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INTERLABORATORY COMPARISON ON ROCKWELL HARDNESS MEASUREMENT IN THAILAND

Tassanai Sanponpute[1], *Veera Tulasombut*[2], *Rugkanawan Kongkavitool*[3], *Apichaya Meesaplak*[4]

[1] National Institute of Metrology Thailand, Pathumthani, Thailand, Tassanai@nimt.or.th
[2] National Institute of Metrology Thailand, Pathumthani, Thailand, Veera@nimt.or.th
[3] National Institute of Metrology Thailand, Pathumthani, Thailand, Rugkanawan@nimt.or.th
[4] National Institute of Metrology Thailand, Pathumthani, Thailand, Apichaya@nimt.or.th

Abstract – Hardness laboratory of National Institute of Metrology Thailand (NIMT) was a pilot laboratory and responsible for coordinating the interlaboratory comparison in Thailand. The two comparison protocols, comparison on Rockwell scale B hardness measurement and comparison in scale C hardness measurement, were set up for participant to choose according to their application. The artifacts used in these comparisons were hardness reference blocks and machinery part such as cylindrical axles and metal sheets. The measurement result and uncertainty budget were reported to pilot laboratory and are used to compute deviation from reference value and En numbers. Most laboratories had En numbers under 0.5 while few laboratories had En numbers between 0.5 to 1. Only one laboratory, who declared unusual BMC, had En number higher than 2.

Keywords Rockwell, Interlaboratory comparison,

1. INTRODUCTION

National Institute of Metrology Thailand(NIMT) has established the hardness measurement club in Thailand in 2006. The objectives of this club are to help and support testing laboratory and calibration laboratory in Thailand. ISO 17025 states under topic 5.9, Assuring the quality of test and calibration results, that the laboratory shall have quality control procedures for monitoring the validity of tests and calibrations undertaken. Participation in interlaboratory comparison is one of the means of monitoring plan [1]. Thus, as the first activity of the club, the members agreed to set up interlaboratory comparisons because the results from this proficiency testing can be used as an indication of a laboratory's competence and are integral part of the assessment and accreditation process.

As discussion among the member of the hardness club, the most common scales in hardness measurement are Rockwell scale B and scale C. Therefore, two protocols were set up in this interlaboratory comparison in order that participant can take part in relevant application. The two protocols are MH-01:Comparison on hardness measurement Rockwell Scale B and MH-02: Comparison on hardness measurement Rockwell Scale C.

As a national metrology institute, NIMT worked as a pilot laboratory and reference laboratory. NIMT also invited Material Properties Analysis and Development Centre to be the co-pilot laboratory in this comparison due to their capability and reputation in material testing in Thailand. The comparisons were carried out during March 2008 to April 2009.

2. ARTIFACT

In protocol MH-01 and MH-02, the comparisons consist of two sections: measurement of hardness reference blocks and measurement of machinery part artifacts.

2.1. Hardness Reference Blocks

Two sets of 9 hardness reference blocks with nominal hardness from 25, 30, 40, 50, 60, 70, 80, 90, 100 HRBS and HRBW were used in protocol MH-01, and 10 hardness reference blocks 20, 25, 30, 35, 40, 45, 50, 55, 60, 65 HRC were used in protocol MH-02. All hardness reference blocks in this comparison, manufactured by Asahi Giken Co.,Ltd. Japan, were engraved as the pattern illustrated in figure 1. Indentation position sheets were distributed to participants in order to identify the indentation position on the blocks for each laboratory. The artifacts were first measured by pilot laboratory and then sent to the next participant (Round Robin Test). Until all participants completed the measurement, the hardness blocks were transported back to pilot laboratory to remeasure in order to evaluate the stability of the hardness reference block. The difference between the first and the end of comparison of all HRB and HRC hardness blocks are significantly lower than the measurement uncertainty. Therefore, the hardness change of the block artefacts is not considered in uncertainty budget.

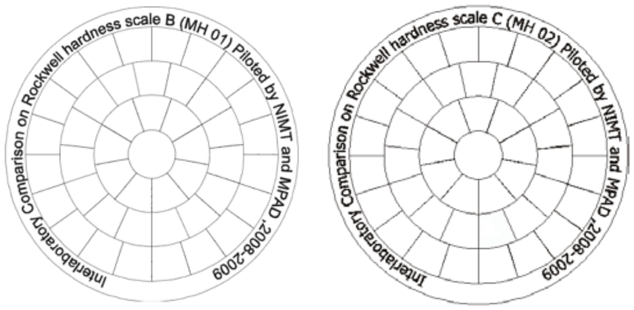

Fig. 1. Engraving pattern on hardness reference block artifact.

2.2. Machinery Part Artifacts

The machinery parts were used to evaluate the competence of participants in measuring the artifacts that requires surface preparation, appropriate anvil selection, and correction value application. In protocol MH-01, three sizes of 100 HRB cylindrical axles: 5 mm, 8 mm and 12.5 mm in radius and two sizes of 70 HRB metal sheets: 3 mm and 4 mm thick were used as machinery part artifacts. Also three sizes of cylindrical axles (5 mm, 11 mm1 19 mm in radius), for each hardness value 25 HRC, 45 HRC, and 60, were prepared as the cylindrical-shaped artifacts in protocol MH-02. Cylindrical axles and metal sheet as well as its indentation-positioning sheet are shown in figure 2.

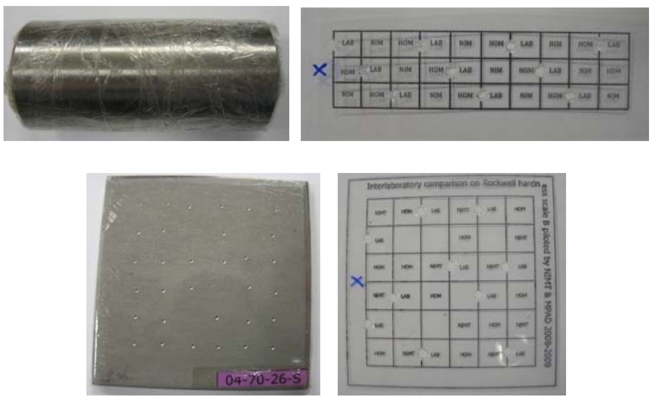

Fig. 2. Machinery part artifacts and indentation-positioning sheet

Since each artifact was measured only by pilot laboratory and one participant laboratory, the co-pilot laboratory was responsible for hardness homogeneity investigation. The investigation was aimed to confirm the homogeneity of the whole piece of each artifact and also to confirm hardness deviation within group. All of samples in one production lot were checked and only satisfying piece for each size were selected as artifacts with the following conditions.

- Non-uniformity of each piece of HRB specimen is $\leq 0.03(130-\overline{H})$ or 1.1 HRB, whichever is greater, and one of HRC specimen is $\leq$ 1 HRC.
- The deviation of the group of selected specimen shall not deviate from their mean 0.5 HRB and 0.5 HRC

All the artifacts used in this comparison passed the criteria and were prepared for each laboratory as a set. It was measured by pilot laboratory before sending to the laboratory.

3. PROCEDURE

The hardness testing machines of each participant used in protocol MH-01 and MH-02 were verified according to ISO 6508-2[2] within 12 months and were checked with indirect verification within 1 month before carrying out the comparison to ensure that the measurement result. Before measuring the artifacts, laboratory cleaned the artifacts and hardness testing machine and determined the deformation of the machine's frame by using plunger with a spherical tip(at least 10 mm diameter) instead of indenter. The indentations were made twice without recording the result and then 3 times with recording the result. Then, participants started to measure the hardness value of all artefacts on the location according to indentation-positioning sheet, with 5 indentations on hardness reference blocks and with 10 indentations on cylindrical axles and metal sheets.

After recording the measurement data, participants evaluated the measurement uncertainty based on the principles introduced in the GUM (Guide to the Expression of Uncertainty in Measurement) [3]. The influence quantities contributing in uncertainty include, but not limited to, hardness testing machine, resolution of hardness testing machine, and repeatability of measurement.

4. ANALYZING METHOD OF COMPARISON RESULTS

The comparison results were calculated in accordance with ISO/IEC GUIDE 43-1: 1997 and ISO/IEC GUIDE 43-2: 1997 "Proficiency Testing by the Interlaboratory Comparisons"[4]. Two parameters, deviation from the reference value (d) and En numbers (E_n), were determined as in (1) and (2) respectively.

$$d = x_i - X_{ref} \tag{1}$$

$$E_n = \frac{x_i - X_{ref}}{\sqrt{U_{(x_i)}^2 + U_{(X_{ref})}^2}} \tag{2}$$

where

- x_i is measured value of participants
- X_{ref} is reference value of pilot laboratory
- $U_{(x_i)}$ is expanded uncertainty of a participant
- $U_{(x_{ref})}$ is expanded uncertainty of pilot laboratory

The obtained results for which $|E_n| \leq 1$ are considered to be satisfactory, and the one with $|E_n| > 1$ are considered to be unsatisfactory. However, the measurement system should be investigated when the results show $0.5 \leq |E_n| \leq 1$.

5. COMPARISON RESULT

The code numbers were set for each participant in the comparison result in order to keep participant result undisclosed.

5.1. MH-01 Comparison Result

In MH-01 protocol, there are 5 participants carried out the comparison in HRBS scale and 1 participant in HRBW scale. The deviations from reference value with measurement uncertainty and En numbers of both HRBS and HRBW hardness reference blocks are shown in figure 3.

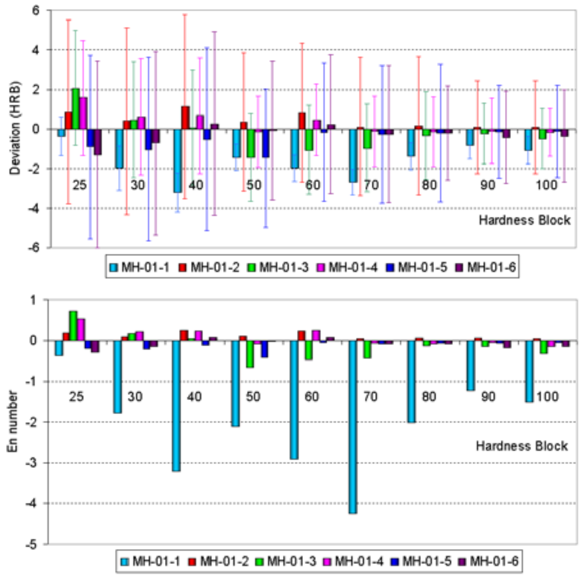

Fig. 3. Deviation from the reference value with measurement uncertainty and En numbers of HRB hardness reference block measurement.

Figure 4 and 5 illustrate the comparison results of HRB cylindrical axles and sheet metal measurement respectively. Both results are shown together with result of reference hardness block with same hardness level to compare the difference of measuring hardness on block artifact and other shapes of artifact.

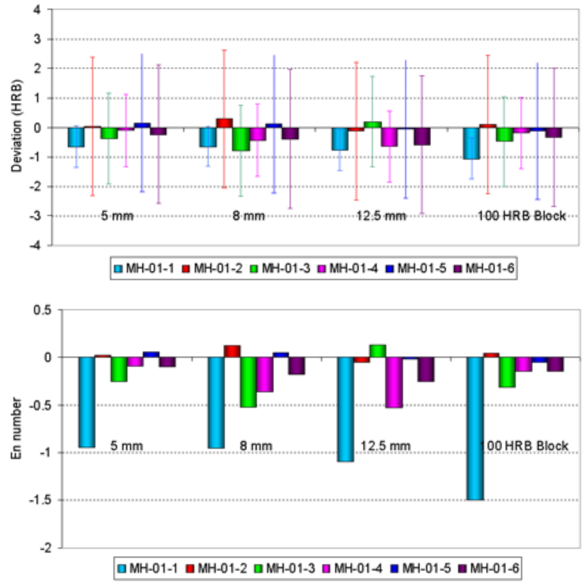

Fig. 4. Deviation from the reference value with measurement uncertainty and En numbers of HRB hardness measurement of cylindrical axles.

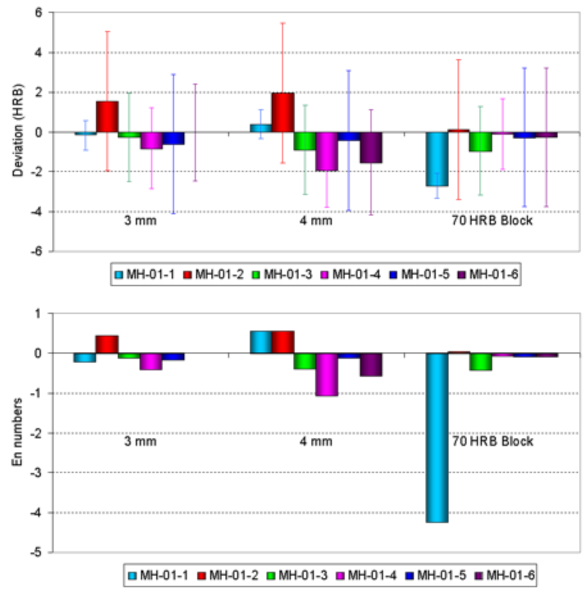

Fig. 5. Deviation from the reference value with measurement uncertainty and En numbers of HRB hardness measurement of metal sheet.

5.2. MH-02 Comparison Result

Three participants worked in this comparison. The results on HRC measurement of reference blocks and shafts are shown in figure 6 and 7.

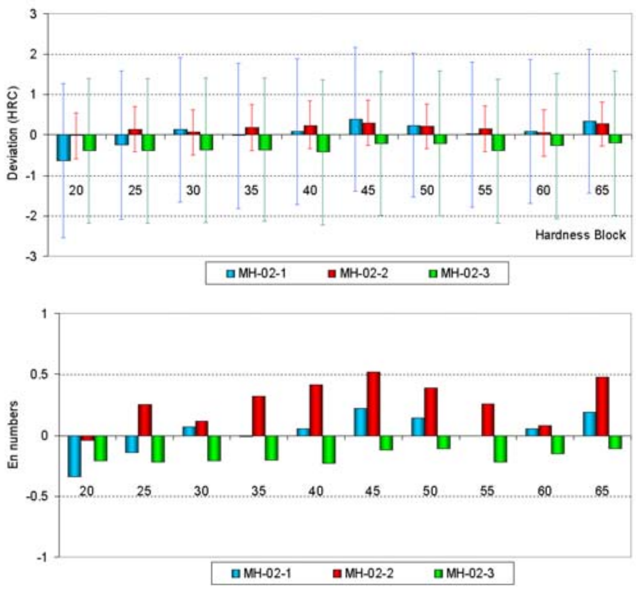

Fig. 6. Deviation from the reference value with measurement uncertainty and En numbers of HRC hardness reference block measurement

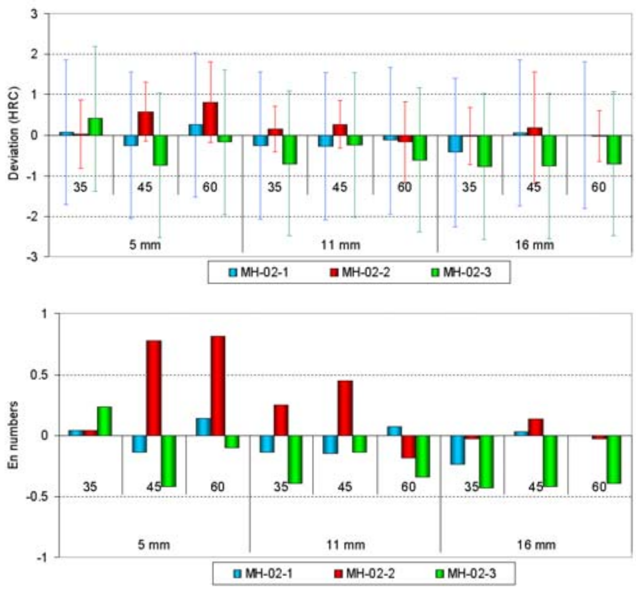

Fig. 7. Deviation from the reference value with measurement uncertainty and En numbers of HRC hardness measurement of cylindrical axles.

5. DISCUSSION

All the testing laboratories, participating in this interlaboratory comparison on Rockwell hardness scale B and C measurement, had their standard calibrated both direct verification and indirect verification. Most laboratory claimed Best Measurement Capability (BMC) according to Maximum Permissible Error (MPE) in ISO 6508-2 which are 4 HRB, 3 HRB, 2 HRB, and 1.5 HRC for hardness range (20-40) HRB, (50-80) HRB, (90-100) HRB and (20-70) HRC respectively. Some laboratories claimed BMC lower than MPE. For example, BMCs of laboratory MH01-4 are approximately half of MPE of HRB scale in ISO 6508-2 and laboratory MH02-2 claimed BMC at 0.45 HRC. However laboratory MH01-1 claimed BMC as low as 0.8 HRB, 0.5 HRB, and 0.6 HRB for hardness range (25-40) HRB, (50-80) HRB, and (90-100) HRB respectively, which are considered impractical.

The comparison result of hardness reference block measurement shows that the deviation from reference value is inversely proportional to hardness level. The deviations are small for high hardness level and deviation are likely higher for lower hardness level. On the other hand, comparison result of cylindrical axles shows noticeably higher deviation from reference value than one of hardness block measurement. These larger deviations result from mis-alignment between indenter and center of cylindrical axles, error from frame deformation when measuring axles, as well as unsuitable anvil selection in case of sheet metal artifact. However, there is inconsistency between measurement of reference block and machinery part for laboratory MH01-1, which could be the result from gross error.

Degree of equivalence was evaluated from En number. Most laboratories, who claimed BMC according to MPE in ISO 6508-2, have En number lower than 0.5 for both hardness block and machinery part measurement. En number of laboratory MH01-4 and MH02-2, who claimed BMC half of MPE and 0.45 HRC respectively, are higher than 0.5, but lower than 1. Claiming unreasonable BMC, laboratory 1-01 has En number higher than 2. It is responsibility the laboratory to review BMC and investigate the cause of inconsistency in measurement result.

6. CONCLUSION

This interlaboratory comparison shows that testing laboratories are capable of measuring hardness of hardness block better than other shapes. Moreover, there is possibility for laboratories to decrease measurement BMC to be lower than MPE as in ISO6508-2. This improvement of BMC, however, should be different between the measurement of block and other shapes. The BMC of other shapes should be set higher that one of blocks.

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