IMEKO 23rd TC3, 13th TC5 and 4th TC22 International Conference
30 May to 1 June, 2017, Helsinki, Finland

RESULTS OF PROFICIENCY TEST OF THE HARDNESS CALIBRATION LABORATORIES USING THE REFERENCE INDENTATION FOR BRINELL HARDNESS

Nae Hyung Tak[1], *Hoon Sik Bae*[2]

[1]KRISS, Daejeon, Korea, nhtak@kriss.re.kr
[2]Korea Instrument Co., Ltd., Busan, Korea, hoonsik1130@hanmail.net

Abstract: The indentation measurement of Brinell hardness is an important element that can determine the accuracy of measurement results. However, although the performance of hardness testers have significantly improved over the years, the deviation of indentation measurements among the testing centers has not changed. It is not even difficult to find testers who have differing measurement results for the same indentations. This paper is related to the proficiency test of calibration laboratories using the Brinell hardness reference indentation specified in ISO 6506-3.

Keywords: Brinell Hardness, Reference indentation, Hardness proficiency test

1. INTRODUCTION

Since Brinell hardness is calculated using indentation diameter, it is difficult to assure the accuracy and reliability of hardness test results without accurately measuring the indentation diameter. Industrial sites often face difficulties because of different measurement results for the same indentations. Although the performance and functionality of hardness testers have significantly improved recently, deviation still occurs because of many factors, including the brightness of the measuring microscope light and numerical aperture (NA). The key comparison of Brinell hardness conducted in 2003 showed that the ability to measure the skill of the reference indentation (called “Brinell hardness dummy indentation” at that time) was closely related to actual Brinell hardness measuring results [1]. It confirms that the ability to measure the indentation is the most important technical element of the ability to measure the Brinell hardness. This paper is related to the proficiency test that manufactures the Brinell hardness reference indentation specimen and use for the test as specified in ISO 6506 part 1, 2 and 3 [2], [3], [4]. Moreover, it provides the Brinell hardness reference indentation that should be used as it shows a significantly improved deviation. This would replace the calibration laboratories’ standard scale calibration that failed the proficiency test. It proves that the Brinell hardness reference indentation is a very effective calibration means to improve the accuracy of Brinell hardness measurements.

2. OVERVIEW OF SPECIMEN OF BRINELL HARDNESS REFERENCE INDENTATION AND PROFICIENCY TEST

Diameter reference indentations of (2-5) mm were used since they are most widely used for measurements in calibration laboratories. Fig. 1 shows the specimen of Brinell hardness reference indentation manufactured for the proficiency test. As shown in the picture, three rectangles with a number were engraved, and the indentation with a different diameter was positioned at the center. The guideline was created to map the center of the indentation with the x- and y-axes of the measuring microscope. Since the reference indentation must clearly show the corners and there must be no crack on the indentation when it is observed by a microscope, the roughness of the measured surface was fabricated to be 0.2 μm Ra or less [3]. The diameter of the reference indentation specimen was 65 mm and the thickness was 15 mm. Table 1 shows the calibration result of each specimen. Participating in the test were 27 calibration laboratories accredited as hardness tester calibration laboratories by KOLAS(Korea Laboratory Accreditation Scheme). To operate the proficiency test efficiently, the participating laboratories were divided into groups A, B, and C, and the specimen was delivered to them on schedule. It took approximately two months to complete the proficiency test.

Fig. 1. Specimen of Brinell hardness reference indentation.

Fig. 2. A transport case with specimen of reference indentation.

Table 1. Calibration results of reference indentation specimens.

Serial No. of specimen	Indentation No.	Diameter (μm)	Measurement uncertainty *k*=2, (μm)
14070081	1	219.2	1.7
	2	249.3	2.1
	3	298.2	2.1
30510723	4	285.0	1.7
	5	324.7	1.6
	6	420.8	2.2
14010091	1	219.9	1.7
	2	250.2	2.1
	3	299.3	2.3
35020518	4	287.4	1.7
	5	326.4	1.6
	6	424.1	1.8
14070084	1	219.1	1.6
	2	249.5	2.1
	3	298.1	2.0
14030584	4	285.7	1.6
	5	325.3	1.6
	6	420.7	2.2

3. RESULTS OF PROFICIENCY TESTS

Figs. 3, 4 and 5 show the results of the proficiency tests, performed by the participants using the reference indentation. The deviation Δd in Figs. 3 and 4 was calculated with Equation (1).

$$\Delta d = \bar{d}_{Lab.} - d_{ref.} \quad (1)$$

where Δd is the deviation from the reference indentation (mm), $\bar{d}_{Lab.}$ is the diameter of indentation, measured by the participant (mm) and $\bar{d}_{ref.}$ is the diameter of the reference indentation (mm). The E_n number in Fig. 5 was calculated with Equation (2).

$$E_n = \frac{\Delta d}{\sqrt{U_{Lab.}^2 + U_{ref.}^2}} \quad (2)$$

where E_n is the normalized deviation ratio, U_{Lab} is the measurement uncertainty of $\bar{d}_{Lab.}$ (k=2) and U_{ref}: is the measurement uncertainty of $\bar{d}_{ref.}$ (k=2) [5].

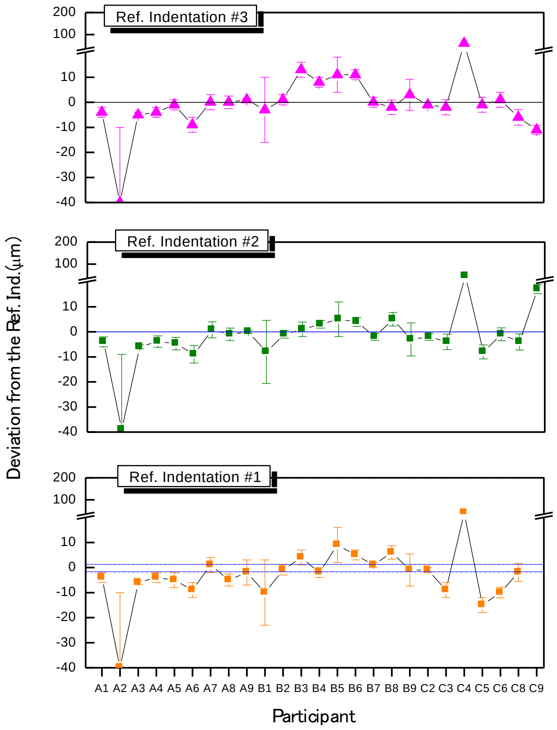

Fig. 3. Results of proficiency test for the reference indentation No. 1, 2 and 3.

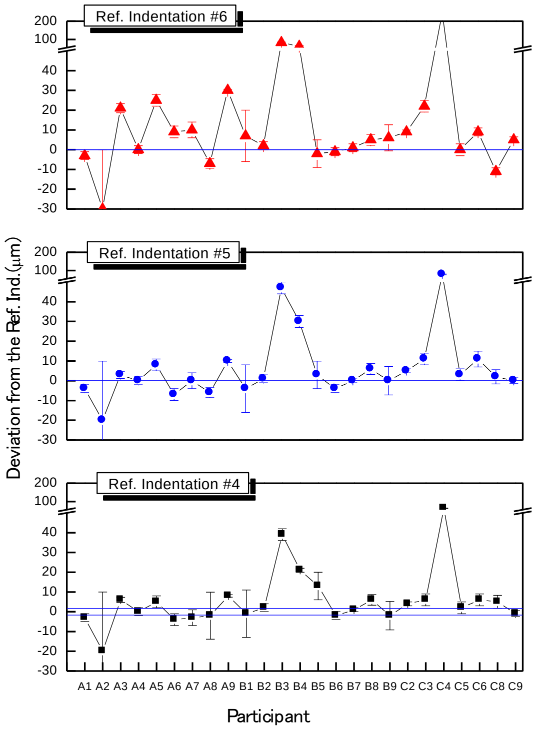

Fig. 4. Results of proficiency test for the reference indentation No. 4, 5, and 6.

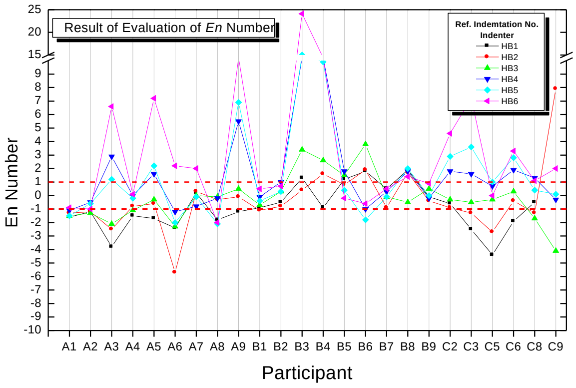

Fig. 5. Calculation result of E_n number.

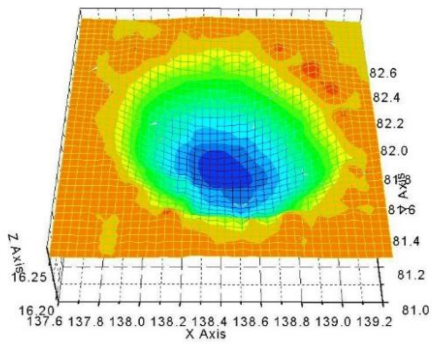

Fig. 6. 3D image of the Brinell indentation.

As shown in Fig. 5, the E_n number, calculated from the measurement results of participant A3, was 6.6, but the E_n number, calculated from participants A5, A6, A9, B3, B4, C3 and C9, varied in the range of 7-24, showing a wide variation. In particular, participant C4, showed the deviation Δd of 0.24 mm, which was much larger than those of other participants. This means that there is a critical problem in the measurement system or in the measurement procedure.

4. RESULTS OF REMEASUREMENT

ISO 6506-2:2014 specifies the use of the reference indentation for microscope calibration in order to measure indentation diameter [3]. The specification was provided to remedy the inaccurate calibrations made by conventional standard scales. Systematic errors using only the standard scale for microscopic calibrations cannot be avoided because the standard scale is 2D while the actual Brinell indentation geometric shape is 3D as shown in Fig. 6. Therefore, using the calibration device or instrument that is closest to the shape to be measured is the most effective way to minimize systematic errors. In this sense, the reference indentation with a reference value was provided to some of the participants who generated the failed results. These participants were asked to use the reference indentation and reference value instead of the standard scale for microscopic calibration and correction value calculation of the tester. It was an experiment to check if the reference indentation could actually reduce systematic errors during calibration. Table 2 shows the result of remeasurement with differences between Δd and $\Delta d_{rem.}$. The absolute reduced relative deviation in Table 2 was calculated with Equation (3)

$$\Delta d_{ARRD} = \frac{|\Delta d| - |\Delta d_{rem.}|}{|\Delta d|} \cdot 100 \qquad (3)$$

where Δd_{ARRD} is the absolute reduced relative deviation in % , and $\Delta d_{rem.}$ is the calculated deviation from the result of remeasurement. The calculated E_n number for each participant is given in Table 3.

Table 2. Results of remeasurement .

Nom. diameter (mm)	Symbol of participant	Absolute deviation (mm)		Absolute reduced deviation (mm)	Absolute reduced relative deviation (%)
		Δd	$\Delta d_{rem.}$		
2.2	A6	0.009 0	0.006 6	0.003 0	26
	B6	0.004 5	0.000 2	0.004 3	95
	C9	0.029 0	0.008 0	0.021 0	72
2.5	A6	0.023 5	0.000 2	0.023 3	99
	B6	0.004 0	0.001 8	0.002 2	55
2.8	B3	0.038 5	0.014 1	0.024 4	63
	B4	0.021 3	0.008 3	0.012 9	61
3	B6	0.011 1	0.000 3	0.010 8	97
	C9	0.011 4	0.001 3	0.010 1	89
4.2	B3	0.082 6	0.018 8	0.063 8	77
	B4	0.062 0	0.011 5	0.050 5	81

Table 3. The change in E_n number of two measurement results.

Nom. diameter (mm)	Symbol of participant	Absolute E_n value	
		1st	2nd
2.2	A6	2.4	1.00
	B6	1.8	0.02
	C9	12.2	3.80
2.5	A6	5.7	0.03
	B6	1.9	0.72
2.8	B3	12.1	3.90
	B4	10.4	0.20
3.0	B6	3.8	0.06
	C9	4.1	0.01
4.2	B3	24.1	5.00
	B4	13.1	0.30

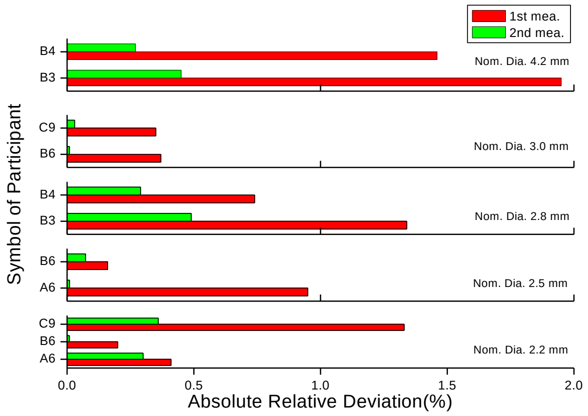

Fig. 7. Comparison of absolute relative deviation between two measurement results.

5. CONCLUSIONS

This proficiency test showed the maximum deviation Δd of 0.24 mm, which was much larger than expected. Therefore, in-depth studies of factors that affect Brinell indention measurements and technical standard presentations to reduce industrial site measurement deviations are needed. The reference indentation to replace the conventional standard scale was provided to participaints who generated the failed results. They were to use it for calibration, such as microscopic calibration related to indentation measurements. The results showed that the deviation is reduced by (26-99)%. This proves that the calibration procedure using the reference indentation is very effective at improving Brinell hardness tests and accuracy. Future plans include improvements in performance and quality in order to use the reference indentation for calibration.

6. REFERENCES

[1] K. Hattori, G.W. Bahng, “Brinell Hardness key comparison CCM.H.-K2”, Final report, Draft A, BIPM, Oct. 2005.

[2] ISO 6506-1:2014, Metallic materials-Brinell hardness test-part 1: Test method

[3] ISO 6506-2:2014, Metallic materials-Brinell hardness test-part 2: Verification and calibration of Testing machines

[4] ISO 6506-3:2014, Metallic materials-Brinell hardness test-part 3: Calibration of Reference Hardness Block

[5] ISO/ISE 17043:2010, Conformity assessment-General requirements for proficiency testing