Vickers hardness quality assessment through interlaboratories comparison

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Abstract. Year by year, many inter-laboratories comparisons (ILC) are performed in Romania. One of these ILC was performed within strength field – Vickers Hardness. This article presents the results of laboratories’ assessment for 5 laboratories involved in testing, which participated at this inter-laboratories comparison. The Objects of this ILC were two metallic samples of Vickers hardness, used as travelling measurement standards.

1. Introduction
ILC Assessment has been performed by a Romanian PT Scheme Provider in compliance with ISO 17043:2010[1], [2].

In the domain of force measurements, the reference laboratory has the following main activities:

a) ensuring of measurements’ traceability to SI;

b) using, preservation and improvement of the national measurement standard;

c) dissemination of unit;

d) using, preservation and improvement of reference measurement standards in force measurements field;

e) performing calibrations.

Reference laboratory has Calibration and Measurement Capabilities (CMCs) and assures the traceability as it follows:

a) in force measurements field, between [0.001 …100 000] N to mass, length and time national measurement standards and between [100 …3 000] kN to PTB Germany measurement standards.

b) in torque/moment of force measurements field, between [0.1 …2 000] N·m to mass, length and time national measurement standards.

c) in hardness measurements field to mass, length and time national measurement standards.

In this ILC, Vickers hardness metallic samples having the appropriate homogeneity of measurement standards, in compliance with ISO 6507-3 - Metallic materials, there were used Vickers hardness test — Part 3: Calibration of reference blocks.

2. Travel of measurement standard
The type of proficiency testing scheme was the quantitative sequential participation scheme. The proficiency test items have been circulated, from the proficiency testing provider to the participating laboratories, as it is schematically presented in figure 1.

The objects of the proficiency test are two metal samples of Vickers hardness. The values and measurement uncertainties were assigned through metrological calibrations, using the traceability chain [3]. As proficiency test items there were used two metallic samples of Vickers hardness, serial numbers TIM ICEM 15-122 and TIM ICEM 15-123, manufactured by S.C TIM-ICEM S.R.L., having the following
characteristics:
a) hardness scale: VH10;
b) nominal values: from 130 VH10 to 200VH10;
c) external diameter: 60 mm;
d) thickness: 6.85 mm.

3. Results and discussions
The reference laboratory of provider firstly performed the characterization of travelling measurement standard. The assigned values taken into account were finally established by the reference laboratory.

Measurement results obtained by reference laboratory, for metallic samples of Vickers hardness having serial numbers TIM ICEM 15-122 and TIM ICEM 15-123 are graphically presented in figure 2, figure 3, being synthesized in table 1 and table 2, respectively.

![Figure 1. Travel route of the measurement standard.](image)

![Figure 2. The results obtained for the first metallic sample.](image)

![Figure 3. The results obtained for the second metallic sample.](image)

Performance evaluation done by the PT provider adds value to the results produced by the participant. The purpose of providing a performance evaluation is to make all PT results comparable, so that the participant can immediately appreciate the significance of the evaluation. The use of measurement uncertainty in the performance evaluation is increasing as the understanding of this aspect is improving.

Two types of measurement uncertainties [4], [5] were taken into account:
a) measurement uncertainty of the assigned value;
b) measurement uncertainty of the participant’s result.
Table 1. Measurement results obtained by reference laboratory and participating laboratories, for metallic samples of Vickers hardness, having serial number TIM ICEM 15-122.

| Laboratory | Vickers Hardness | U |
|------------|-----------------|---|
|            | H₁ | H₂ | H₃ | H₄ | H₅ | H  | VH10 |
| Reference  | 127.8 | 132.6 | 132.6 | 130.5 | 127.8 | 130.2 | 2.5 |
| 1ˢᵗ        | 137.0 | 136.0 | 136.0 | 135.0 | 136.0 | 136.0 | 4.6 |
| 2ⁿᵈ        | 126.0 | 128.0 | 133.0 | 133.0 | 130.0 | 130.0 | 2.6 |
| 3ʳᵈ        | 132.6 | 132.1 | 133.2 | 138.8 | 137.8 | 134.9 | 6.2 |
| 4ᵗʰ        | 130.0 | 130.0 | 131.0 | 130.0 | 133.0 | 130.8 | 3.0 |
| 5ᵗʰ        | 135.0 | 132.0 | 134.0 | 134.0 | 133.8 | 133.8 | 5.3 |

Table 2. Measurement results obtained by reference laboratory and participating laboratories, for metallic samples of Vickers hardness, having serial number TIM ICEM 15-123 where H₁.. H₅ are the measured values for Vickers Hardness – VH10 and H represents the mean calculated value of VH10).

| Laboratory | Vickers Hardness | U |
|------------|-----------------|---|
|            | H₁ | H₂ | H₃ | H₄ | H₅ | H | VH10 |
| Reference  | 193.0 | 193.0 | 193.0 | 196.8 | 194.2 | 194.0 | 1.7 |
| 1ˢᵗ        | 194.0 | 197.0 | 196.0 | 194.0 | 197.0 | 195.6 | 4.8 |
| 2ⁿᵈ        | 195.0 | 193.0 | 192.0 | 193.0 | 192.0 | 193.0 | 3.9 |
| 3ʳᵈ        | 190.1 | 194.6 | 196.4 | 196.3 | 198.1 | 195.1 | 6.1 |
| 4ᵗʰ        | 197.0 | 195.0 | 195.0 | 194.0 | 194.0 | 195.0 | 3.0 |
| 5ᵗʰ        | 197.0 | 195.0 | 197.0 | 196.0 | 198.0 | 196.6 | 5.3 |

The evaluation of acceptance criteria for each laboratory was performed by using the following formula:

$$E_n = \frac{x-X}{\sqrt{U_x^2+U_{ref}^2}} \quad (1)$$

where:
- x - measurement result of i laboratory, for each measurement point;
- X - assigned value of PT object;
- Uₓ - expanded uncertainty of the participant’s result x;
- U_ref - expanded uncertainty of the assigned value X determined in a reference laboratory.

The values obtained after the processing of the results for the Evaluation of acceptance are presented suggestively in figure 4, figure 5.

The significance of the obtained evaluation of acceptance is here detailed:
- $|E_n| \leq 1.0; the score indicates “satisfactory” performance,
- $|E_n| > 1.0; the score indicates “unsatisfactory” performance.

Evaluation of participating laboratories’ performance based on normalized error criterion is presented in table 3.
Figure 4. The Evaluation of acceptance $|E_n|$ for the first metallic sample.

Figure 5. The Evaluation of acceptance $|E_n|$ for the second metallic sample.

Table 3. Evaluation of participating laboratories’ performance based on normalized error criteria

| Laboratory | Measurement results for metallic samples of Vickers hardness |
|------------|-------------------------------------------------------------|
|            | Vickers hardness  | Extended Uncertainty | Normalized Error |
|            | serial number TIM ICEM 15-123 | serial number TIM ICEM 15-123 |
| Reference  | VH 10              | VH 10               | En           | VH 10              | VH 10               | En           |
| 1st        | 130.2              | 2.5                 | -            | 194.0              | 1.7                 | -            |
| 2nd        | 130.0              | 2.6                 | -0.1         | 193.0              | 3.9                 | -0.2         |
| 3rd        | 134.9              | 6.2                 | 0.7          | 195.1              | 6.1                 | 0.2          |
| 4th        | 130.8              | 3.0                 | 0.2          | 195.0              | 3.0                 | 0.3          |
| 5th        | 133.8              | 5.3                 | 0.6          | 196.6              | 5.3                 | 0.5          |

4. Conclusions

All participants have met the imposed acceptance criteria of competence for $|E_n|$ coefficients (smaller than 1.0), with only one exception. For metallic samples of Vickers hardness (130.2 ± 2.5) HV 10, having serial numbers TIM ICEM 15-122, $|E_n|$ numbers were between: [0.0-0.2] for 2 values – 40 %, (0.2-0.5] for 0 values – 0 %, (0.5-0.7] for 2 values – 40 %, 1 value of $|E_n|$ was 1.1, representing accordingly 20 %.

For metallic samples of Vickers hardness (194.0 ± 1.7) HV 10, having serial numbers TIM ICEM 15-123, $|E_n|$ numbers were between: [0.0-0.2] for 2 values – 40 %, (0.2-0.5] for 0 values – 60 %.

For Proficiency Testing scheme $|E_n|$ numbers were between: [0.0-0.2] for 4 values – 40 %, (0.2-0.5] for 3 values – 30 %, (0.5-0.7] for 2 values – 20 %, 1 value of $|E_n|$ was 1.1, representing 10 %.

References

[1] JCGM 200:2008, *International Vocabulary of Metrology, Basic and General Concepts and Associated TermsVIM, 3rd edition*
[2] ISO/IEC 17043:2010, *Conformity assessment – General requirements for proficiency testing*
[3] Czichos & others 2011, *Handbook of Metrology and Testing*, Springer
[4] Eurachem Guide 2014, *The fitness for purpose of analytical methods, 2nd edition*
[5] ISO 13528 2005, *Statistical Methods for Use in Proficiency Testing by Interlaboratory Comparisons*