ROUND ROBIN TEST ON THE CALIBRATION OF MATERIAL TESTING MACHINES (ISO 7500-1)

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Abstract:

This paper describes two ISO 7500-1 round robin tests in Germany, which were undertaken as a tool to meet the requirement of ISO/IEC 17025:2017 for interlaboratory comparisons. Up to 40 accredited laboratories calibrated the force measuring devices of different material testing machines at the IfEP, the Institute for Proficiency Tests. The method, uncertainty calculation and results of the round robin tests are described here.

Keywords: round robin test; ISO 7500-1; material testing facility; force measuring device

1. INTRODUCTION

Section 7.7.2 of ISO 17025:2017 [1] demands that accredited laboratories participate in interlaboratory comparisons. In Germany, such intercomparisons for material testing machines were formerly organized between single labs. However, these tests always remained within a limited circle of cooperating laboratories. To enable a round robin test within the range of nearly all the accredited laboratories in Germany, the German Calibration Service's (DKD's) Technical Committee for Materials Testing Machines decided to realize such a round robin test. This test was carried out by the IfEP, which also provides the machines to be calibrated. PTB agreed to support the interlaboratory comparisons by calibrating these machines using a special procedure and providing an uncertainty budget to define a reference indication deviation q with its related uncertainties. The results were compared with the calibration results of the participating laboratories.

2. DESCRIPTION OF THE WORK

In the first two comparisons realized to date, the force ranges up to 20 kN and 100 kN in compression and up to 50 kN and 100 kN in tension were selected. The decision about these ranges was made within the DKD's Committee for Materials Testing Machines. The aim was to select a force range covered by most of the participants' accreditations.

Within the DKD committee, a time schedule for future round robin tests with all relevant measurands was established to meet the demands of ISO 17025:2017. The last (and up to now also the second) comparison was planned for 2020. Due to the pandemic situation, it was however only realised in the autumn of 2021.

This round robin test contained the static calibration of the extensometer system of the testing facility. Many laboratories with an ISO 7500-1 [2] accreditation are also accredited for ISO 9513:2013. Furthermore, the time frame for the work at the machines was about six weeks.

For the first comparison, a Zwick "Z250/SN5A Universalprüfmaschine" and a Hegewald & Peschke "inspekt desk 20 kN" were used. The second comparison was realised using a Zwick/Roell "100 kN allround table top".

For the ISO 7500-1 comparison, the aim was to define a reference indication deviation. Therefore, PTB selected a set of transfer standards with a well-known history and a low drift. The transducers were calibrated according to ISO 376:2011 [3]. First, the transducers were used to check the general suitability of the testing facilities at IfEP. The repeatability, reproducibility, hysteresis and zero return of the force indication of the machine were checked. The values were surprisingly good. As an example, the machine used for the second round robin test could enable a repeatability and reproducibility that were lower than 0.01 % at 10 % of the nominal load. This could be achieved using a high-quality transfer standard.

The machines were then completely calibrated (in line with ISO 376:2011) at the beginning and the end of the round robin test. In addition, between the work of single participants, single measurement series were observed to check the stability of the machine and to detect any possible failure during the comparison. These series were also performed to calculate the stability variance of the machines' indication system – based on a wide variety of observations.

For the determination of the indication deviation q, it was important to reduce influences by mounting parts. The decision was taken to build special adaptation parts for the material testing facility (shown in Figure 1) in which the same ballnut/ballcups and tension rods can be used. This process is thus similar to the transducer's calibration at PTB. Using these adaptation parts, the aim was to investigate the material testing facility with the same equipment which was used in the force standard machine (FSM) in PTB. This was undertaken, as it is known that sometimes, especially in the case of tensile measurements, different mounting parts can result in deviations up to 0.005 % at a nominal load or 0.01 % at a 20 % load. Such deviations are just caused by manufacturing tolerances of tension rods as they are screwed into a transducer. This effect can also differ with different transducers of the same type. A model of the same type with two pairs of mounting parts that were identical showed exactly half of the values stated above. However, this might not be interesting for laboratories with accredited uncertainties in the 0.1 % range. After all, all uncertainty sources should be kept as small as possible to result in a low uncertainty of the resulting indication deviation stated by PTB as a reference for the participants.

Figure 1: Picture of the machine to be calibrated and the mounting parts for the ballcup/ballnut used during the force transducer calibration in the FSM

Within the measurements, a surprisingly relevant effect could be detected. The connection of the force application parts towards the machine and the reference transducer is made via a bolt, which is countered with a preload nut. Despite vigorous tightening of this counter screw without preloading the machine, there was a relatively high reversibility at first. Regarding the linearity deviation relative to the nominal load, it could be stated that there is a strong, nearly linear increase over the first 20 % of load. Afterwards, the value stays relatively constant. Next, the counter screw was tightened under maximum load. In this case, the transfer standard acts as it does in the FSM. The reason for this behaviour might be alignment problems because when loaded, the elastic deformation will soon overcome the preload realized by the preload nut. Normally, it is recommended to tighten the counter screw under load, but it could be clearly seen if this hasn´t been done correctly – and this might result in critical deviations. Figure 2 shows the maximum detected deviation caused by this mounting effect, measured with the 50 kN transfer standard during the second round robin test.
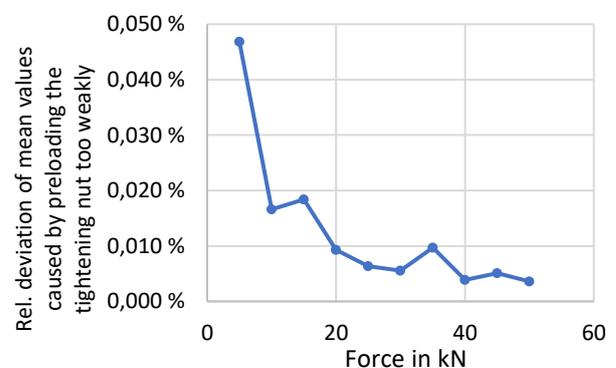

Figure 2: Deviation caused by tightening the counter screw at zero or nominal load

ISO 7500-1, Annex A, requires a general inspection of a testing machine. This was witnessed during the work of the laboratories, including the detection of some issues. To ensure that the participants do not feel distracted by the organisers, students were engaged to witness the work using a questionnaire on typical aspects of the work. The questionnaire included points on inspecting the machine, preparing the measurement chain, correctly mounting and assembling parts, and the correct time schedule (such as taking the zero value after 30 s). During the second round robin test, it was decided not to undertake witnessing because of the corona virus situation.

After this work, all the participants submitted a final calibration certificate as the final result of their work. It was reviewed by experts from IfEP and PTB.

3. CALCULATION OF THE UNCERTAINTIES

Mean values are often used as reference values for round robin tests. For this particular test, the aim

was to define a reference value with direct traceability to the SI units. Any influence of a participant's mean value caused by the laboratories calibrating the participants' force transducers was to be avoided.

When realising such an extensive test, it would not be enough to just use a single ISO 7500-1 calibration for the determination of q. A procedure was thus developed using several ISO 376 calibrations at PTB and in the testing facility. The results were compared and the deviation between both results can be safely used as the reference indication deviation q_{PTB}. This reference indication deviation needs an uncertainty model according to the GUM. A sum model was set up, combining several uncorrelated uncertainties as shown in equation (1). The single components and the way they were estimated will be explained in the following.

$$w_{q_{\mathrm{PTB}}} = \sqrt{w_{\mathrm{TS}}{}^2 + w_{\mathrm{drift\ TS}}{}^2 + w_{\mathrm{temp}}{}^2 + w_{\mathrm{rot}}{}^2 + w_{\mathrm{res}}{}^2 + w_{\mathrm{drift\ and\ repeat.\ of\ TF}}{}^2} \tag{1}$$

w_{TS}

The measurement uncertainty of the transfer standard w_{TS} was determined using the calibrations at PTB. It was simply taken from the certificate for every load step. Because decreasing series were also measured, case D of ISO 376 was selected.

$w_{\mathrm{drift\ TS}}$

The drift of the transfer standard $w_{\mathrm{drift\ TS}}$ was calculated from a rectangular distribution associated with the drift between the beginning and the end of the round robin test, and it was measured within the calibrations at PTB. The drift of the transducer's sensitivity is extremely low. Especially the now 10-year-old 50 kN transducer showed deviations lower than 0.001 %. The three-year-old 100 kN transducer had values lower than 0.003 %.

w_{temp}

The uncertainty w_{temp} caused by temperature influences was calculated using the manufacturer's information about the sensitivity factor and the measured temperatures during all calibrations of the material testing facility. The temperature was in a range of 3 °C. The temperature sensitivity factor of the transducers was 0.001 %/°C.

w_{rot}

During the round robin tests, the transfer standards and the DMP40 amplifier of PTB stayed at the IfEP. Several single measurement series with the transfer standards were also slotted in the intervals between the work of the participants. They were to monitor the machines' drift and detect if any malfunction might occur. These series were also used to gain better knowledge about the mean value of a machine's indication deviation, having significantly more measurements (up to 20 additional series). However, as they were done only in one rotational position, a component for the missing uncertainty of the different mounting positions should be taken into account. To add the reproducibility (named as w_2 in ISO 376), the uncertainty contribution w_{rot} was also included. It was measured within the two ISO 376 calibrations of the transfer standard in the testing machine at the beginning and the end of the work.

w_{res}

The uncertainty contribution w_{res} depends on the resolution of the indication system of the material testing facility. It could be quite high especially in the lower force range. It should not be forgotten that the uncertainty of the resolution w_{res} is influenced twice by the resolution because of the two measurements of the unloaded and loaded indication of the machine, as detailed in [2].

$w_{\mathrm{drift\ and\ repeat.\ of\ TF}}$

The last uncertainty component named in equation (1) is the general repeatability $w_{\mathrm{drift\ and\ repeat.\ of\ TF}}$. It is influenced by the drift of the sensitivity of a machine's reference transducer and the instant repeatability of the machine. This was measured within all the single series performed between the work of the participants and the eight increasing series of the two ISO 376 calibrations. The variance over all single load steps in all series was taken to calculate the uncertainty $w_{\mathrm{drift\ and\ repeat.\ of\ TF}}$.

Summary

Table 1 shows the results of those uncertainty components measured with the 100 kN transfer standard in the second round robin test. Non-relevant positions after the decimal point have been printed to give an impression of the tendency of the values.

Table 1: Uncertainties estimated with the 100 kN transfer standard used for the second round robin test

Force / kN	q_{PTB} / %	w_{TS} / %	$w_{drift\ TS}$ / %	w_{temp} / %	w_{rot} / %	w_{res} / %	$w_{drift\ and\ repeat.\ of\ TF}$ / %	$w_{q_{PTB}}$ / %
10	0.021	0.008	0.000 7	0.000 9	0.000 8	0.004 1	0.006 6	0.018
20	0.028	0.006	0.001 3	0.000 9	0.001 5	0.002 0	0.003 8	0.012
30	0.033	0.005	0.001 3	0.000 9	0.000 9	0.001 4	0.002 8	0.009
40	0.039	0.005	0.001 3	0.000 9	0.000 7	0.001 0	0.002 7	0.008
50	0.044	0.005	0.001 3	0.000 9	0.000 9	0.000 8	0.002 1	0.007
60	0.048	0.004	0.001 4	0.000 9	0.000 9	0.000 7	0.001 7	0.007
70	0.053	0.004	0.001 3	0.000 9	0.000 8	0.000 6	0.001 5	0.006
80	0.056	0.004	0.001 5	0.000 9	0.000 6	0.000 5	0.001 5	0.006
90	0.059	0.004	0.001 7	0.000 9	0.000 5	0.000 5	0.001 7	0.006
100	0.060	0.004	0.001 7	0.000 9	0.000 4	0.000 4	0.001 6	0.006

A similar table was set up for the 50 kN transfer standard. The reference indication could thus be measured with a defined uncertainty in the range from 5 kN to 50 kN in eleven steps and from 10 kN to 100 kN in ten steps. The measured values are presented in Figure 3. The figure shows the overlap of the two reference curves including error bars for the uncertainties calculated as explained before.
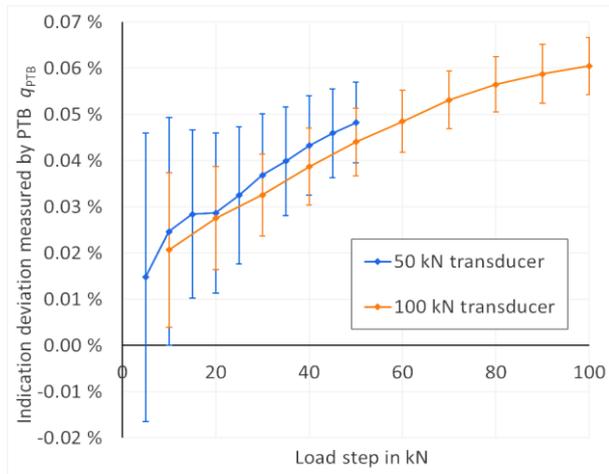

Figure 3: Overlap of two reference curves measured with two different sensors

4. EVALUATION AND REPORTING

All participants submitted their results by sending a certificate. Each certificate was checked to see if all the demands of ISO 7500-1 and the German accreditation body DAkkS were fulfilled. In the first round robin test, it was noticed that many laboratories did not state the relative zero-point deviation of the force measuring device of the testing machine f_0.

The indication deviation from the certificates was compared against the reference values q_{PTB}. The results were visualised as shown in Figure 4. The reference value is drawn with the uncertainty limits, and the values determined by the laboratories are added with uncertainty bars depending on the accredited expanded measurement uncertainty. In addition, the hysteresis measured by the laboratories was reviewed. The maximum values stated on the certificates were checked against the values measured by PTB. Generally, the measured hysteresis is the sum of the machine's hysteresis plus the hysteresis of the transducer of the laboratory. When calculating the machines' hysteresis by subtracting the transducers' values, it should be taken into account that the ISO 376 calculates the absolute values. If the transducer is overcompensated and shows a negative hysteresis, this must be corrected.

Finally, a report was written containing information in particular about the indication deviation but also about the hysteresis, the reproducibility and the review of the certificates.
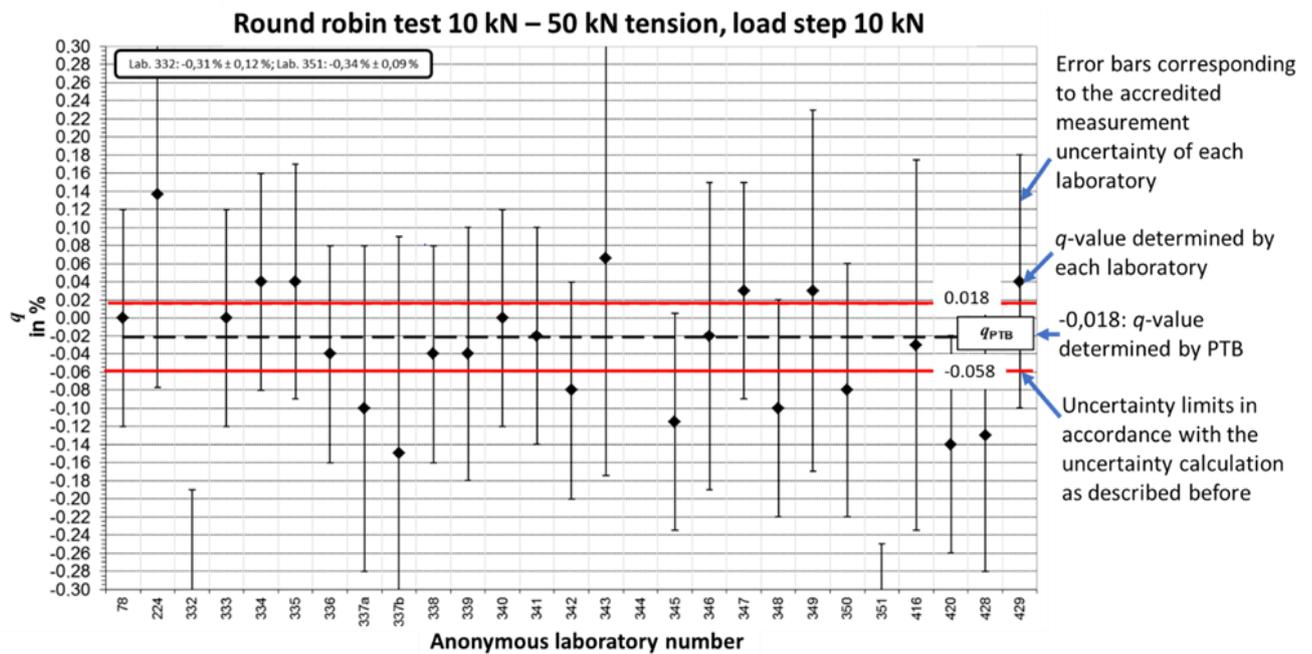
Figure 4: Results of the round robin test for the 10 kN load step

5. SUMMARY

The suitable conception of a round robin test via a national technical committee was successfully developed and implemented in practice. Fixed time schedules in the technical committee give the accredited laboratories the opportunity to meet the requirements of ISO 17025 with simple means.

The results show a very good agreement between the indication deviations determined by the laboratories and the PTB reference values.

A plan for future comparisons was defined and presented to the DKD board.

6. REFERENCES

[1] ISO/IEC 17025, "General requirements for the competence of testing and calibration laboratories", 2017.

[2] ISO 7500-1, "Metallic materials - Verification of static uniaxial testing machines - Part 1: Tension/compression testing machines - Verification and calibration of the force-measuring system", 2018.

[3] ISO 376, "Metallic materials - Calibration of force-proving instruments used for the verification of uniaxial testing machines", 2011.