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Primary hardness standard of Brinell hardness in Japan

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Abstract: In the hardness standard, the top of national traceability chain is the primary hardness blocks. The National Metrology Institute of Japan (NMIJ) will start calibration service of primary Brinell hardness blocks. The uncertainty of the Brinell blocks is considered following to the test conditions presented in the paper.

Keywords: uncertainty, Brinell hardness.

1. INTRODUCTION

National Metrology Institute of Japan will start to provide Brinell hardness standard following to the ISO 6506-3 requirements. In the ISO standard, a few test conditions are determined slightly wide range, which may cause the large uncertainty when the whole range of ISO determination is used for the calibration.

Therefore, we determined the test conditions in side the ISO range. The uncertainty of the primary Brinell hardness block is calculated using the variance from the determined test conditions. In the presentation, we explained out target test conditions and the uncertainty calculation with our uncertainty budgets.

2. Measurement conditions to provide the Brinell hardness and uncertainty

To determine our conditions, the followings are considered.

a. The actual tolerance of our primary machine, such as force variation under actual calibration.

b. The relations between the tolerance of the ISO standards and uncertainty.

2.1. Primary hardness machine

The Brinell hardness is realized by the combination of the force applied system, ball indenters and diameter measurement system.

For the indenters, the hard-metal ball is used. The bearing ball has good spherical shape and that is easy to use our purpose. The ISO tolerance gives the uncertainty 0.1 or 0.01 lower than that of other sources. Then we use the ISO tolerance for the ball indenter.

For the force application system, the primary Brinell hardness machine of NMIJ is the lever-amplified dead weight. We determined the tolerance of the lever position which is easily controllable range. The actual measurement can be carried out within the half of that tolerance (target force range). The force variations are depending on the test force, for instance, about 0.6N for 187.5N and about 2N for 29420 N. which is depending frictions and sensitivity of the lever positions.

For the diameter measurement system of the indentation, commercial industrial microscope was used; however, the stage movement was measured by using interferometer system with resolution of 10nm. The uncertainty of the measurement device is restricted by the standard deviations of verification and the stage micrometer, which is used to verify the total system performance. The uncertainty of the stage micrometer is about 400nm.

2.2. Measurement conditions

For the test cycles, we determined the 8sec. for the force application time, and 15sec. for the force duration time, respectively.

In the Brinell hardness measurements, the optical conditions may give the largest uncertainty. It is widely know that the magnification of objective lens causes the difference of the Brinell indentation in the report [2].

In the optical measurement system, numerical aperture (N.A) is the one of index of the system performance. We considered that the effect of N.A.

Assume that the cross-sectional view of the indentation, in which the slope of Brinell indentation shows most accurate change at the edge, and the angle difference between original surface and indented surface also show the largest value. To detect the edge, the optical system should have the sensitivity for the angle at the edge.

If the critical illumination (confocal) method was used , the lowest N.A. is given by the illuminating light just out-side of the measurement angle of the objective. That is shown in the table 1. So that we use the objective N.A.=0.55 for the diameter length measurement.

That result is derived from the simplest consideration. Actually, we used Koehler illumination and it gives much more large divergence for the illumination.

Table 1. lowest N.A. to the measurement of the Brinell indentation

Nominal Hardness [HBW10/3000]	N.A.
650	0.24
600	0.25
550	0.26
500	0.27
450	0.29
400	0.31
350	0.33
300	0.35
250	0.38
200	0.43
150	0.49
100	0.59

2.3. Uncertainty budget

We calculate the measurement uncertainty following to the GUM and EA. guideline.

In our uncertainty calculation, the values between first and second measurement can be corresponding within the calculated uncertainty. Therefore, the uncertainty due to the uniformity of the blocks is combined into the calculation.

In the figure 1, we show the typical example of the uncertainty budget of out measurement.

3. Summary

In this paper, we introduced how to provide the primary Brinell hardness blocks and its uncertainties. On the international level, the Key comparison of the Brinell hardness has been carried out. The effect of the N.A. is also discussing at the CCM working group on hardness. We would like to determine final calibration uncertainty of NMIJ for Brinell hardness following the result of Key comparison.

REFERENCES

[1] ISO 6506:1999, “Metallic materials-Brinell harndess test –part 1-3”, International standard organization.

[2] Takeo YOSHIZAWA, "hardness test methods and its applications", Shokabo, Tokyo Japan (1967), in Japanese.

450HBW10/3000

	source of uncertainty		estimated value	unit	Limit value	Distribution type	Standard uncertainty	unit	Sensitivity coefficient, ci	unit	uncertainty contribution, u(H),	type
	division	subdivision										
1	Force	-	29420	N	-	Normal	1.925E+00	N	1.53E-02	HBW/N	2.94E-02	A
2	Length measuring device	Length measuring device	2.883	mm	-	Normal	2.675E-04	mm	-3.19E+02	HBW/mm	8.54E-02	A
3		Repeatability of readings	0	mm		Normal	2.595E-03	mm	-3.19E+02	HBW/mm	8.28E-01	B
4	Indenter geometry	Diameter of the ball	10	mm	1.00E-03	Rectangle	2.887E-04	mm	2.00E+00	HBW/mm	5.76E-04	A
5	Testing cycle	Force application time	8	sec	0.5	Rectangle	2.887E-01	sec	2.07E-01	HBW/sec	5.98E-02	B
6		Test force dulation	15	sec	0.5	Rectangle	2.887E-01	sec	-1.61E-01	HBW/sec	4.65E-02	B
7	Uniformity of Blocks	-	455.8	HBW	-	Normal	2.790E-01	HBW	1.00E+00	-	2.79E-01	A
combined standard uncertainty, u [HBW]											0.882	
expanded combined standard uncertainty, U [HBW] (k=2)											1.76	

Fig. 1. Example of the uncertainty budget, 450HBW10/3000