SIE 2012 5th International Symposium of Industrial Engineering IE
supported by: Steinbeis Advanced Risk Technologies

DEVELOPMENT OF COMPETENCES OF NATIONAL REFERENCE LABORATORY FOR MASS MEASUREMENT

Dr.sc. Samir Lemeš[a], Dr.sc. Nermina Zaimović-Uzunović[a], M.sc. Šejla Ališić[b], M.sc. Haris Memić[b]
[a] University of Zenica, Mechanical Engineering Faculty, Zenica, Bosnia and Herzegovina
[b] Institute for Metrology of Bosnia and Herzegovina, Sarajevo, Bosnia and Herzegovina

Abstract: The national reference laboratory for mass in Bosnia and Herzegovina uses non-automatic weighing scales as a national reference standard. This research was performed in order to prove competences of this laboratory through accreditation in accordance with international standard EN ISO/IEC 17025. The analysis of measurement results obtained by calibration of weighing instruments described in this paper, describes the effects of individual contributions to the combined measurement uncertainty.
Key words: Mass measurement, Calibration, Measurement uncertainty, Interlaboratory comparison

INTRODUCTION

Metrology Institute of Bosnia and Herzegovina (IMBIH) contains the National laboratory for mass. Laboratory intercomparisons are one of the basic requirements to prove laboratory competence. National Mass Laboratory uses standards (weights) in the range from 1 mg to 50 kg, traceable towards international standards. The traceability is realized through a calibration set of national weights (E1 accuracy class from 1 mg to 5 kg), while dissemination of mass is realized by transfer of mass unit from national sets to weights with lower accuracy class, which have applications in various fields of industry and commerce.
Calibration of these weights is performed on the comparators and balances with different accuracy classes, while the calibration of comparators and scales is performed using a calibrated scale weights (mutual dependence).
A large number of laboratories in Bosnia and Herzegovina is designated by the Institute of Metrology of Bosnia and Herzegovina to enable them to perform verification in the field of mass. In order to ensure the performance of these laboratories, the Institute of Metrology aims to provide them with the same laboratory calibration services of their working standards and provide calibration of their scales which are used for the verification of working weights for third parties, who used to perform calibration out of the borders of Bosnia and Herzegovina, requiring signifficant expenses and time of transport.
National Laboratory for the mass is currently in the process of proving its competence through Regional Metrology Organization (RMO) EURAMET.
Laboratories can demonstrate their competence in two ways, namely through accreditation in accordance with EN ISO/IEC 17025, or via RMO (technical Committee for a particular field of metrology and technical committees for quality), but in this case it is valid only for national metrology institutes and laboratories which are holders of national standards. As no inter-calibration of scales exists at the RMO level, this leads to aggravation of proving competence in the field of calibration of non-automatic weighing scales, MIBH decided to demonstrate its competence through accreditation in accordance with standard EN ISO/IEC 17025.

CALIBRATION OF NON-AUTOMATIC SCALE XS 205

The scale being calibrated (Fig. 1) is manufactured by Mettler Toledo. Maximum load is 220 grams. The smallest unit in the first measurement range (up to 81 g) is d_1 = 0,00001 g. The smallest unit in the second measurement range (maximum load 220 g) is d_2 = 0,0001 g.
The environmental conditions were as follows:
- Air pressure: 964 mBar
- Humidity: 61,00 %
- Temperature: 19,65 °C
- Temperature of weighs: 18,70 °C
- Acclimatization time: 24 h

Fig. 1. Non-automatic scale XS 205

The ratio of the maximum scale capacity (220 g) and test division (0.001 g) gives total number of divisions of 220000, which indicates that the scale has class I accuracy.

The greatest contribution of measurement uncertainty when small masses are used comes due to repeatability and contributions from the working standards (weights). In the range near the maximum of scale capacity, the largest total contribution comes due to the eccentricity. In the range near the minimum of scale capacity the major contribution is due to applied working standards (weights).

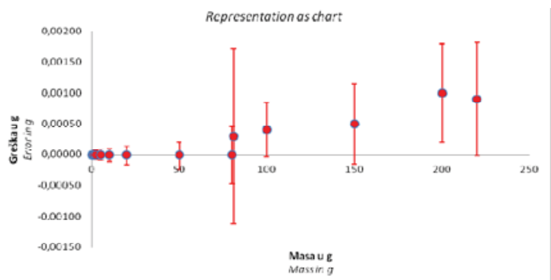

Fig. 2. Calibration results for XS 205

CALIBRATION OF NON-AUTOMATIC SCALE CENT 6000 HR-CM

The scale being calibrated (Fig. 3) is manufactured by Gibertini. Maximum load is 6200 grams. The smallest unit d = 0,01 g.

The environmental conditions were as follows:

- Air pressure: 964,7 mBar
- Humidity: 54,70 %
- Temperature: 21,40 °C
- Temperature of weighs: 20,80 °C
- Acclimatization time: 24 h

Fig. 3. Non-automatic scale CENT 6000 HR-CM

The ratio of the maximum scale capacity (6200 g) and test division (0.01 g) gives total number of divisions of 62000, which indicates that the scale has class II accuracy. The greatest measurement uncertainty occurs near the maximum of the scale range. The greatest contribution to measurement uncertainty is due to repeatability. In the range near the maximum of scale capacity, the largest total contribution comes due to the eccentricity and contributions from the working standards (weights).

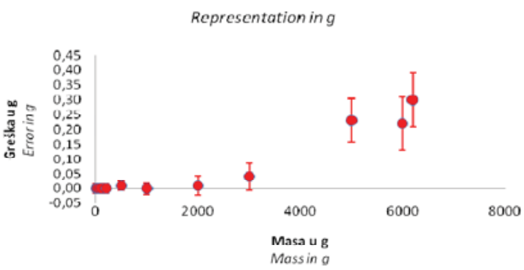

Fig. 4. Calibration results for CENT 6000 HR-CM

CALIBRATION OF COMPARATOR CCE60K2

The comparator is manufactured by Sartorius (Fig. 5). Maximum load is 64000 grams. The smallest unit d = 0,01 g.

The environmental conditions were as follows:

- Air pressure: 964,6 mBar
- Humidity: 34,05 %
- Temperature: 21,74 °C
- Temperature of weighs: 20,35 °C
- Acclimatization time: 24 h

As the total number of divisions of this comparator is larger than 10^6, we can observe it as an analytical scale. When calibration was performed with small weights, the measurement uncertainty was 3,6%, and in other cases (larger weights) the measurement uncertainty was between 0,072% for 50 g weights and 0,0009% for 64 kg weights.

The major contribution comes from eccentricity.

Fig. 5. Comparator CCE60K2

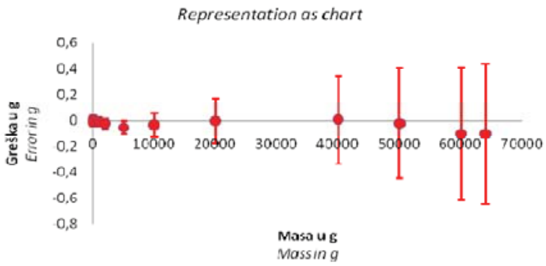

Fig. 6. Calibration results for CCE60K2

CALIBRATION OF 1 kg MASS STANDARD

The calibration procedure requires verification of weights magnetism. Magnetic fields inside and outside the scales may increase systematic error of weighing, if the weighed subject has strong magnetic susceptibility. The maximum measured polarity is 8,0 µT, and this weight, with E_2 accuracy class had polarity of 0,03 µT.The maximum allowed magnetic susceptibility is 0,07, and the measured susceptibility is 0,00345.

Fig. 7. Comparator Sartorius CCE1000 S-L and susceptometer

Measurement uncertainty analysis

Standard uncertainty of weighing process is calculated from standard deviation:

$u_A = 0,002069$ mg

Type B uncertainty of calibration reference is:

$u(m_{cR}) = 0,075$ mg

Measurement uncertainty due to drift of the reference since last calibration:

$u(m_d) = 0,00866$ mg

Measurement uncertainty of air density, derived from the CIPM formula is:

$u(\rho_a) = 0,00065$ kg/m^3

Variance of measurement uncertainty due to the effect of buoyancy:

$u_{cb}^2(\Delta m_w) = 0,003840$ mg^2

Measurement uncertainty of the comparator resolution:

$u_d = 0,00048248$ mg

Measurement uncertainty due to the eccentricity of the comparator:

$u_E = -0,000052$ mg

Measurement uncertainty due to the sensitivity of the comparator:

$u_S = 2,71288 \cdot 10^{-8}$ mg

The standard uncertainty of type B evaluation is:

$u_B(m_{cT}) = 0,097677$ mg

Extended standard measurement uncertainty (with coverage factor k=2):

$U(m_{cT}) = 0,20$ mg

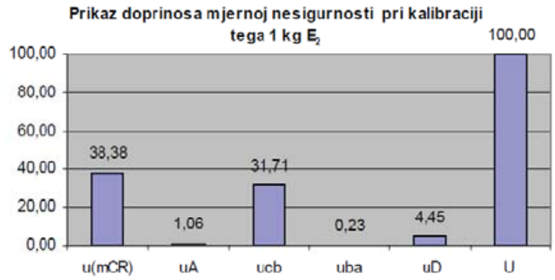

Fig. 8. Contributions to measurement uncertainty of reference mass standard of 1 kg

The analysis of contributions to measurement uncertainty presented in Fig. 8, leads to conclusion that the dominant contribution to measurement uncertainty of the standard and its share in the expanded measurement uncertainty is 38,8%.

The following contribution with significant impact is the standard uncertainty due to buoyancy, because the measurements were performed in air and density of standards and test loading weights are different, and next to the measurement uncertainty the mass correction due to differences in the density of the two loading weight is done.

The measurement uncertainty due to drift of standards, which represents the internal stability of the standard uncertainty, reflects the full impact of standards on this calibration and the precise calibration of standards that prove lower levels cannot be ignored.

Measurement uncertainty of type A, which comes from the reproducibility of the measurement and the contribution of measurement uncertainty of the comparator (including eccentricity, sensitivity and resolution effects) represent the influence of the instrument which is measured, and in this case it has no significant share in the expanded measurement uncertainty, because it is a precise high-performance instrument.

If one observes contribution to the uncertainty of comparator/scale, it is noticeable that the largest share of uncertainty comes due to the scale resolution, which is also called the measurement uncertainty of indication.

Table 1. Measurement uncertainty of standard mass of 1 kg (E_2 accuracy class) using substitution method with 6 ABBA cycles, automatic measurements

Case	Comparator used	division d (mg)	Expanded measurement uncertainty
1	CCE1000 S-L	0,001	0,195399
2	CCE1000 S-L	0,001	0,279226
3	C 1000S	0,002	0,240776
4	C 10000 U-L	0,01	0,237594

Measured standard uncertainties are the same as the 1 kg standards (accuracy class E_1) were used which are calibrated with U = 0,15 mg, and this is the limit for this measurement uncertainty and this weight class accuracy.
The standard uncertainty of the drift depends on the history of a weight standards, and it is more precise when weight has documented history, while the location in the case 2 is estimated.
The appearance of buoyancy of the air is a significant source of uncertainty.
Standard uncertainty of type A assessment, which includes the statistical analysis of series of observations, is smaller than the standard measurement uncertainty obtained from type B assessment, which is based on scientific judgment and use of available data. Type A uncertainties largely depend on the devices and methods of measurement. If all measurement on all instruments are automatic (or more accurately semi-automatic because the operator only sets the weights to the recepient of weight) and the actual impact of the operator during the measurement is off. In fact, prior to measurements the comparators are centered by repeatedly raising and lowering them.
The largest contribution to measurement uncertainty of the comparator is at a device with worst resolution and the weakest repeatability. The same is concluded with a standard uncertainty of type A, where the worst case is case 4.

CONCLUSION

The subject elaborated in this paper includes calibration of mass with high accuracy and analysis of sources of measurement uncertainty and assessment of their contribution to the uncertainty budget. The research involves determination of sources of measurement uncertainty, measuring process model equation specific for determination of conventional mass, approach for assessment of the contribution of measurement uncertainty that are based on statistical calculations and scientific assessments. Assessment of measurement uncertainty of measurement is based on the GUM, Guide for the estimation of measurement uncertainty, which provides a framework for assessment of the dispersion of measurement results.
The results of calibration and analysis of compared measurements showed that the Reference laboratory for mass at the National Metrology Institute of Bosnia and Herzegovina confirmed the competences and the reliability of measurements. It is important to present a reliable measurement uncertainty which is part of the complete results of the mass calibration, and which allows the comparability of measurements, and proper dissemination of measurement unit.
The future researches should include intercomparisons, at least with other reference laboratories in the region.

Fig. 9. National laboratory for mass in Bosnia and Herzegovina Institute for Metrology

REFERENCES

[1] EURAMET cg.18/v.02 (2009): Guidelines on the Calibration of Non- Automatic Weightings Instruments
[2] Bich W., Tavellab P. (1994) *Calibrations by comparison in metrology: A survey*, ISA Transactions, Vol.33, Issue 4, December 1994, pp 391–399, doi: 10.1016/0019-0578(94)90022-1
[3] Adriana Vâlcu (2007): Calibration of non-automatic weighing instruments, OIML Buillten
[4] BAS EN ISO/IEC 17025 (2006) Opšti zahtjevi za kompetentnost laboratorija za ispitivanja i kalibraciju
[5] Schwartz R., Borys M., Scholz F. (2007) Guide to Mass Determination with High Accuracy, PTB-MA-80e, Physikalisch-Technische Bundesanstalt Braunschweig and Berlin (Ed.), Wirtschaftsverlag NW, Bremerhaven
[6] Petley BW (2007) The atomic units, the kilogram and the other proposed changes to the SI, Metrologia 44, BIPM, pp 69-72
[7] EA-4/02 (1999) Expression of the Uncertainty of Measurement in Calibration