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Nordic Intercomparison of Calibration of the Material Testing Machines Report of the Force Calibration

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Abstract

For us there was not known intercomparison for the calibration of uniaxial testing machine. It was the reason to work out this kind of comparison during the year 1999. By planning the comparison there was two main problems by this kind of comparison. The first one; the object can not be circulated from calibrating laboratory to next one. The second one is that the testing machine should be measured to get the status of a reference standard. The first problem was solved tat every laboratory had to travel to the location, where testing machine was. Second problem meant that the history of testing machine should be known well and the calibration of the pilot should be made very careful. FINAS has organized this intercomparison for the calibration of the uniaxial testing machine in the year 1999 in Finland. There was three laboratories participating the comparison, two from Finland and one from Denmark. The results has shown some main problems:

- The stability of the testing machine must be investigated well
- The calibration method for force has high importance

This paper gives some numerical value of these problems and the experiences during the intercomparison.

1. Introducion

The reliability and the uniformity of the results of uniaxial testing machines are very important in monitoring of the quality of different metallic products and constructions. An intercomparison for this kind of calibration is very difficult because there are not real standards, which can be used and circulated. In this intercomparison a typical uniaxial material testing machine has been used as a standard which has been controlled by pilot laboratories with a higher class of standards. Participants were asked to make calibration for extensiometer measuring device and force measuring device of this machine. The purpose of this interlaboratory comparison was:

- to demonstrate the metrological competence of the participating laboratories;
- to identify problems and differences in measurement procedures and in the interpretation of standard.

The idea of the comparison of calibration of uniaxial testing machines was introduced at the meeting of the *EA Dimensional Metrology Expert Group* and *EA Mass Metrology Expert Group* but it has been kept too difficult. Finland proposed this comparison at the meeting of Nif-Conference in year 1998 for Scandinavian area and it has been accepted with the number M3 for NIF registration. The comparison was financed by the Centre for Metrology and Accreditation, MIKES, and organised by Raute Precision Oy, Force and Mass Laboratory.

1.1. Participants and Time Schedule

There were three laboratories, two from Finland and one from Denmark. The calibrations have been made in June 1999 as well the calibration of the reference laboratories as the calibration from participated laboratories.

1.2. Calibration Object

As object was well known, a good level uniaxial testing machine, which was to calibrate in the force and in the length. Type MTS ±250 kN, Model 810.

1.3. Measurement Instructions

The task was to calibrate;

Extensiometer:

- nominal gauge length 25 mm, extension 0,5 mm with points 0,05 mm; 0,10 mm; 0,15 mm; 0,20 mm; 0,25 mm; 0,30 mm; 0,35 mm; 0,40 mm; 0,45 mm; 0,50 mm
- according EN 10002-4.

This paper concentrates only for force calibration therefore extensiometer is further excluded.

Force:

- 50 kN (tension and compression)
- 250 kN (compression)
- according EN 10002-2

The laboratories had to give a calibration certificate from both quantity and they should give also the uncertainty budget.

1.4. Pilot Laboratories

The organising pilot laboratory was Raute Precision Force and Mass Laboratory in Finland, the laboratory was responsible for complete intercomparison and for force. VTT Manufacturing Technology was responsible as national laboratory for mechanical length for calibration of extensiometer.

2. Calibration of the Force

2.1 Reference Value of the Force

The results of participating laboratories will be evaluated against calibration results from pilot laboratory. To establish the reference values it has been used force transducers, with nominal values 50 kN and 500 kN. These transducers have a long well known metrological history and the capability of transducers is as well known.

The calibrations have been carried out before the calibration from participating laboratories and after completed work from participating laboratories.

The used reference value for the testing machine is the mean value of these two calibration, $(R_1 + R_2)/2$.

<u>Reference value of the uniaxial testing machine to be calibrated</u>

Reference values for the force calibration has been built with transfer transducers measured in the uniaxial testing machine. These measurements were carried out as well twice, before and after actually calibration from participating laboratories.

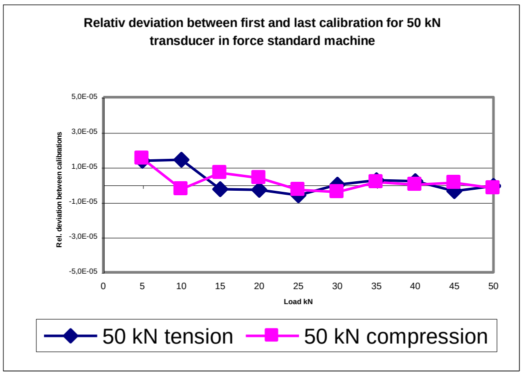

Figure 1. Relative deviations between the first and last calibration in force standard machine for 50 kN transducer in compression and in tension.

The establishment of the reference value by this procedure causes several problems. The goal of calibration is to confirm the capability of force measurement unit of testing machine to measure the force with enough low uncertainty for given tasks. It is very difficult to bring the reference transducer to equivalent position belonging to the parasitic components of force-measuring systems, on the other hand measurement system of the measured testing machines and on the other hand measurements system of the reference machine. The reference values has been calculated using two measurements according EN-10002-2, the reference mean values calculated from individual measurement before and after the actual calibration of participants. The calculation of the uncertainty is based on the factors of characterisation in the standard EN-10002-2 for calibrations the force measuring device and on the difference between two calibrations, which includes the stability of the transducers. Following figure 2. shows the results of calibrations and the final uncertainty used in the calculations. The first measurement of Pilot laboratory is called “Ref. Lab. meas. A“ and the second is called “Ref. Lab. meas.B“.

The following figure 3 shows the behaviours of the machine by 50 kN transducers in compression.

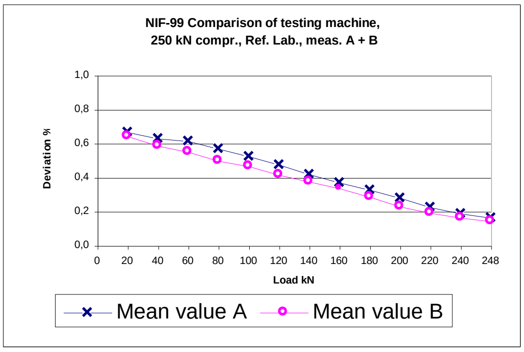

Figure 2. Calibration A and B of Reference Laboratory for range 250 kN in compression.

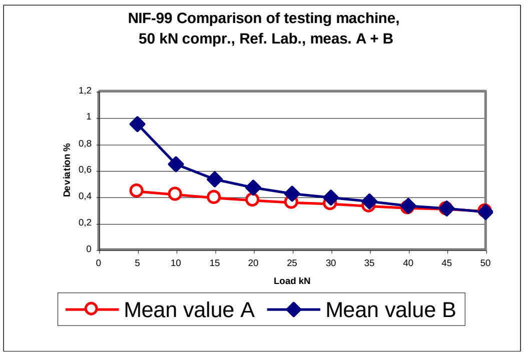

Figure 3. Calibration A and B of Reference Laboratory for range 50 kN in compression.

In this case it is to see very clear difference between the measurements A and B on the range from 5 kN to 45 kN. The reason for this deviation is not known. All series in both of measurements are giving good repeatability; the mechanical application was direct on the top of actuator rod.

These two measurements are very similar, the only deviation is the reversibility of the first measurement, which can assume to be an instability from the testing machine.

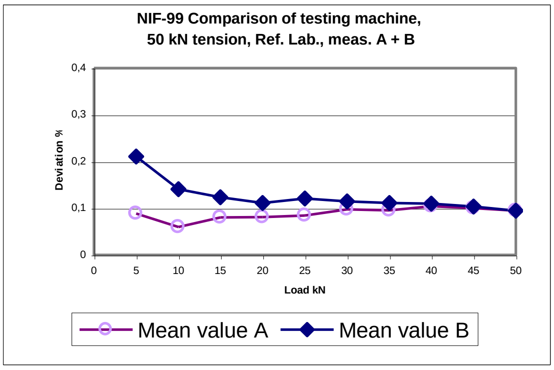

Figure 4. Calibration A and B of Reference Laboratory for range 50 kN in tension.

3.2 Summary of the Results

3.2.1 Diagrams

Diagrams show the deviation between participatory laboratory and pilot laboratory. One of the diagrams is fitted with uncertainty bars. The deviation between zero line and pilot laboratory shows the deviation from “true value” for measurement system of the calibrated uniaxial testing machine.

The standard EN 10002-2 gives possibility to do the calibration wit or without reversibility. Only the laboratory A made calibration with and without reversibility.

The diagrams show measurement without reversibility because the reversibility is depend more from testing machine than from used transducers.

Table 1. Summary of the uncertainties for reference calibrations.

Expanded uncertainties U ($k = 2$)							
250 kN, compression				50 kN tension		50 kN compression	
Force kN	U [%], with reversibility	U [%], without reversibility	Force kN	U [%], with reversibility	U [%], without reversibility	U [%], with reversibility	U [%], without reversibility
25	0,20	0,13	5	0,34	0,30	0,27	0,09
50	0,22	0,10	10	0,28	0,13	0,19	0,06
100	0,11	0,04	20	0,07	0,06	0,11	0,03
150	0,08	0,04	30	0,03	0,03	0,05	0,02
200	0,06	0,04	40	0,03	0,01	0,03	0,02
245	0,03	0,03	50	0,01	0,01	0,02	0,02

250 kN Range, compression

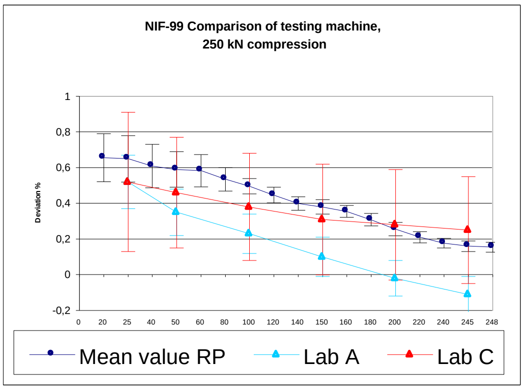

Figure 9. Range 250 kN, compression without reversibility

Range 50 kN Range, compression

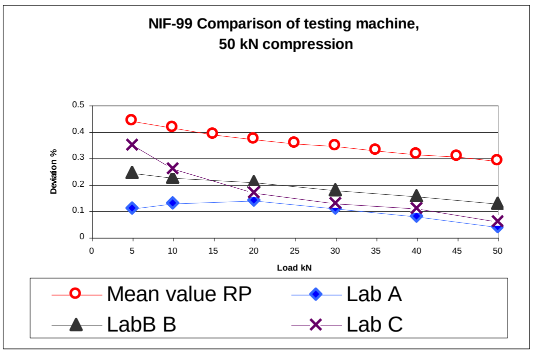

Figure 10. Range 50 kN, compression without reversibility

Range 50 kN Range, tension

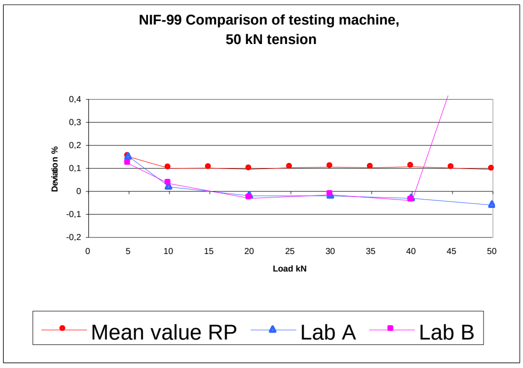

Figure 11. Range 50 kN tension without reversibility

Calibration the uniaxial testing machine by tension seems to give the lowest deviation from true value and as well the deviation between laboratories is low. The reason is that the force transmitting is more uniform by tension.

4.3.2 Summary of Results and Analysis

The evaluation of the results has been made using the nominal error method according EA recommendation.

$$En = \frac{X_{LAB} - X_0}{\sqrt{U^2_{LAB} + U^2_0}} \qquad (1)$$

Where:

X_{LAB}= the value measured by the laboratory

X_0 = the reference value

U_{LAB}= the uncertainty reported by the laboratory

U_0 = the uncertainty of the reference value.

Every laboratory was not able to do calibration of all ranges. Laboratory A has made all force calibrations: 250 kN compression, 50 kN compression and 50 kN tension. Laboratory B made: 50 kN compression and 50 kN tension. Laboratory C made: 250 kN compression and 50 kN compression. In the following summary is given the results of the individual laboratories and ranges.

Range 250 kN Compression

Table 2. Results of the laboratory A and C for range 250 kN compression

Range 250 kN				
	Laboratory A		Laboratory C	
Force kN	Measured deviation %	Normalised error without reversibility,E_n	Measured deviation %	Norma-lised error with rever-sibility, E_n
25	0,52	-0,3	0,52	-0,2
50	0,35	-0,7	0,46	-0,5
100	0,23	-1,1	0,38	-0,8
150	0,10	-1,2	0,31	-0,9
200	-0,02	-1,3	0,28	-1,0
245	-0,11	-1,4	0,25	-1,0

Range 50 kN Compression

Table 3. Results of the laboratory A , B and C for range 50 kN compression

Range 50 kN compression						
	Laboratory A		Laboratory B		Laboratory C	
Force kN	Measured deviation %	Normalised error without reversibility E_n	Measured deviation %	Normalised error without reversibility, E_n	Measured deviation %	Normalised error without reversibility E_n
5	0,11	-0,9	0,244	-0,6	0,35	-0,2
10	0,13	-1,5	0,226	-1,3	0,26	-0,5
20	0,14	-1,7	0,209	-1,4	0,17	-0,7
30	0,11	-2,2	0,179	-2,2	0,13	-0,7
40	0,08	-2,3	0,156	-6,4	0,11	-0,7
50	0,04	-2,4	0,128	-2,5	0,06	-0,8

Range 50 kN Tension

Table 4. Results of the laboratories A and B for range 50 kN tension

Range 50 kN tension				
	Laboratory A		Laboratory B	
Force kN	Measured deviation %	Normalised error without reversibility E_n	Measured deviation %	Normalised error without reversibility E_n
5	0,15	0,0	0,119	-0,2
10	0,02	-0,5	0,034	-0,7
20	-0,02	-1,0	-0,030	-1,2
30	-0,02	-1,2	-0,150	-3,9
40	-0,03	-1,3	- 0,040	-4,4
50	-0,06	-1,5	0,987	11,8

5. Conclusion

The force calibration depends on the quality of the machine it self and from the force transmitting. One reference calibration before and after the actual measurement of the participants is not sufficient to define the quality of the uniaxial testing machine. The practical method to fix the force transducers for force transmitting is most important. In these cases the used force transducers have been fixed for reference calibration and for calibration of participants on different ways.

This is possible according the EN 10002-2 because it does not give any mandatory guidelines for that. The difference of approximately 0,2 % for compression of 50 kN calibration is a consequence of that. For the laboratory B the normalised error is high, but it can depend on the fact that in the calculation pilot laboratory has used the double value of standard deviations, given by laboratory’s measurements, as measurement uncertainty. The laboratory did not give any uncertainty according EA-Guide for the calibration.

As summary for future investigations:

A. The uniaxial testing machine, which functions as standard, must investigate well for the efficiency. It is difficult to get lower uncertainty for reference than 0,05 %.

B. The force transmission must be defined well; otherwise the comparing of results is not equal.

C. To show the capability for calibration with uncertainty 0,1 % or lower it needs carefully analysing of reference and using well-known transducer on range over 40 % from full capacity.