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Application News

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Dynamic Ultra Micro Hardness Tester

# Hardness Test of Mechanical Pencil Leads

The writability of mechanical pencils differs depending on the hardness of the pencil lead. Writing becomes darker as the lead becomes softer and it is possible without breaking the lead as it becomes harder. Therefore, leads are used in different applications depending on their hardness. For example, softer leads are used in sketching and harder leads are used in drafting technical drawings.

The leads of mechanical pencils are made by compounding graphite and resin. After extrusion molding, the compound is baked at approximately 1200 °C and then impregnated with an oily material to impart depth of color and lubricity.

The symbols B and H mean "black" and "hard," respectively, and HB means "hard & black," an intermediate quality between H and B. Accordingly, the order of hardness of mechanical pencil leads is 2H > H > HB > B > 2B.

Although the symbols B and H are defined by the density drawn on drawing paper by a density measurement machine, there is no scientific definition of pencil lead hardness. Therefore, the following introduces an example of a hardness test of mechanical pencil leads. The hardness of mechanical pencil leads was confirmed by using a SHIMADZU DUH-211 Dynamic Ultra-micro Hardness Tester.

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## Specimens

Table 1 shows the specimens used in the measurements, and Fig. 1 shows a schematic diagram of the test method.

As specimens, 2H, H, HB, B, and 2B leads were selected from commercial mechanical pencil leads. These leads were inserted in a mechanical pencil, and the tip was flattened by polishing the end surface by drawing lines on paper (Fig. 1(a)). Air was then blown on the tip of the lead to remove the dust resulting from polishing, and the test was performed with the pencil secured in a vise (Fig. 1 (b)).

**Table 1 Specimens**

| Specimen Name | Mechanical Pencil Lead | | | | |
|---|---|---|---|---|---|
| | 2H | H | HB | B | 2B |
| Specimen No. | No.1 | No.2 | No.3 | No.4 | No.5 |
| Specimen Shape | Diameter: 0.5 mm, Length: 60 mm | | | | |

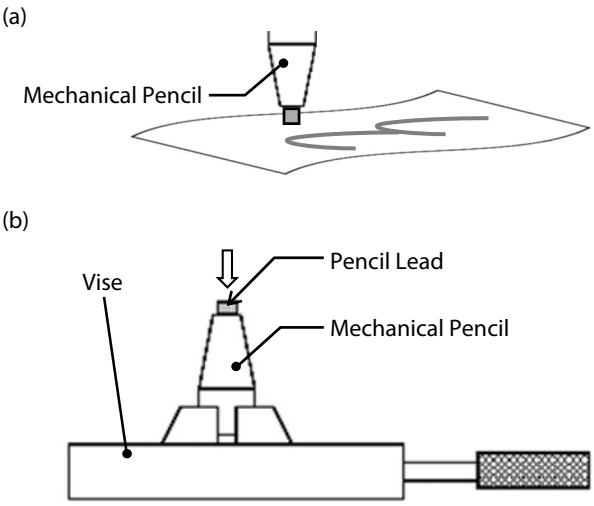



**Fig. 1 Schematic Diagram of Test Method**
**(a) Polishing by Line Drawing**
**(b) Holding Method**

## Test Conditions and Instrument

Table 2 shows the test conditions, and Fig. 2 shows the SHIMADZU DUH-211 Dynamic Ultra-micro Hardness Tester. Although many types of characteristic values can be obtained with this instrument, it was used here to evaluation hardness by Martens hardness.

**Table 2 Test Conditions**

| | |
|---|---|
| Instrument | : SHIMADZU DUH-211 Dynamic Ultra-micro Hardness Tester |
| Top Indenter | : Berkovich indenter (diamond) |
| Test Mode | : Load - Unload Test |
| Maximum Force (mN) | : 49.00 |
| Loading Speed (mN/sec) | : 4.4413 |
| Holding Time (sec) | : 15 |

**Fig. 2 SHIMADZU DUH-211 Dynamic Ultra-micro Hardness Tester**

## Martens Hardness

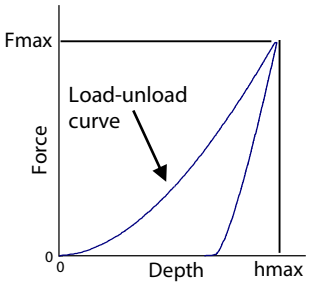
Martens hardness (HM) is the hardness measured when a specimen is loaded with a force and is defined as the "value obtained by dividing the force F by the indenter penetration surface." Martens hardness is expressed by the unit N/mm$^2$ (ISO 14577-1).

With the DUH-211 series, it is also possible to express HM by conversion to the dynamic hardness (DH).

$HM = F / As = F / (26.43 \times h^2)$

F : Force
h : Indentation depth
As : Indenter penetration surface

$DH = HM / 9.80665$
(acceleration of gravity)




## Test Results

Table 3 shows the test results (average values), and Fig. 3 shows the "Force – Depth Graphs." Table 3 shows the Martens hardness [MPa] calculated from the indentation depth [$\mu$m] at the force of 49 mN.

**Table 3 Hardness Test Results by DUH-211 (Average Values)**

| Specimen Name | | Force [mN] | Depth [µm] | Martens Hardness [MPa] |
|---|---|---|---|---|
| Mechanical Pencil Lead | 2H | 49.0 | 2.457 | 286 |
| | H | 49.0 | 2.665 | 243 |
| | HB | 49.0 | 2.730 | 232 |
| | B | 49.0 | 2.833 | 216 |
| | 2B | 49.0 | 2.906 | 207 |

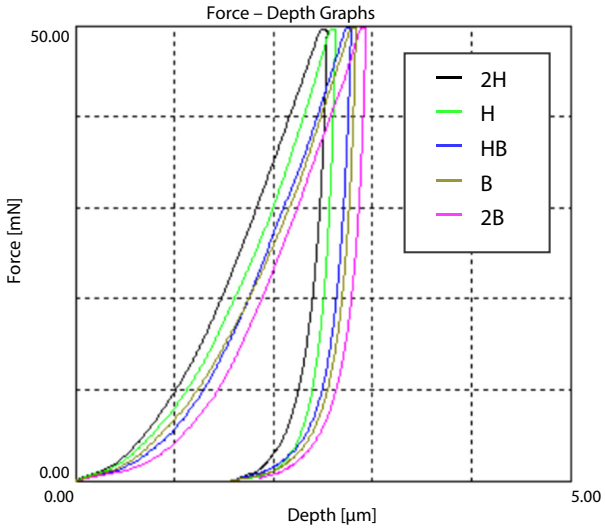



**Fig. 3 Force – Depth Graphs**

## Images of Indentations After Test

Fig. 4 shows images of the indentations in each tested specimen. Because the boundary lines of the indentations cannot be observed clearly, it is difficult to obtain the hardness from the size of the indentation, as is done with Vickers hardness testers. However, with the DUH-211, it is not necessary to observe the indentations, as hardness can be calculated automatically from the measured indentation depth.

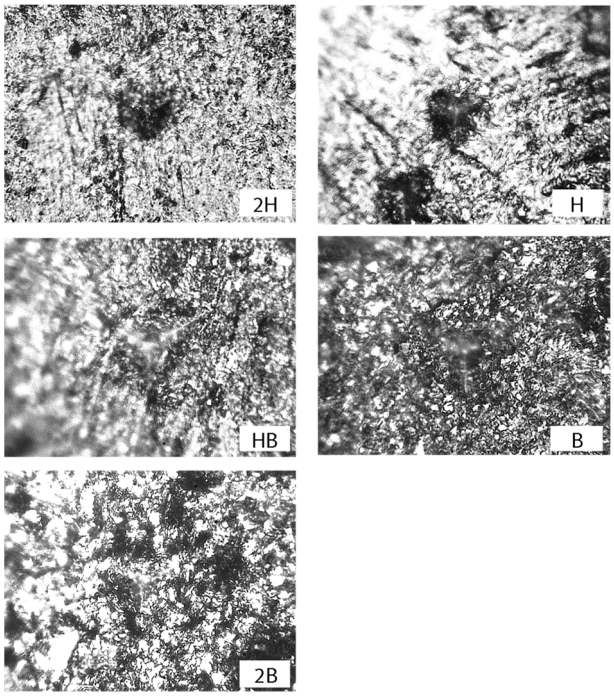



**Fig. 4 Images of Indentations**

## Summary of Test Results

From Table 3, the order of Martens hardness of the mechanical pencil leads was as follows.

2H > H > HB > B > 2B

As this result agrees with the order of high hardness of the mechanical pencil leads, the hardness of the leads could be evaluated by Martens hardness.

## Conclusion

By using the SHIMADZU DUH-211 Dynamic Ultra-micro Hardness Tester, differences in mechanical pencil leads can be evaluated by the hardness value rather than the density of drawn images. This article introduced an example in which hardness was evaluated by Martens hardness, enabling hardness measurement of materials that do not display a clear indentation.

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