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ISO HARDNESS STANDARDS INDENTATION HARDNESS TESTS AND HARDNESS STANDARD BLOCKS

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Abstract – ISO standards for hardness are established from metrological standards for force, length, etc. and daily control requirements via hardness standard blocks. The authors have already stated that the unification of loading speed via ISO standards is important both industrially and economically. In consideration of the international importance of ISO standards for hardness testing, the authors review the current ISO specifications in this report, particularly their definition of loading speed, tolerances for Rockwell reference loads, and other test-block requirements, based on our own experiments.

Although it may be necessary to have continuous experimental findings using various hardness testers and test blocks, the following conclusions can be said at present.

(1) As a result of reviewing the basis of defining test force application, it can be generally concluded that LRT would be more appropriate than the indentation velocity as a basis of defining the test force application for indentation hardness tests.

(2) Considering the experiment results and the present situation concerning testing machine and method, the tolerances for the first and second reference loads for Rockwell hardness should be specified independently, and it may be necessary to loosen the tolerance for the second reference load.

(3) In the future, it is hoped that the test load tolerances for overall indentation hardness tests will be reviewed by studying the method of testing the dynamic load being applied during hardness testing, rather than the checking mass of weight or static load.

(4) As regards the ISO requirement for hardness block thickness, it is desirable that that for micro Vickers blocks should be 5 mm or more, and that for non-ferrous HR blocks should be 7 mm or more, based on a through consideration of the characteristics of individual testing methods, test forces, and block materials, as is the case with JIS standards.

(5) It has been confirmed that high-precision hardness blocks play an important role in the experimental verification of various aspects of hardness testing.

Keywords: ISO, Standard blocks, Indentation hardness

1. DEFINITION OF LOADING SPEED FOR INDENTATION HARDNESS TESTING

ISO defines the load speed using the time until the specified load is reached: Load Rise Time, or LRT. As stated in our previous report[1], a change in LRT results in a change in hardness values measured. Therefore, an agreement must be made in the LRT employed between the maker of a hardness block when it determines its standard value of hardness, and its users when they use it. In addition to LRT, loading speed can also be defined using the speed of indenter penetration, or indentation velocity. This is discussed in the following, based on the results of our HV hardness testing experiments via standard blocks described in the previous report.

1.1 Equation of calculating the velocity of indenter penetration

The average velocity of indenter penetration can be obtained by dividing the final depth of indentation by LRT. However, some argue that the last-minute speed of the indenter has more effect on the value of hardness measured, so the authors introduced an equation for calculating the indentation velocity with constants: *HV* kgf/mm2, *P*max. kgf, and *T* s for the harness of the block, the specified test load, and LRT, respectively. Then, at a given time of *t*, the load will be *P(t)* kgf; the diagonal length of a Vickers indentation *d(t)* mm; its depth *h(t)* mm; and the indenter penetration speed *V(t)* mm/s. $HV = 1.8544\ P/d^2$, so $h(t) = d(t)/7 = \sqrt{1.8544P(t)/HV}/7$. The hardness tester used for these experiments was load-controllable, so $P(t) = P\text{max} \cdot t/T$, and by differentiating *h* with the time *t*,

Vickers Indenter Penetration Speed V(t) is given by:

$$V(t) = 0.09727\sqrt{\text{Pmax}/HV \cdot T \cdot t}\ \text{mm/s} \quad (1)$$

over a load-increasing period of $0 < t \le T$. Similarly, in the case of Velcovich indenters, which are frequently used for nano-indentation, if we defined the value of hardness based on the surface area of an indentation as HBVs kgf/mm^2 [2], Berkovich Indenter Penetration Speed is given by:

$$V(t) = 0.09776 \sqrt{Pmax / HBVs \cdot T \cdot t} \text{ mm/s} \qquad (2)$$

again over a period of $0 < t \leq T$. Therefore, if LRT is the same, not only the last-minute speed, but also the speed of indentation at any given time is proportional to the square root of the specified load. This way of introducing indentation velocity is considered to apply generally to hardness tests where the Law of Similitude is in effect, if a change in applied load is given as a function of time.

1.2 Comparison of definitions between LRT and indentation velocity

Figure 1 shows the previous report's LRT-based test results rearranged according to average indentation velocity. If LRT is the same, the indentation velocity for 150 kgf in Pmax, or specified load, is always 3.2 times faster than that for 15 kgf during the load-increasing period according to calculations using Equation (1). However, the HV values for both specified loads remain almost the same. From the results shown in Figure 1, it is regarded as reasonable to employ the current ISO policy, or LRT, to define the requirements for load application. It is speculated that apparent changes of hardness value with indentation velocity are actually related to possible changes in LRT.

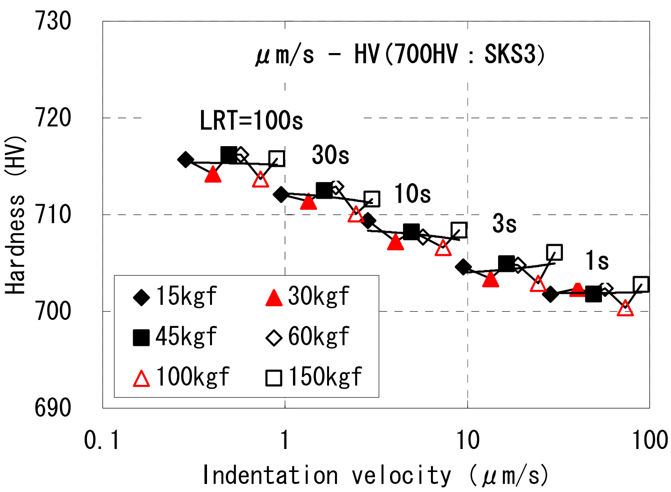

Figure 1: Effects of Loading Velocity on HV Values

2. TOLERANCES FOR ROCKWELL HARDNESS REFERENCE LOADS

In HV hardness tests, the origin of depth is defined when the initial load is applied, and the load is increased until it reaches the full load, then it is decreased back to the initial force when the depth of the indentation is measured. For both the initial and full loads, ISO specifies a tolerance of ±2% for hardness testing machines, and ±0.2% for hardness standard blocks[3]. To verify if these tolerances are

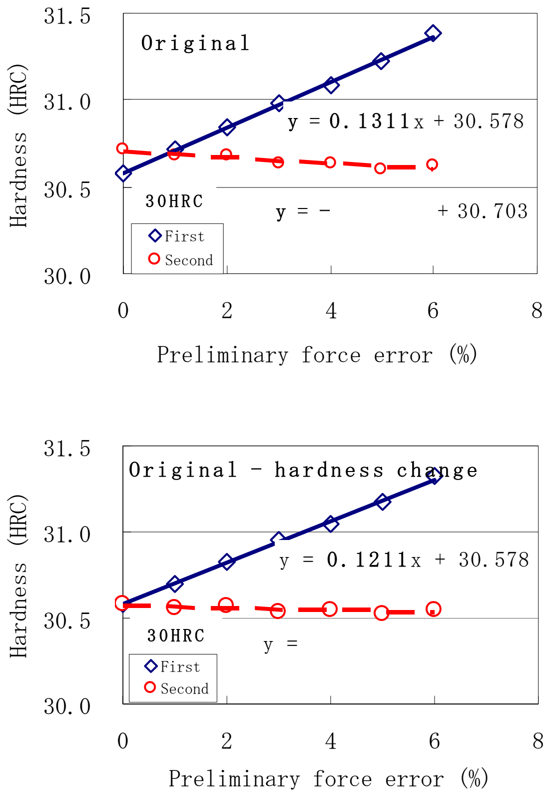

Figure 2.1: Effects of Reference Load Errors on 30 HRC Block (Upper: Original, Below: Original – hardness change)

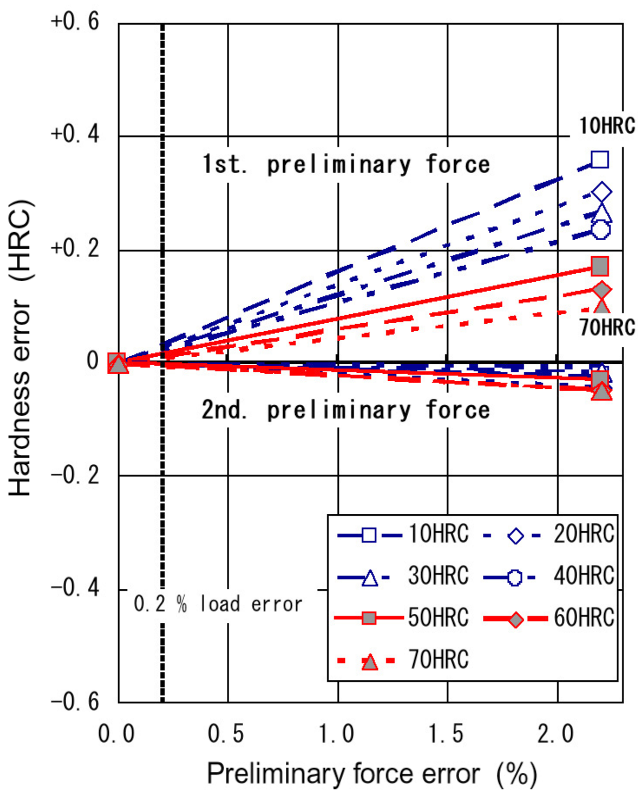

Figure 2.2: Effects of Reference Load Errors on HRC Values

reasonable, we carried out an experiment using standard blocks as shown in Figure 2, where the initial and full loads were independently varied, while trying not to generate errors in the test forces. As we expected, the effect of the second, or full load errors to have on HRC values is far smaller than that of the first, or initial load errors.

3. INDIRECT VERIFICATION OF ROCKWELL DIAMOND INDENTERS

Figure 3 shows the results of calculating the depths of indentations on a hardness block from their diameters for hardness scales from HR15N to HRC. As for HR diamond indenters, ISO requires indirect verification using the hardness blocks: 23HRC (indentation depth: about 210μm), 55HRC (about 130μm), 43HR45N (about 80μm), and 91HR15N (about 15μm), because testing for geometrical errors at the indenter spherical tip alone can cause problems in actual applications[3]. If the usable range of indenter depth is set at 40-240 μm for Rockwell hardness and 10-120 μm for Superficial Rockwell hardness, it follows that users of Rockwell testers need to do the test with a Superficial Rockwell tester as well, and vice versa. Therefore, it is desirable that either test can be done independently.

4. DEFINING THE THICKNESS OF STANDARD BLOCKS

ISO specifies the thickness of an HR test block to be 6 mm or more, and further recommends a thickness of 12 mm or more[3]. However, such a thickness is undesirable for test blocks that are chiefly used for testing elongated copper products, such as HRB blocks, because the sufficient effect of rolling becomes harder to attain with thicker blocks[4]. The fact that the thickness requirement of 6 mm or more is also applied to micro Vickers blocks whose test force is only between 1/100 and 1/10,000 of that for HRC cannot be considered appropriate.

5. CONCLUSIONS

Although it may be necessary to have continuous experimental findings using various hardness testers and test blocks, the following can be said at present.

(1) As a result of reviewing the basis of defining test force application, it can be generally concluded that LRT would be more appropriate than the indentation velocity as a basis of defining the test force application for indentation hardness tests.

(2) Considering the experiment results and the present situation concerning testing machine and method, the tolerances for the first and second reference loads for Rockwell hardness should be specified independently, and it may be necessary to loosen the tolerance for the second reference load.

(3) In the future, it is hoped that the test load tolerances for overall indentation hardness tests will be reviewed by studying the method of testing the dynamic load being applied during hardness testing, rather than the checking mass of weight or static load.

(4) As regards the ISO requirement for hardness block thickness, it is desirable that that for micro Vickers blocks should be 5 mm or more, and that for non-ferrous HR blocks should be 7 mm or more, based on a through consideration of the characteristics of individual testing methods, test forces, and block materials, as is the case with JIS standards.

(5) It has been confirmed that high-precision hardness blocks play an important role in the experimental verification of various aspects of hardness testing.

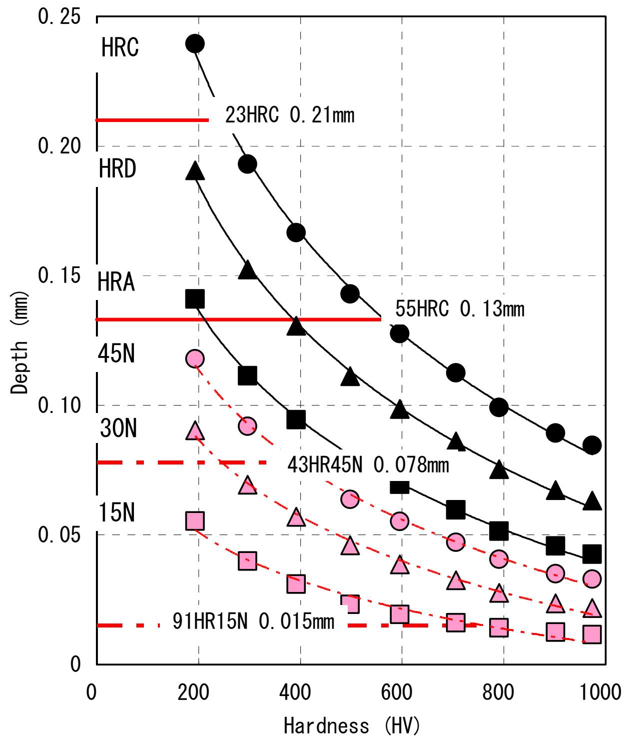

Figure 3: Depth of HR Indentation Made by Diamond Indenters

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