Development & Performance of Hardness Testing Machine Calibration Processor

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Abstract:
The calibration device capable of performing direct verification of both test force & indentation depth, which are fundamental elements of a Rockwell type hardness tester, was developed. This device can also carry out verification of operating conditions.
In this paper, the examples of uncertainty of hardness calculated, based on uncertainty of each element, using this device are shown and the calibration results on the conventional testing machine calibrated by the standardized Rockwell hardness testing machine, which has been used at Akashi Corp., are also shown.

1. Introduction

In order to calibrate a testing machine, it is necessary to measure elements constructing a testing machine and to find uncertainty of hardness from measured results obtained.
Furthermore, verification of operating conditions as defined in ISO 6508-3 is also an important item. Results of uncertainty of hardness found by measuring elements with the calibration device we developed and results of verification of operating conditions are shown as follows.

2. Calibration Device

With the built-in force meter (load cell) traceable to force standards, preliminary test force and total test force can be measured. Load cell was specially designed so as to yield distortion of 80 to 100 μm at total test force loading in order to realize conditions of a testing machine only for this calibration device when measuring 60HRC mostly being used in the industrial field. A frictionless force transfer shaft to guide force other than force of perpendicular direction was placed on the upper part of force meter. Force meter itself was fixed at an anvil, thus causing its position in the device to be fixed.
With the built-in displacement meter traceable to length standards, display value of hardness value indicator under preliminary test force loading can be measured.
The construction allows to directly measure the movement of a force transfer shaft with non-contact laser displacement meter. Furthermore, as the device has the real time acquisition function of test force and displacement during testing, it is possible to verify operating conditions and also to confirm other testing processes and malfunctions during testing. The structure of the device is shown in Fig.1 and the device installed on a testing machine is shown in Fig. 2.

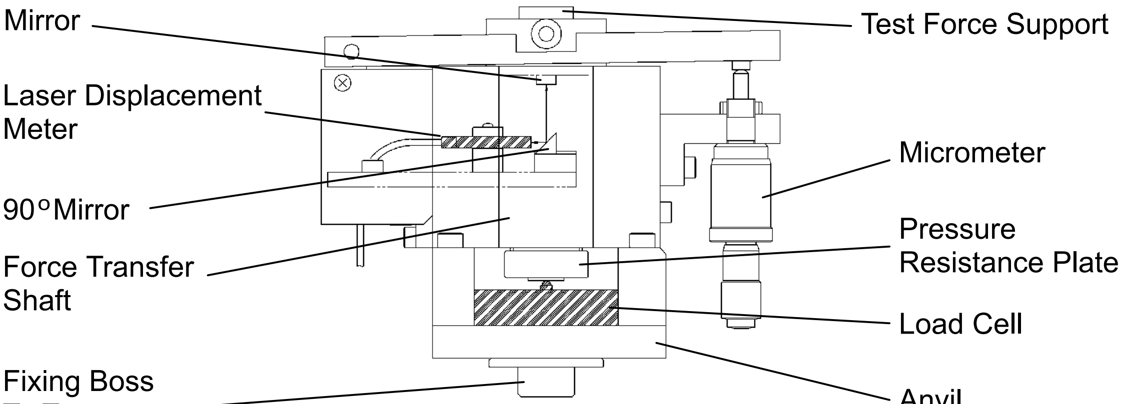


Fig. 1 Structure of Device

Fig. 2 Device installed on H. Tester

3. Measurement of Test Force and Calculation of Uncertainty

Test force measurements at 3 positions within the range of the loading shaft movement (positions of 20, 50, 70HRC) were conducted and measurements were made three times at each position. Uncertainty of test force u_F' was calculated using the following equation .

$$u_F' = \sqrt{\frac{\sum (y_i - M)^2}{9} + u_{FS}^{\ 2}} \qquad (1)$$

where, y denotes 9 measured values, M denotes test force defined and u_{FS} denotes uncertainty of this calibration device.

As uncertainty calculated above is that of test force, it is necessary to convert it to uncertainty of hardness. Conversion adjustment to uncertainty of hardness is a change of hardness against a change of test force, then it is required to find this beforehand. [3] An equation is as follows.

$$u_F = \beta \cdot u_F' \qquad (2)$$

4. Measurement of Length (Display Value of Hardness Value Indicator) and Calculation of Uncertainty

Measurements of display value of hardness value indicator for every 10 graduations between 0 to 100 at preliminary test force loading condition were conducted and measurements were made 3 times at each graduation. Change of movement of hardness graduation of indicator were given by this calibration device. Uncertainty of graduation of indicator u_L was calculated using the following equation.

$$u_L = \sqrt{\frac{\sum (y_i - M)^2}{33} + u_{LS}^2} \tag{3}$$

where, y denotes graduations of a testing machine (33 measurements), M denoted graduation of this calibration device and u_{LS} denotes uncertainty of calibration device.

5. Uncertainty of Measured Hardness Value

Hardness measurements of reference hardness blocks (3 levels: 20, 40, 60HRC, 2 pcs. each, and 6 points measurement for each reference block) were conducted.

Operating conditions were: Loading speed 10 μm/s, Total test force duration time 10 s, Measuring position on reference block: typical 6 sections. Same indenter was used for both the standardized machine and a machine used, thus assuming hardness value variation due to difference of indenter shape to be disregarded.

Uncertainty of measured hardness value u_H was calculated using the following equation.

$$u_H = \sqrt{\frac{\sum (y_i - M)^2}{12} + u_{HS}^2 + u_e^2} \tag{4}$$

where, y denotes hardness obtained by a machine, M denotes hardness obtained by standardized machine, u_{HS} denotes uncertainty of hardness obtained by standardized machine and u_e denotes uncertainty due to hardness non-uniformity of reference block at measuring positions.

6. Combine of Uncertainty

Combine standard uncertainty u' was calculated using the following equation.

$$u' = \sqrt{u_{F0}^2 + u_{F1}^2 + u_L^2 + u_H^2 + u_S^2} \tag{5}$$

where, u_{F0} denotes uncertainty of hardness at preliminary test force, u_{F1} denotes uncertainty of hardness at total test force, u_L denotes uncertainty of hardness at graduation of hardness indicator, u_H denotes uncertainty of measured hardness value (including non-uniformity of reference block at measuring position) and u_S denotes uncertainty of standardized machine.

Extended standard uncertainty U' was calculated using following equation (6), using coverage factor k = 2.

$$U' = 2u' \tag{6}$$

7. Verification of Coherence of Hardness Value between Standardized Machine and Testing Machine

This verification is carried out by finding difference between mean hardness value obtained by the standardized machine and that obtained by a testing machine.

This difference Δ was found by using the following equation.

$$\Delta = \left|\overline{x} - \overline{x_S}\right| \tag{7}$$

where, $\overline{x_S}$ denotes average values of 6 points measured by standardized machine, $\overline{x}$ denotes average values measured by a testing machine.

If this difference were within uncertainty range, the coherence were inferred to be consistent and a testing machine is ensured to be coherent to the standardized machine. If the difference were out of uncertainty range, the coherence were not inferred to be consistent and re-adjustment for elements constructing a machine should be necessary.

8. Uncertainty of Hardness Standards

Hardness testing is performed by measurements of each element where an indenter is involved. Uncertainty of hardness standards therefore depends on not only extended standard uncertainty found by measurement of each element but also uncertainty of indenter u_P. Uncertainty of indenter is changed by an indenter to be used, but when the standard indenter traceable to national standards [2] (with corrections to be added) were used, uncertainty of indenter can be found by adding uncertainty of correction value. Uncertainty, found by such method, obtained by a testing machine and this is uncertainty of hardness standards *U* which is ultimate uncertainty after machine calibration.

$$U = 2 \cdot \sqrt{\left(\frac{U'}{2}\right)^2 + u_P} \tag{8}$$

9. Calibration Result

Uncertainty of calibration device we developed is shown in Table 1.

Uncertainty of standardized machine used and conversion adjustment to uncertainty of hardness were those found by experimental planning method. [3]

Table 1 Uncertainty of Calibration Device

Primary Factor	Symbol	Uncertainty of Hardness
Preliminary Test Force	u_{FSO}	0.039
Total Test Force	u_{FS1}	0.007
Graduation of Indicator	u_L	0.010

Table 2 shows the calibration results for 5 testing machines calibrated by this calibration device.

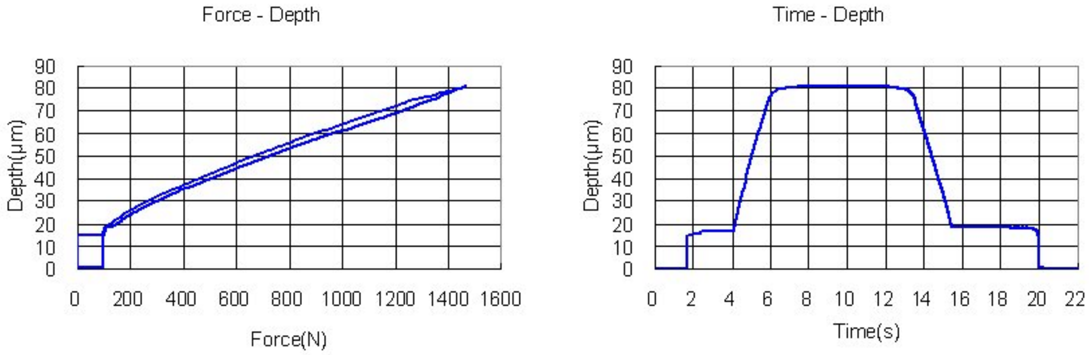
Table 2 Calibration Result

Serial No. / (Tester Model)		200575 (ATK-F3000)	200576 (ATK-F3000)	200577 (ATK-F3000)	233409 (AR-10)	233410 (AR-10)
Uncertainty of Pre.Test Force	u_{F0}	0.005	0.015	0.017	0.022	0.004
Uncertainty of Total Test Force	u_{F1}	-0.035	-0.046	-0.010	-0.008	-0.068
Uncertainty of Length	u_L	0.029	0.064	0.038	0.014	0.014
Uncertainty of Measured Hardness Value	u_{60HRC}	0.25	0.31	0.54	0.26	0.44
	u_{40HRC}	0.30	0.25	0.35	0.38	0.32
	u_{20HRC}	0.52	0.44	0.28	0.51	0.69
Extended Standard Uncertainty	U'_{60HRC}	0.51	0.63	1.09	0.53	0.88
	U'_{40HRC}	0.60	0.53	0.70	0.75	0.64
	U'_{20HRC}	1.05	0.89	0.56	1.01	1.37
Coherence	Δ_{60HRC}	0.02	-0.18	-0.48	0.08	0.36
	Δ_{40HRC}	-0.16	0.04	-0.24	0.28	0.20
	Δ_{20HRC}	-0.46	-0.36	0.12	0.44	0.64
Uncertainty of Hardness Standards	U_{60HRC}	0.79	0.87	1.24	0.80	1.06
	U_{40HRC}	0.85	0.80	0.92	0.96	0.88
	U_{20HRC}	1.21	1.08	0.82	1.18	1.50

10. Confirmation of Operating Condition

As this calibration device has a real time acquisition function for test force and displacement during testing, it is possible to verify operating conditions defined in ISO 6508-3 and it is also possible to confirm the testing processes such as Iindentation speed, loading time and duration time as well as confirmation of malfunctions during testing.

Fig. 3 shows the verification results of operating conditions for the tester S/No. 200575 listed in Table 2.



Duration of Preliminary Test Force(1 to 5 s)	2.0 s
Loading Time of Total Test Force(1 to 8 s)	3.6 s
Duration Total Test Force(4±2 s)	4.0 s
Indentation Speed(20 to 40μm/s)	29.3 μm/s
Final Reading Time of after removing Additional Force(3 to 5 s)	4.0 s

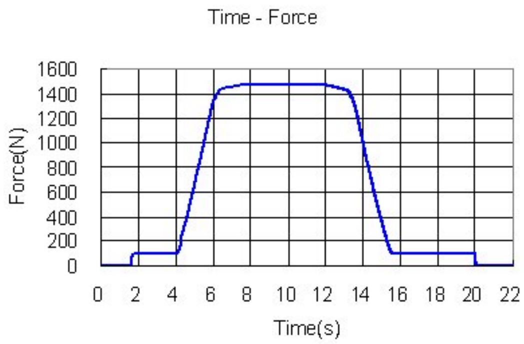


Fig. 3 Verification of Operating Conditions

11. Conclusion

We developed a newly designed calibration device for Rockwell type hardness testing machine and confirmed that direct verification of both force and length and verification of operating conditions defined in ISO 6508-3 could be effectively performed by this single device. With this device, each element of a conventional testing machine was measured respectively and this machine was calibrated by the standardized machine. As results, uncertainty of the machine used at experimental work was in the range from ±0.7 HRC to ±1.5 HRC.

References:

[1] ISO 6508-1,2,3 (Metallic materials - Rockwell hardness test -)

[2] YONO H, ISHIDA H and KAMOSHTA T "Characteristics of Standard Rockwell Diamond Indenters and Method of Establishing Standard Indenters", 7th IMEKO Physikalisch Technische Bundesanstalt P.16,1976.

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