

TRACEABILITY OF THREAD RING CALIBRATION ON A CO-ORDINATE MEASURING MACHINE

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Abstract: Thread rings are widely used for screw thread gauging. They can be calibrated on 1D measurement machines with ball probes, by using control thread plug gauges, or on three co-ordinate measurement machines (CMMs) by using special probes and software. The last method is used in our laboratory for calibrating rings from 5 to 300 mm. The calibration procedure based on this method was accredited by RvA which is EAL member and signatory or MRA. The basic problem by creating the procedure was traceability of the CMM measurement. Since the CMM is used as a calibration device in this case, simple periodical performance tests are not sufficient for assuring traceability at a certain level of uncertainty. Therefore, a special substitution method [1] was involved. Reference standards in the substitution procedure are gauge rings, which are calibrated on 1D measurement instrument by using laser interferometer as the linear measurement system. Reference values are set by combination of gauge blocks. Basic approaches are presented in the paper.

Keywords: traceability, calibration, screw thread ring

1 INTRODUCTION

Gauge rings are calibrated in our laboratory with the CMM using special "T" shaped probes. Measurement range is limited by the probes and by measurement range of the CMM to 6-300 mm. Calibration procedure is accredited by our national accreditation body and by RvA from the Netherlands. Traceability is assured with gauge rings that are used as reference standards in the procedure. Calibration is performed with a substitution method, where measured pitch diameter is compared with the diameter of a gauge ring.

2 CALIBRATION PROCEDURE

The calibration is performed in the following order:

- gauge ring is fixed into the rotary table of the CMM (gauge axes is parallel with the z axes of the coordinate system) in the approximate machine coordinates $x = 400$ mm, $y = -800$ mm, $z = -400$ mm,
- T-shape probe is chosen in accordance with measured thread gauge (Table 1) and calibrated on the ball $\Phi 5$ mm.
- the gauge ring is probed in zero plane in 4 points as shown in Figure 2 - circle with diameter $d_{r_{izm}}$ is calculated through measurement points,
- diameter is compared with the calibrated diameter of the gauge ring d_r and the difference $e_d = d_{r_{izm}} - d_r$ is calculated,
- the thread gauge is fixed into the rotary table of the CMM (gauge axes is parallel with the z axes of the coordinate system) in the approximate machine coordinates $x = 400$ mm, $y = -800$ mm, $z = -400$ mm,
- thread gauge is probed in 4 points T_1 to T_4 (see Figure 2) using self-centering procedure for positioning the probe in the center of the gap (see Figure 1) - circle diameter is calculated. This diameter is uncorrected measure over-ball $M_{izm,0}$,
- measure over-ball is corrected for the value e_d :
$$M_{izm} = M_{izm,0} - e_d$$
,
- measure M_{izm} is recorded in the record sheet.

Table 1. Dimensions of probes in accordance to pitch of measured screw thread

Pitch P [mm]	Dimensions of the probes Diameter of probing ball [mm]
0,5	0,3
0,8; 1,0	0,5
1,25; 1,5; 1,75	0,8
2,0; 2,5	1,35
3,0; 3,5	1,8
4,0; 4,5	2,3
7	3,5
8	4

The diameter of the reference gauge ring may differ from the diameter of the thread ring for at most 10% in order to get reliable values.

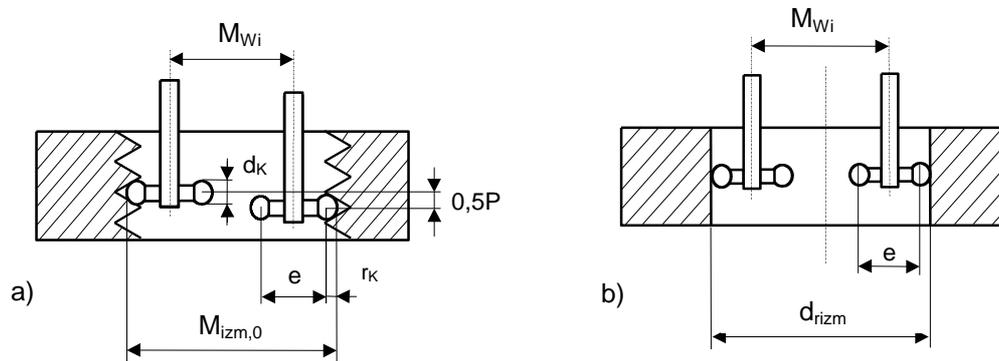


Figure 1. Probing procedure for the thread ring and the gauge ring

The pitch diameter is calculated from measured value, ball diameter, indentation and the pitch. The ball is measured on 1D instrument using laser interferometer as measuring system. Different indentations by ball calibration and the thread measurement are considered. They were calculated using Roark's formulae and material properties (ruby ball, hard metal probes) given by the producers. The results were checked by an experiment.

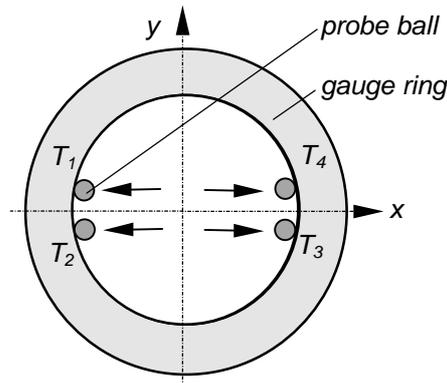


Figure 2. Probing points on gauge ring

3 TRACEABILITY CHAIN

Traceability of the calibration procedure is assured by "calibration" of the CMM with the gauge ring (task related calibration). The gauge ring is calibrated with 1D instrument where laser interferometer is used as a linear measurement system and gauge blocks are used for setting reference values. Laser interferometer is traceable to an European national laboratory and the gauge blocks are traceable to primary standard. An additional calibration is necessary for the probe balls made of ruby. The ball diameter is used for the calculation of the pitch diameter. Traceability of this calibration is assured by using laser interferometer as measurement system.

4 UNCERTAINTY CONTRIBUTIONS

4.1 Uncertainties of different calibration levels

Each calibration in the traceability chain has evaluated uncertainty which is used in the uncertainty budget of the lower level calibration. Uncertainties are evaluated according to ISO guide (GUM) and [4]. Uncertainty of the substitution method is evaluated from the uncertainty of the gauge ring calibration and the statistical evaluation of standard deviation by the correction factor calculation. Uncertainty budgets, which also include other influences, like environmental conditions and readings of the results are included in calibration procedures. The values are shown in Figure 2.

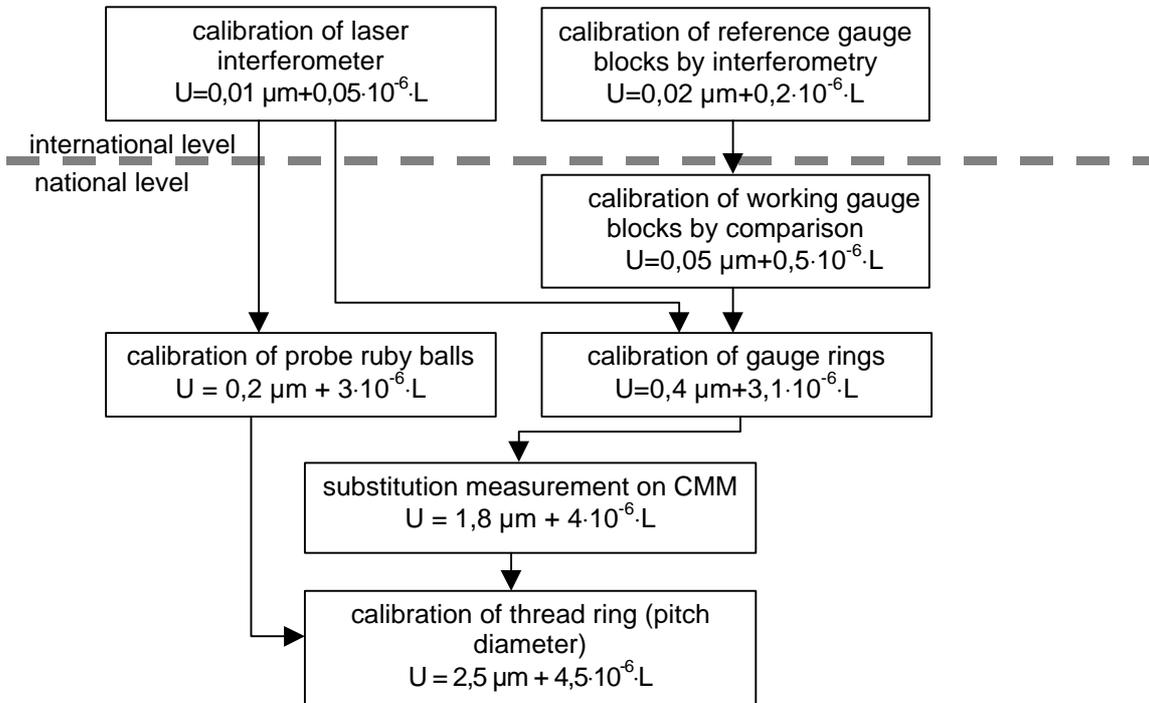


Figure 3. Traceability chain with uncertainties of calibrations

The uncertainty of the gauge ring calibration will be reduced by using reference gauge rings instead of gauge blocks for setting of 1D instrument. In that case additional calibration of reference gauge rings would be necessary on international level.

4.2 Evaluation of uncertainty of the substitution method on CMM

Global principle of the calculation of uncertainty is shown in Figure 4.

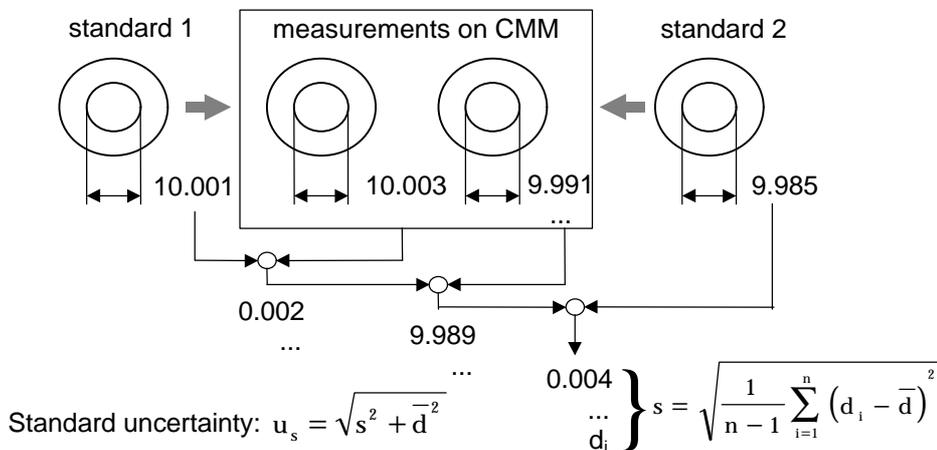


Figure 4. Determination of uncertainty of comparative measurement on CMM

Two slide different standards (or a standard and a measuring object of known dimension) can be used for determining uncertainty at certain dimension. The uncertainty must be determined at approximately same place in the measuring volume as the measurement that follows (same plane - e. g. xy, same co-ordinates and the same orientation of standards). Temperature influences are not considered in Figure 4. Measurements of standards should be repeated at least ten times in order to determine standard deviation.

5 INTERCOMPARISON

An intercomparison between the National laboratory of Croatia that is located at the University of Zagreb, accredited Slovenian calibration laboratory STO Ravne and our laboratory was performed in April 2000 in order to evaluate the calibration procedure and the uncertainty claim.

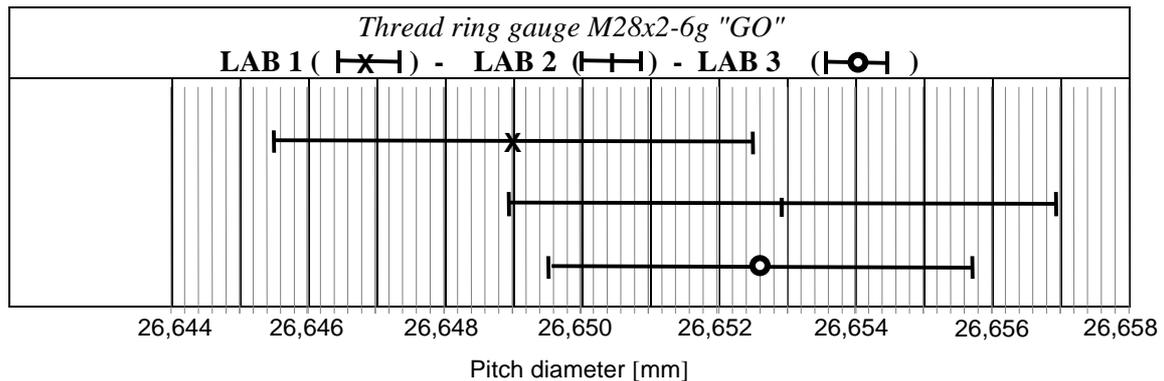


Figure 5. Graphical presentation of the intercomparison results for screw thread gauges

The results show that all the laboratories are able to perform calibrations with stated uncertainties although different methods were applied in different laboratories. Measurements in our laboratory were performed on a CMM, whether in the other two laboratories they were performed on universal length machines using special screw thread kit. The results are shown in figure 3. Our laboratory in this figure is LAB 3

6 CONCLUSIONS

The calibration procedure for thread rings was made in the year 1997 and was tested on several gauge rings before applying for accreditation which was granted in the beginning of 1999. Intercomparison measurements for proving uncertainty claim were performed on base of bilateral agreement between Slovenian and Croatian national laboratories and has shown good results. The uncertainty of the substitution procedure was proved by statistical evaluation in accordance with [1]. Repeated tests are performed periodically. The claim in the calibration procedure and in Figure 3 represents the "worst" case. Additional research is performed in the field of ball indentation under different flank angles. Experiments are performed with different measurement forces on 1D measurement instrument and are compared with analytical results.

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