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Application News

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Micro Vickers Hardness Tester

Vickers Hardness Test of Curved Surfaces

Vickers hardness is used as an index of the mechanical and physical properties of materials in a variety of fields, including quality control at production sites, research and development, and analysis. A distinctive feature of the Vickers hardness test is its simplicity. Among the many advantages of this method, the time required for one measurement is extremely short, and accurate measurement values can be obtained by personnel without special skills.

Vickers hardness is calculated from the length of the diagonals of the indentation that remains when Vickers indenter is pressed onto the surface of a sample with an arbitrary test force and that force is then removed. When the sample surface is curved, it is necessary to measure the length of the diagonal of the indentation on the curved surface correctly. ISO 6507-1 and JIS Z 2244, which are standards for Vickers hardness measurement methods, provide methods for converting the apparent hardness when testing curved surfaces to the hardness of a plane surface by using a correction factor.

In this test, we introduce an example of correction using a Shimadzu HMV-G series micro Vickers hardness tester as an example of a Vickers hardness test of curved surfaces.

C. Oya

Hardness Correction Factors in Tests of Curved Surfaces (ISO 6507-1, JIS Z 2244)

The above-mentioned ISO and JIS standards describe correction factors for converting the apparent hardness of curved surfaces to the hardness of a plane surface based on the ratio of the mean diagonal length d of the indentation to the diameter D of the curved surface. Correction factors are provided for concave and convex spherical surfaces and concave and convex cylindrical surfaces. For example, if d/D of a convex spherical surface is 0.206, the correction factor assumes the value of 0.850, meaning that the hardness value evaluated on a plane surface is equal to 85 % of the hardness value evaluated on a curved surface (apparent hardness). The following shows the calculation equation for Vickers hardness (HV) when correction is necessary.

$$HV = 0.1891 \times F/d^2 \times k \quad \ldots (1)$$

- d : mean diagonal of indentation (mm)
- D : diameter of the curved surfaces (mm)
- F : test force (N)
- HV : Vickers hardness
- k : correction factor corresponding to d/D

(Ex.) Correction factors for hardness of convex spherical surface

d/D	Correction factor
0.185	0.860
0.195	0.855
0.206	0.850

(From ISO 6507-1 Tables B.1 - B.6, JIS Z 2244 Tables B.1 - B.6)

Test Conditions

Table 1 and Table 2 show the test conditions and sample information, respectively, and Fig. 1 shows the sample holding method and the test conditions. The metal sphere and metal cylinder were used in their original product forms without grinding. The sample parts were fixed in a Shimadzu slender sample attachment (option) by means of a metal band as shown in Fig. 1, and the test was conducted at the apex of the curved surface.

Fig. 2 shows the sample shape selection screen. The software of the HMV-G series enables automatic correction of Vickers hardness for curved surfaces by selecting the sample shape and inputting its diameter.

Table 1 Test Conditions

Testing machine	: HMV-G series Micro Vickers Hardness Tester
Indenter	: Diamond square pyramid indenter, tip angle: 136° (Vickers indenter)
Test force	: 490.03 mN
Holding time (s)	: 10
Number of tests	: 5 times

Table 2 Sample Information

Sample	Metal sphere	Metal cylinder
Dimensions	φ2 mm	φ2 mm × 30 mm
Material	SUS304	S45C

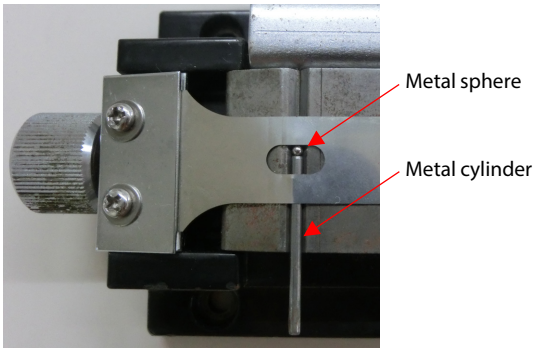

Fig. 1 Image of Sample

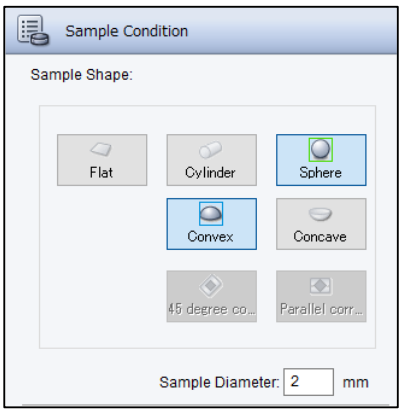

Fig. 2 Sample Shape Selection Screen

Test Results

Table 3 and Fig. 3 show the test results (average values). As a result of measurement under the conditions in Table 1, indentations having a diagonal length d of approximately 65 µm were observed in the metal sphere and metal cylinder with the diameter D of 2 mm. In the standards, the correction factor tables show the values of d/D for correction factors with intervals of 0.05. In the case where it becomes necessary to calculate a value of d/D which is not shown in the table, the correction factor is determined by interpolation from the corrections factors before and after the desired d/D value, and the corrected Vickers hardness is calculated automatically.

Table 3 Test Results (Average Value)

	Diagonal length (µm)	HV (apparent)	HV (corrected)	Correction factor
Metal sphere	65.6	215.6	208	0.965
Metal cylinder	65.7	214.7	211.3	0.984

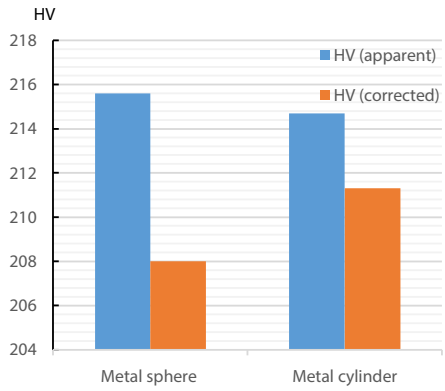

Fig. 3 Test Results (Average Values)

Indentation Image After Test

Fig. 4 shows an image of the indentation after the test of the metal sphere, and Fig. 5 shows a schematic diagram of the indentation as seen from the horizontal direction. Although the shape of the indentation was also observed from the perpendicular direction, i.e., the direction in which the test force was applied, at a glance the shape is not distorted, but when seen from the horizontal direction, the length of the diagonal on the curved surface is shorter in comparison with the one on the plane surface.

As the cause of this difference, assuming that the tip of the indenter reaches the same depth from the sample surface in both samples, in comparison with a flat sample (Fig. 5 (a)), the diagonal length of the indentation formed by pressing the indenter into a sample having a certain curvature (Fig. 5 (b)) will be shorter by an amount corresponding to that curvature.

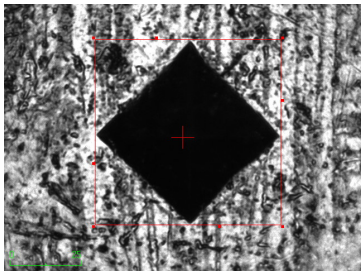

Fig. 4 Image of Indentation After Test of Metal Sphere

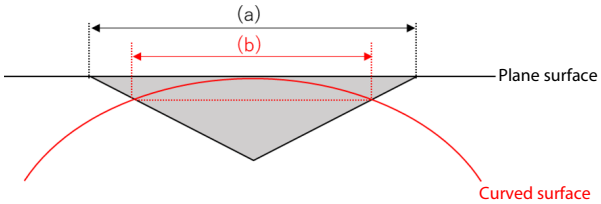

Fig. 5 Schematic Diagram of Indentation from Horizontal Direction
(a) Length of Diagonal in case of Plane Surface
(b) Length of Diagonal in case of Curved Surface

Conclusion

The hardness obtained in Vickers hardness tests of curved surfaces is in an apparent hardness because the length of the diagonal changes along the curved surface. In converting apparent hardness to the hardness of a plane surface, it is necessary to calculate the correction factor from the ratio of the mean diagonal length d of the indentation with respect to the diameter of the sample D.

As shown in the example of the correction factors in Equation (1), for example, in case of a convex surface, the correction factor decreases as the ratio of the diagonal length to the diameter increases, and the hardness of the plane surface is smaller than the apparent hardness. Normally, it is necessary to correct for curvature by a manual calculation at the time of measurement. However, the HMV-G series allows to automatically calculate the correction factor and therefore the Vickers hardness of a curved surface.

The HMV-G series product line includes the HMV-G30 (manual diagonal length measurement), HMV-G31 and HMV-G31-FA (automatic diagonal length measurement), each of which is equipped with the correction function, enabling simple and correct hardness measurements of samples featuring curved surfaces.

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