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THE PROFICIENCY TESTING ANALYSES FOR DIMENSIONAL LABORATORIES USING THE GAUGE BLOCKS

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ABSTRACT
Proficiency testing is (PT) is determination of the determination of calibration or testing performance of a laboratory by means of interlaboratory comparison. Participation in proficiency testing schemes provides laboratories with an objective means of assessing and demonstrating the reliability of the data they are producing. In this paper intercomparison of set gauge blocks (class K) thru four dimensional laboratories and their results will be demonstrated. The technical protocol was issued to all participants prior to comparison. The reported measurement results are analyzed by simple statistical means and investigated statistical distribution of the results. It was clear that the uncertainties quoted by participants are different from one participant to another, so it wasn't suitable to use simple arithmetic mean as an estimator of the true mean. Instead, it was used weighted mean, and that approach requires that the participants have made correct estimates of their uncertainty of measurements.
Keywords: proficiency testing, gauge blocks, interlaboratory comparisons.

1. THE ROLE OF PROFICIENCY TESTING
Proficiency testing (PT) is an indispensible tool for developing and maintaining of infrastructure of modern society built of competent measurements, standards and accreditation. The most appropriate means of monitoring the quality of the measurement results of laboratories is to include them in programs proficiency testing or external quality assessment or participate in other inter-laboratory comparisons, [1.2]. Interlaboratory comparisons (ILC) represent organization, implementation and evaluation of measurements or tests on identical or similar items carried out in two or more laboratories in accordance with pre-determined conditions, while proficiency testing (proficiency testing, PT) refers to evaluation competence of the participants according to predetermined criteria by interlaboratory comparisons.
The primary aim of proficiency testing is to provide a quality assurance tool for individual laboratories to enable them to compare their performance with similar laboratories, to take any remedial action, and to facilitate improvement. Also, proficiency testing is powerful tool to help laboratory to demonstrate competence to an accreditation body or other third party, enables laboratories to monitor their test over time as well as tool for education and self-improvement.

2. STATISTICAL ASPECTS OF PROFICIENCY TESTING
The statistical methods which organizer of proficiency testing is used for processing of the results are intended to show the results of tests and evaluation in a way that allows participating laboratories, as well as other interested parties, simply and clearly consideration. Analysis of the data must identify extreme results and assess, in a certain level of confidence, their impact on the final statistical results, in accordance with statistical design of PT schemes. There are different methods in application, from numerical to graphic, as described in ISO 5725 and ISO 13528, which are used in a function of PT schemes.

During of a statistical analysis of the results obtained in the interlaboratory comparison is necessary to consider:

- number of participating laboratories;
- number of samples for testing and the number of tests on each sample;
- assessment of the assigned values;
- accuracy and trueness of the results obtained;
- differences between participating laboratories at a desired level of confidence;

The consensus values have to be determined on the basis which enables correctly evaluating the results of participating laboratories. Consensus values can be determined in several ways as results obtained in the reference laboratories or consensus values from expert laboratories. A consensus value has the advantage that it often has a lower uncertainty than the value reported by reference laboratory.

3. STATISTICAL ANALYISIS OF THE MEASURING RESULTS

Organizer ILC/PT scheme was Laboratory for dimensional metrology on Mechanical Engineering Faculty in Sarajevo, which analyzed and processed the results of all participants according to the standards ISO/IEC 17043: 2010 and ISO 13528: 2005, [1,3], and official reports of regional metrology organizations, [4,5]. It is analyzed situation in these laboratories in field of length unit using calibration process of gauge blocks on mechanical comparator. For intercomparison the set of class K gauge blocks is used thru four dimensional laboratories. The technical protocol was issued to all participants prior to comparison. The reported measurement results are analyzed by simple statistical means and investigated statistical distribution of the results. It was clear that the uncertainties quoted by participants are different from one participant to another, so it wasn't suitable to use simple arithmetic mean as an estimator of the true mean. Instead, it was used weighted mean, and that approach requires that the participants have made correct estimates of their uncertainty of measurements, [2, 4]. For each laboratory measured deviation from nominal size is denoted as x_i and its associated standard uncertainty $u(x_i)$.

The normalized weight, w_i, for the result x_i is given by:

$$w_i = C \cdot \frac{1}{[u(x_i)]^2} \tag{1}$$

Where the normalizing factor, C, is given by:

$$C = \frac{1}{\sum_{i=1}^{I} \left(\frac{1}{u(x_i)} \right)^2} \tag{2}$$

Then the weighted mean is:

$$\bar{x}_w = \sum_{i=1}^{I} w_i \cdot x_i \tag{3}$$

The uncertainty of the weighted mean can be calculated as so-called internal standard deviation. Internal standard deviation is based on estimated uncertainties, $u(x_i)$, as reported by the participants:

$$u_{int}(\bar{x}_w) = \sqrt{\frac{1}{\sum_{i=1}^{I} \left(\frac{1}{u(x_i)} \right)^2}} = \sqrt{C} \tag{4}$$

After deriving the weighted mean and its associated uncertainty, the deviation of each laboratory's result from weighted mean is determined simply as $x_i - \bar{x}_w$. The uncertainty of this deviation is calculated as a combination of the uncertainties of the result, $u(x_i)$, and the uncertainty of the weighted mean. In the case considered in this research, the uncertainty of the weighted mean is taken as $u_{int}(\bar{x}_w)$. The uncertainty of the deviation from the weighted mean is given by equation (5), which includes a minus sign to take into account the correlation between two uncertainties, [4,5],.

$$u(x_i - \bar{x}_w) = \sqrt{[u(x_i)]^2 - [u_{int}(\bar{x}_w)]^2} \quad (5)$$

A check for statistical consistency of the results with their uncertainties is made calculating the E_n value for each laboratory:

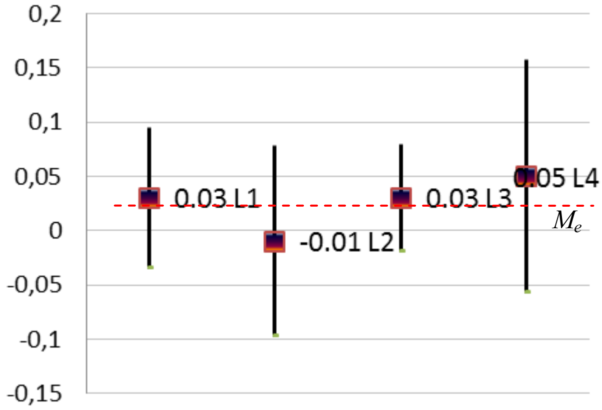
$$E_n = \frac{x_i - \bar{x}_w}{\sqrt{[u(x_i)]^2 - [u_{int}(\bar{x}_w)]^2}} \quad (6)$$

E_n values for each laboratory have been calculated and given in Table 1. In the Figure 1 the deviation in central length of 50mm gauge block is given.

Table 1. Results of measurement and calculation of E_n number for gauge block 50 mm

	L1	**L2**	**L3**	**L4**
d_I	30	-10	30	50
$u(d_I)$	32.5	44	25	54
$1/u(x_i)^2$	0.000947	0.000517	0.0016	0.000343
w_i	0.277947	0.151643	0.46973	0.100068
$w_i \cdot x_i$	8.338407	-1.51643	14.09191	5.033975
x_i-w_t mean	4.05	-35.95	4.05	24.05
E_n	0.07	-0.44	0.11	0.23

Figure 1. Deviation in central length of 50 mm *gauge block*



The analysis is quite straightforward since all of the results have E_n value less than one, at confidence level 95% (k=2) confidence level. This means that the results are all in agreement with the relevant weighted mean, and there are there no outliers.

4. CONCLUSION

Results of statistical analysis vary in different ways, pointing to the fact that with caution it must be chosen way of processing results of proficiency testing. For this detailed approach to the processing of data of proficiency testing should be a great experience in such schemes. That leads to good knowledge of the participating laboratories, their technical capabilities, personnel and environment conditions, as well as the status of the laboratory with regard to accreditation, traceability levels, whether national laboratories and more.

5. REFERENCES

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