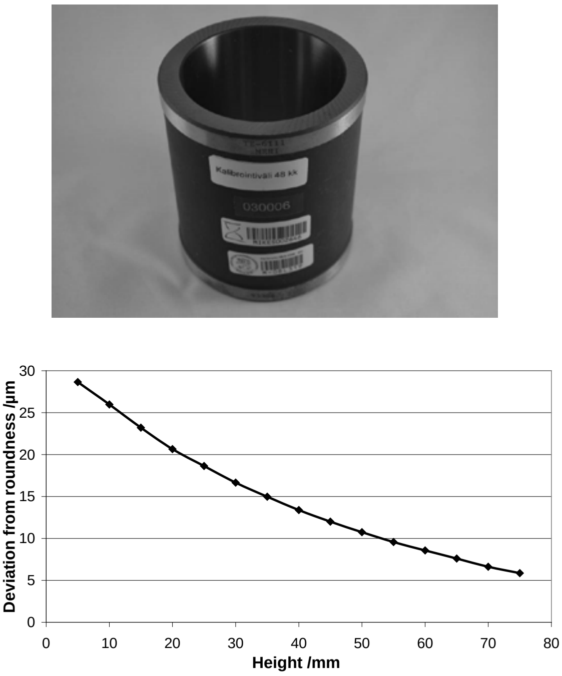

Fig. 5. Ellipse standard with internal cylinder above and below deviation from roundness.

2.4 Multi-wave standards

A recent example of multi-wave standards (MWS) are those developed by Fraunhofer Institute for Production Technology (IPT). Their profiles contain a superposition of sinusoidal waves with wave numbers 5, 15, 50, 150 and 500 UPR (undulations per revolution). The advantages of MWS compared to Flicks are better signal to noise ratio and low sensitivity to noise in measured profiles [8]. A Euramet comparison of a Flick standard and MWS showed that the spectral analysis (harmonics) of MWS leads to good agreement and stability [8].

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[2] V-P Esala

2.5. Asymmetric multi-wave

The asymmetric multi-wave standards have been developed to calibrate large roundness measuring machines based on the Ozono-method. These machines are used when rolls in paper- and steel industry are grinded in the production process (Fig. 6). There the grinding process is often controlled according to the measured geometry data. The measuring range for diameter is 300 to 2000 mm.

As with MWS these discs have waves but the shape is not symmetric (Fig. 7). The shape and the waves are found suitable for the Ozone method. Because of the large size typical roundness measuring machines cannot be used for calibration. Instead either CMM or specially built setups for roundness measurement must be used.

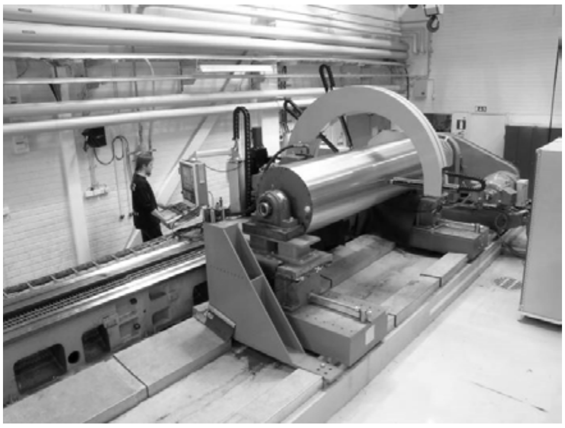

Fig. 6. Four-point measurement instrument.

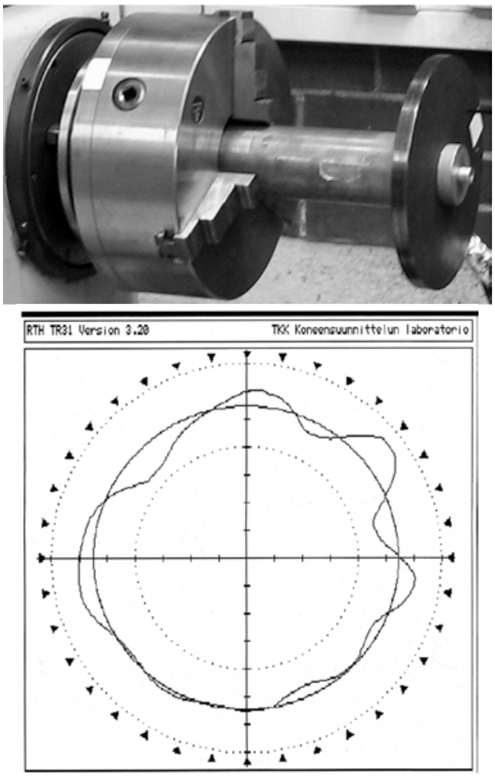

Fig. 7. Disc above and below roundness plot [4].

3. PROPOSED ROUNDNESS STANDARDS

The measurement standards are intended to quantify error sources found in large measurement systems that are based on the Ozono method. The developed measurement standards are also useful for calibration of two-point and one-point measurement systems. The error sources which are expected to be found are errors of the transducers, angular orientation error and positioning error of transducers. Thermal expansion and vibration of the measurement frame (Fig. 8) are other possible error sources.

The algorithm of the measurement systems have already been validated by simulation, but functional testing is possible and valuable to perform with the developed discs.

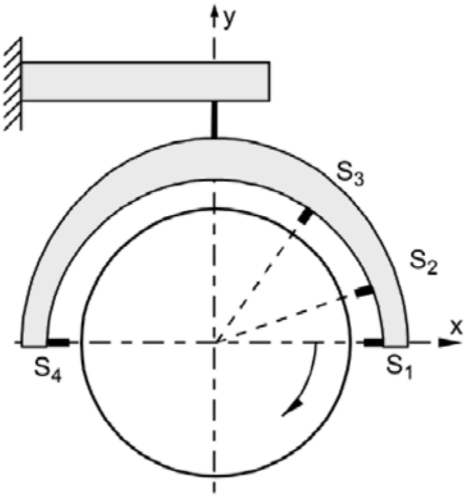

Fig. 8. Typical orientation of probes in a four-point measurement systems

All standards are discs with the diameter of 500 to 550 mm. This is the largest diameter that can be easily measured in laboratories and not too small to be measured by in process roundness measurement systems in industry. Larger discs were also considered but weight and handling would bring problems. The thickness of the discs will be 30 to 50 mm which is enough for robustness and yet not too heavy to handle. The types and requirements of the selected standards are shown in Table 1.

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.

Name	Form	Roundness error / µm
Type A	round	0 to 2 µm
Type B	21 UPR	20 to 25 µm
Type C	asymmetric multiwave, 2 to 30 UPR	10 µm / undulation

Table 1. Requirements for the measurement standards.

Type B is selected as it has one 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 type C, asymmetric multi wave, consists of several waves. Standards of this type have previously been used and they are expected to work as overall test standard.

Previously only type C discs have been used in the calibration. However it is assumed that using multiple discs different types of error sources can be evaluated.

All standards will be calibrated by roundness measuring instrument with a rotary table. Additional measurements to get other form errors like cylindricity will be done in a CMM.

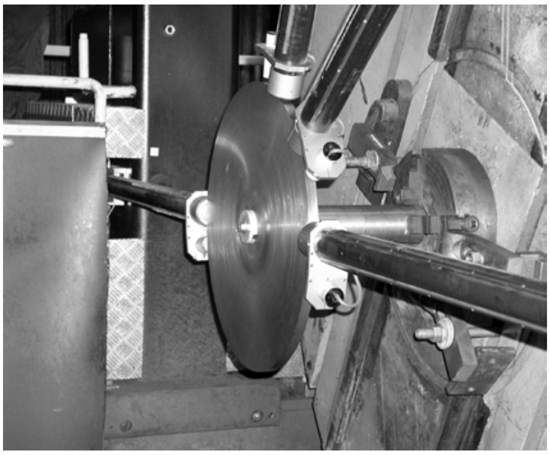

Fig. 9. Calibration of a multi-point roundness measurement device.

7. CONCLUSION

The Flick standard is the most used type of magnification standard for one-point roundness instruments, but is not ideal with multi-point instruments.

The diameters of the most roundness standards are below 500 mm and are intended for use in metrology laboratories and are not suitable to ensure traceability for measurement of large parts in industry. Some asymmetric multi-wave standards are large and already used in paper- and steel industry. Other standards proposed in this paper will be manufactured. In future tests with these standards will be performed in the industry. Using all these standards traceability will be achieved and uncertainty for roundness will be evaluated.

ACKNOWLEDGEMENT

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