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Verification Results of Leeb Hardness Indicating Devices from Different Manufacturers Using the Leeb Hardness Reference Voltage Signal

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Abstract – The indicating device of a Leeb hardness tester is an important device that determines the performance of tester. As such, the indicating device needs verification just like the depth-measuring system of a Rockwell hardness tester. This paper presents the verification results of indicating devices from different manufacturers. For the verification, a calibrator to output the reference voltage signal was designed and used for the test. The results showed that the maximum deviation was 24 HLD.

Keywords: Hardness, Leeb Hardness, verification of indicating device.

1. INTRODUCTION

To use the specialized calibration system, ISO 6507-2 and ISO 6508-2 specify the calibration of elements such as the depth-measuring system (dial gauge or digital type) of the Rockwell hardness tester and the diagonal length measuring system of the Vickers harness tester. That is because accurately measuring the depth or area of indentation generated by the interaction of elements other than these two during hardness testing is very important in a hardness test.

The indicating device in the Leeb hardness tester is equivalent to the depth-measuring system of the Rockwell hardness tester and the measuring microscope of the Vickers hardness test. It uses the voltage signal V_A and the V_R output of the impact device to calculate hardness in accordance with equation (1) to calculate the Leeb hardness and displays it. However, it should be noted that a different hardness value may be output even when the same voltage signal is input to the indicating device, since the performance and the method of processing the voltage signal differs depending on the manufacturer of the indicating device.

As such, the indicating device of a Leeb hardness tester needs verification and calibration just like the depth-measuring system of a Rockwell hardness tester and measuring microscope of a Vickers hardness tester. Note, however, that ISO 16859 has yet to provide the detailed procedure for verifying the indication device of a Leeb hardness tester. This paper presents the verification results of indicating devices for the Leeb hardness testers from different manufacturers. For the verification of the indication devices, a calibrator for the Leeb hardness indication device to output the reference voltage signal was devised and used for the test.

The result of testing indication devices showed that the maximum deviation of Leeb hardness indication was 24 HLD.

$$\mathrm{HL} = \frac{\nu_R}{\nu_A} \cdot 1000 \propto \frac{V_R}{V_A} \cdot 1000 \quad (1)$$

Where ,
HL Leeb hardness value
ν_A : impact velocity
ν_R : rebound velocity
V_A : induced voltage proportional to impact velocity
V_R : induced voltage proportional to rebound velocity

2. CALBRATOR FOR INDICATING DEVICE OF LEEB HARDNESS TESTER

Figure 1 shows the circuit board of a calibrator specially designed to verify the Leeb hardness indication device. The voltage output terminal (the yellow and black cables shown in the picture) of the calibrator outputs the voltage corresponding to the impact velocity ν_A and the rebound velocity ν_R of Leeb hardness, and the rebound voltage V_R can vary within a range of -20 mV to -200 mV. Figure 2 shows a sample of the actual voltage signal output by this calibrator. Although the sample voltage signal shown in Figure 2 differs somewhat from the actual Leeb hardness voltage signal in terms of its shape, there was no problem with its operation as the Leeb hardness indicating device detected the peak-to-peak voltage of the voltage signal in a preliminary test. Moreover, the calibrator was designed to implement t_1 and Δt (the time between peak voltage and zero crossing) specified by ISO 16859-2 within the allowed limit. The nominal values of V_A and V_R of the voltage signal sample shown in the figure are 205 mV and 101 mV, respectively, i.e. equivalent to Leeb hardness of 493 HLD.

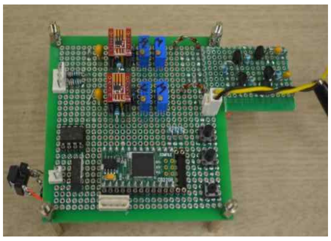

Fig. 1. Circuit board of calibrator for a indicating device of Leeb hardness tester.

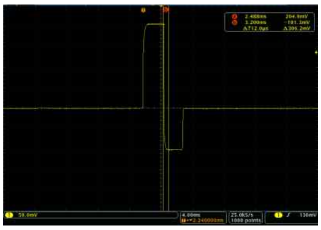

Fig. 2. Voltage signal sample output by the calibrator

3. VERIFICATION RESULTS OF CALIBRATOR FOR INDICATING DEVICE OF LEEB HARDNESS TESTER

The calibrator was verified to check whether it would be suitable for verifying the indicating device of a Leeb hardness tester and for evaluating its uncertainty. For verification, the output voltage of the calibrator was set to be eqivalent to the nominal hardness of 500 HLD, and the voltage output by the output terminal was measured 20 times with an oscillioscope. Table 1 summarizes the calibrator mesurement data and the verification result. The verification showed that the average values of V_A and V_R were 202.8 mV and 101.3 mV, respectively, which is equivalent to Leeb hardness of 499 HLD, indicating a deviation of -1 HDL with a set nominal hardness of 500 HLD. The result of evaluation of measurement uncertainty, expanded uncertainty of the calibrator was 6.2 HLD(k=2).

Table 1. Verification result of calibrator for indicating device

No. of Data	Voltage of, V_A [mV]	Voltage of V_R [mV]	Calculated Hardness [HLD]
1	201.7	101.1	501
2	202.2	100.9	499
3	202.6	100.2	495
4	202.1	100.7	498
5	202.5	101.4	501
6	202.2	101.3	501
7	202.6	101.0	499
8	202.9	101.1	498
9	202.9	101.0	498
10	202.8	100.7	497
11	202.4	100.7	498
12	202.9	101.5	500
13	202.5	101.7	502
14	202.8	101.9	502
15	203.8	101.5	498
16	203.3	101.7	500
17	203.3	101.6	500
18	203.8	101.4	498
19	202.7	101.9	503
20	203.1	101.5	500
Average	202.8	101.3	499
Standard uncertainty[mV]	0.9	0.4	-
Standard uncertainty[HLD]	2.18	2.22	-
Measurement uncertainty(k=2), U	6.2 HLD		

4. VERIFICATION RESULTS OF INDICATING DEVICES

The indicating devices of three manufacturers were tested with the verified calibrator. Each device was twice tested for 20 measurements. Table 2 and Figure 3 summarize the verification results. Table 2 shows that the the maximum hardness indication devation among the tested indicating devices was 24 HLD. The maximum indication deviations of device A and device C were 3.4 % and 4.0 %, respectively. Given that Section 5.4 of ISO 16859-2 specifies the maximum permissible error for a testing instrument when the nominal hardness is less than 500 HLD to be ± 4.0 % or 20 HLD or less, there is a problem with the accuracy of indication. Such indicating devices will not provide an accurate hardness measurement due to the built-in indication deviation even when there are no problems with the impact device and the impact body of the Leeb hardness tester.

Figure 4 shows the verification results of the same type of indicating devices tested in accordance with the indirect verficiation procedure specified in Section 5 of ISO 16859-2. The same impact devices were used to prevent the type of systematic error occasioned by the use of different impact devices, and two reference blocks with a hardness of 466 HLD and 773 HLD were used. As was the case when using the calibrator, the deviations of indicating devices A and C were still too high at 6 HLD ~ 13 HLD, although the values decreased.

Table 2. Verication results of the three different indicating devices.

Indicating device	Avg. of $\frac{V_R}{V_A}$	Ave. of applied Hardness [HLD]	Avg. of Indicated Hardness [HLD]	Deviation [HLD]
A	0.4951	495	512	17
	0.4965	497	510	13
B	0.5005	501	498	-3
	0.5015	502	498	-4

C	0.4971	497	515	18
	0.4943	494	514	20

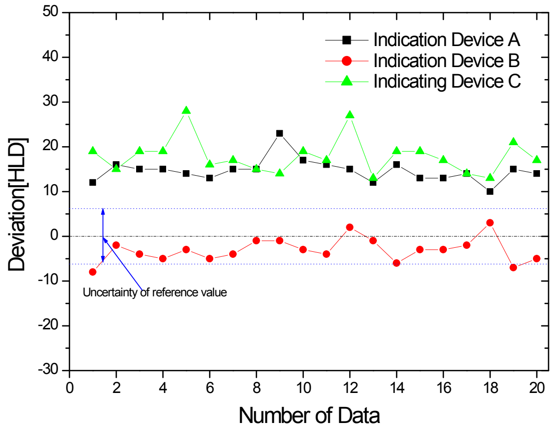

Fig. 3. Verification results of the Leeb hardness indicating devices from different manufacturers

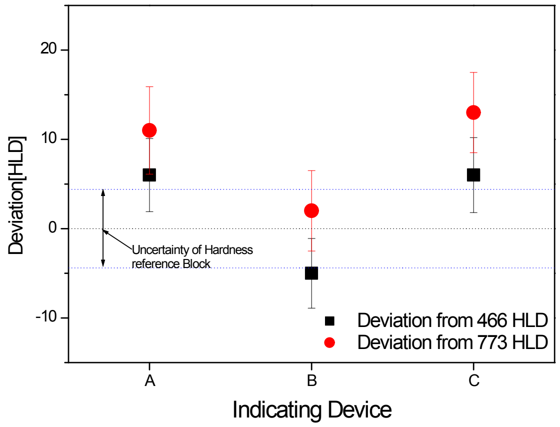

Fig. 4. Verification results of indicating devices using the reference block for Leeb hardness

5. CONCLUSIONS

The verification of Leeb hardness in three indicating devices produced by different manufacturers using a calibrator outputing the voltage signals V_A and V_R showed that the maximum hardness indication deviation among the indicating devices was 24 HLD. The result was consistent with the result of an indirect verification of ISO 16859-2 in deviation characteristics. If the performance of the calibrator used in this study is improved in the future, we are confident that better results will be obtained.

Since the performance of a Leeb hardness tester may differ according to not only the impact body and the impact device currently specified in ISO 16859-2 but also according to the indicating device, further discussion and study will be necessary.

REFERENCES

[1] ISO/DIS 16598-1:2015(E), Metallic materials-Leeb hardness test- part 1: Test method

[2] ISO/DIS 16598-2:2013, Metallic materials-Leeb hardness test- part 2: Verification and calibration of the testing device

[3] ASTM A 956-06, Standard Test Method for Leeb Hardness Testing of Steel Products.

[4] Konrad Herrmann, Hardness Testing Principles and Applications, Pages 78-86, Leeb Method, DIN 50156, ISBN-13:978-1-61503-832-9, 2011