XX IMEKO World Congress
Metrology for Green Growth
September 9–14, 2012, Busan, Republic of Korea

COMPARISON OF THE CALIBRATION RESULTS OF INDUSTRIAL FORCE TRANSDUCERS OBTAINED BASED ON THE NEW VS. THE OLD VERSION OF ISO 376

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Abstract: The new version of the international standard ISO 376:2011 [1] gives the possibility to carry out the calibration of force transducers without hysteresis and provides a new approach for calculation of the expanded measurement uncertainty. This paper presents an overview of how the changes affect the results in the calibration certificates of different types of industrial force transducers. A comparison is made between classification and measurement uncertainty based on ISO 376:2004 [2] and EA10/04 [3] and the same values based on the new ISO 376:2011 version.

Keywords: Force Calibration, Force Transducer, ISO 376:2011, Classification, Measurement Uncertainty

1. INTRODUCTION

With the new version of the international standard ISO 376:2011 [1] several changes affecting the calibration of force transducers have come into effect. It is now possible to carry out a calibration without decreasing force, instead creep is taken into account. In addition, Annex C describes a new approach to calculation of the expanded measurement uncertainty. Creep is taken into account instead of hysteresis and calculation of the variances has changed compared to EA10/04 [3] which was the common guideline in Europe before. In addition, the expanded measurement uncertainty is given by a fit curve allowing calculation of the expanded relative measurement uncertainty for any force within the calibration range. The limitation of uncertainty related to the classification of the force transducer as specified in EA10/04 [3] is not applied any more.

ISO 376:2011 now specifies 4 different cases for classification. Table 1 shows an overview of the criteria included.

The changes in the standard have different effects on the results depending on the type of force transducer. Three different types of force transducers from Hottinger Baldwin Messtechnik GmbH are presented in this paper. Table 2 shows the types of force transducers and the reasons for selecting them.

Table 1: Criteria limiting the classification for the 4 different cases of ISO 376:2011

	Case A	Case B	Case C	Case D
Reproducibility	✓	✓	✓	✓
Repeatability	✓	✓	✓	✓
Zero error	✓	✓	✓	✓
Applied calibration force	✓	✓	✓	✓
Interpolation error			✓	✓
Reversibility		✓		✓
Creep	✓		✓	

The three different types of force transducers are all based on measuring bodies with installed strain gauges. However, the measuring bodies work on different principles. TOP-Z30A is based on the parallel double bending beam principle [4] giving a very high accuracy. C9B is based on a miniaturised membrane measuring body optimised for production control with lower accuracy where space is limited. Z12 is a discontinued force transducer originally designed to be used in material testing machines as force indicator and not for the calibration of material testing machines.

Table 2: Selected types of force transducers and reasons for selecting them

Type	**Reason for selection**
TOP-Z30A	Much better than class 00
C9B	Industrial transducer, poor rotation
Z12*	Industrial transducer, poor hysteresis

*discontinued

For industrial calibration laboratories, changes to a standard mean that they have to change the software accordingly and that they need to be prepared to answer customers' questions arising from the changed values for classification and measurement uncertainty. Comparing the new with the old resuslts is of great interest.

Calibrations have been carried out with force reference standard calibration machines based on direct loading with dead weights to achieve the least possible influence of the calibration machine on the result [5].

2. CLASSIFICATION

First, the difference in classification between the new and the old version of the standard will be discussed.

The criteria for type Top-Z30A are much better than class 00 with the old and with the new version of the standard (no table needed).

The main criteria for C9B with poor rotation have not changed. Table 3 shows the same classification according to the new and the old version of the standard.

Table 3: Classification according to the former version of ISO 376:2004 compared with the now 4 different cases for C9B with poor rotation

	ISO 376:2004	Case A	Case B	Case C	Case D
2 kN	2	2	2	2	2
4 kN	1	1	1	1	1
6 kN	1	1	1	1	1
8 kN	0.5	0.5	0.5	0.5	0.5
10 kN	0.5	0.5	0.5	0.5	0.5
12 kN	0.5	0.5	0.5	0.5	0.5
16 kN	0.5	0.5	0.5	0.5	0.5
20 kN	0.5	0.5	0.5	0.5	0.5

The transducer type Z12 with poor hysteresis shows a different picture (table 4 and table 5). Because creep is class 00, the whole transducer is now classified 00 for case A and case C.

Table 4: Classification of the different criteria at different applied force steps for Z12 with poor hysteresis

	b	b'	f_c	f_0	v	r	force
5 kN	00	00	00	00	0.5	00	00
10 kN	00	00	00	00	0.5	00	00
15 kN	00	00	00	00	0.5	00	00
20 kN	00	00	00	00	0.5	00	00
25 kN	00	00	00	00	00	00	00
30 kN	00	00	00	00	00	00	00
40 kN	00	00	00	00	00	00	00
50 kN	00	00	00	00	00	00	00

Table 5: Classification according to the former version of ISO 376:2004 compared with the now 4 different cases for Z12 with poor hysteresis

	ISO 376:2004	Case A	Case B	Case C	Case D
5 kN	0.5	00	0.5	00	0.5
10 kN	0.5	00	0.5	00	0.5
15 kN	0.5	00	0.5	00	0.5
20 kN	0.5	00	0.5	00	0.5
25 kN	00	00	00	00	00
30 kN	00	00	00	00	00
40 kN	00	00	00	00	00
50 kN	00	00	00	00	00

The experiences gathered with the first calibrations and development results did not show any transducers reaching a classification of less than 00 for creep. This has also been confirmed in earlier publications of IMEKO conferences [6]. When taking into account the principles of measuring bodies, the correlation between creep and hysteresis cannot be generally stated and the limit for class 00 of the creep criteria should be reconsidered.

3. MEASUREMENT UNCERTAINTY

The major change resulting from the new version of ISO 376:2011 affects calculation of the measurement uncertainty. To compare the results with the former version of ISO 376:2004, the different variances (quadrature of the uncertainty components) have been plotted for the first force step at 10% of nominal force (figure 1 to figure 3). To compare the hysteresis values, their variance is calculated according to Annex C.2 "Uncertainty during the force-proving instrument's subsequent use".

For TOP-Z30A (figure 1), the hysteresis is higher, however, compared to the overall uncertainty and variance of the applied force of 1E-08 it is still negligible.

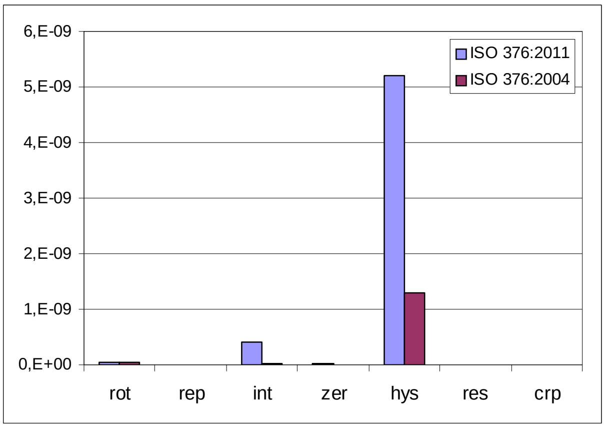

Figure 1: Variances for type TOP-Z30A force transducer with criteria much better than class 00

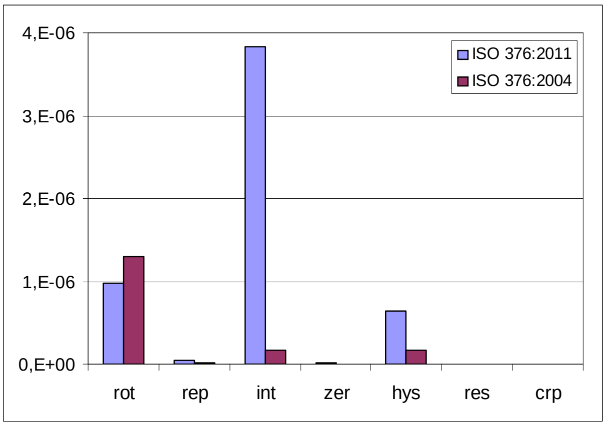

Figure 2: Variances for type C9B force transducer with poor rotation

For C9B (figure 2) the variance for rotation is lower because of the statistic approach. In contrast, the interpolation error and hysteresis are significantly higher. Now the interpolatipon error is the main component of uncertainty.

For Z12 (figure 3) with the known poor hysteresis this variance is significantly higher.

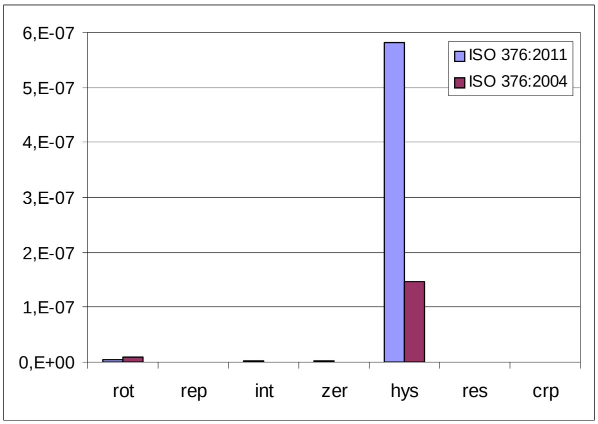

Figure 3: Variances for type Z12 force transducer with poor hysteresis

The expanded measurement uncertainties (k=2, 95% probability) for the different types of force transducers show higher values for the new 2011 version (figure 4 to figure 6). Reasons are the higher values of the variances and the fit curve for calculation of the expanded measurement uncertainty.

For the type TOP-Z30A force transducer the difference in expanded measurement uncertainty between the old and the new version of ISO 376 is quite small (figure 4) due to the excellent overall uncertainty.

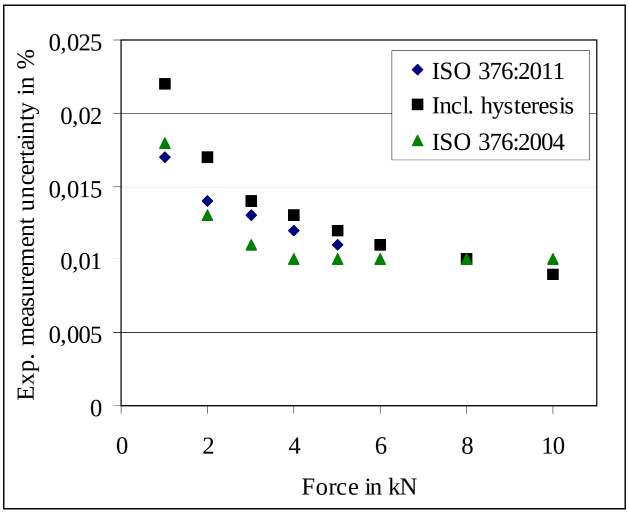

Figure 4: Expanded measurement uncertainty for type TOP-Z30A force transducer with criteria much better than class 00

For the type C9B force transducer the expanded measurement uncertainty is significantly higher, especially for the lower force steps (figure 5), because the higher variances for hysteresis and interpolation error (shown in figure 2) are taken into account.

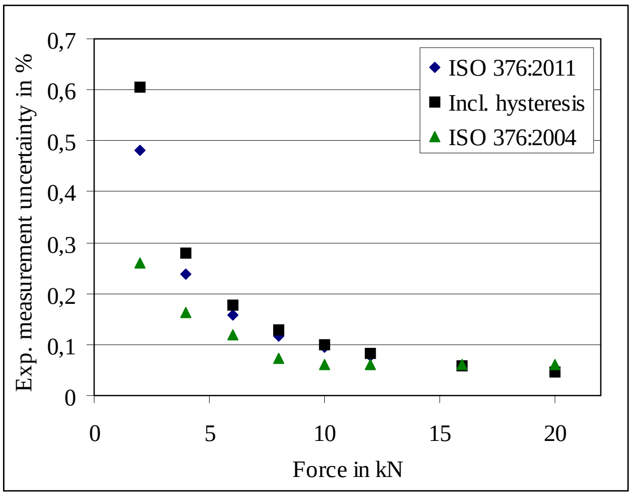

Figure 5: Expanded measurement uncertainty for type C9B force transducer with poor rotation

Figure 6 shows a special situation for the type Z12 force transducer. Here, the results for the new version of the standard, without taking into account the hysteresis, are lower than before. The limits given by the EA 10/04 guideline require that the expanded measurement uncertainty is not lower than 0.06% for class 0.5 and that the value for the uncertainty remains unchanged from 50% up to 100% of the calibration force. However, including the hysteresis for the application significantly increases the expanded measurement uncertainty.

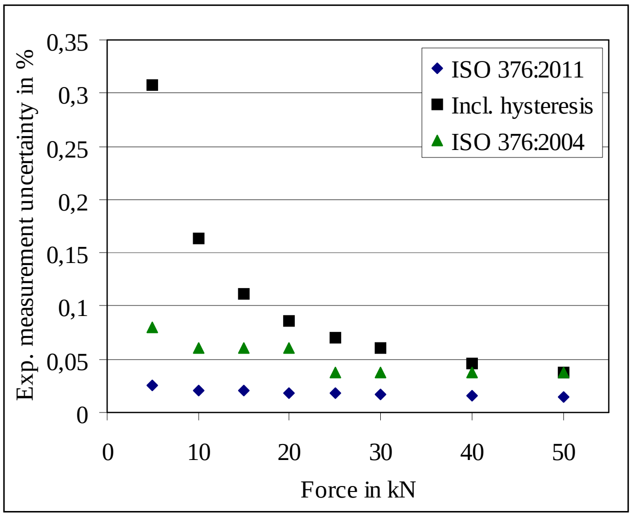

Figure 6: Expanded measurement uncertainty for type Z12 force transducer with poor hysteresis

Figure 7: Calibration in a test bench using a type Z4A force transducer

4. CONCLUSIONS

The changes resulting from the new version of the ISO 376 standard have different influences on the different types of transducers. This is highly dependent on the individual characteristics. The calibration result of transducers with excellent characteristics like TOP-Z30A will not show any significant change. However, transducer types with poor linearity, rotation and especially hysteresis may show, on the one hand, better results for some cases in classification and, on the other hand, the expanded measurement uncertainty will significantly increase, especially when taking into account the hysteresis for the application with decreasing forces. Unfortunately it is not possible to predict the changes of the calibration result in general, as it depends too much on the individual case.

5. REFERENCES

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