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TEST CYCLE CALIBRATION SYSTEM FOR ROCKWELL HARDNESS TESTER

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Abstract – The direct verification of Rockwell testing machines comprises four parts such as test force, indenter, depth measuring device, and testing cycle as seen in ISO 6508-2. Among them, the verification of testing cycle is generally carried out by using a stopwatch on industrial sites, which is not so reliable. In addition to this, most of commercial hardness testing machines produced nowadays are automatically controlled by the embedded software, which makes it much more difficult to calibrate the testing cycle. It implies that even though hardness testing machines are advanced more, the calibration of the testing cycle does not keep up with their advancement. To overcome this problem, an on-site calibration system was developed to calibrate the testing cycle of both the automatically controlled as well as manually controlled Rockwell hardness testing machines. The calibration system is composed of load cell, indentation depth measuring apparatus and embedded clock. Using this system, measurement of test force, application velocity of test force, and indentation depth are possible simultaneously in real time, which enhances the efficiency and reliability of calibration procedure.

Keywords: Calibration, Testing cycle, Rockwell hardness

1. INTRODUCTION

Rockwell hardness measurements have been widely used in iron and steel industry since it was invented by S.P. Rockwell in 1919. Rockwell hardness is measured by procedural definition which comprises two load levels, two dwell times, two application times, and two depths, etc [1]. To calibrate these parameters, components of testing machines such as loading system, measuring system, and indenters should be calibrated directly [2,3]. Among them, loading and measuring systems are related with the testing cycle of Rockwell hardness measurements. In industry, the testing cycles are calibrated by using a stopwatch and load cells, respectively, one by one. The loads and times have not been calibrated dynamically at the same time. Individual calibration of loads and times may cause a different testing condition from real testing cycle. Recently, it becomes more important to know the application time and dwell time as well as loads and depths for the uncertainty determination of testing machines [2-4]. However, there have been few examples of calibrating the test cycle in industry because its importance has not only been recognized but also there have been few instruments capable of calibrating it. In present study, we introduce a new concept calibration system, called Rockwell test cycle-calibration system (IT5P), that Rockwell hardness testing cycles of load levels and depths are measured simultaneously in real time. The new concept calibration system is expected to be applicable to solve the calibration problems of other on-site hardness testing machines.

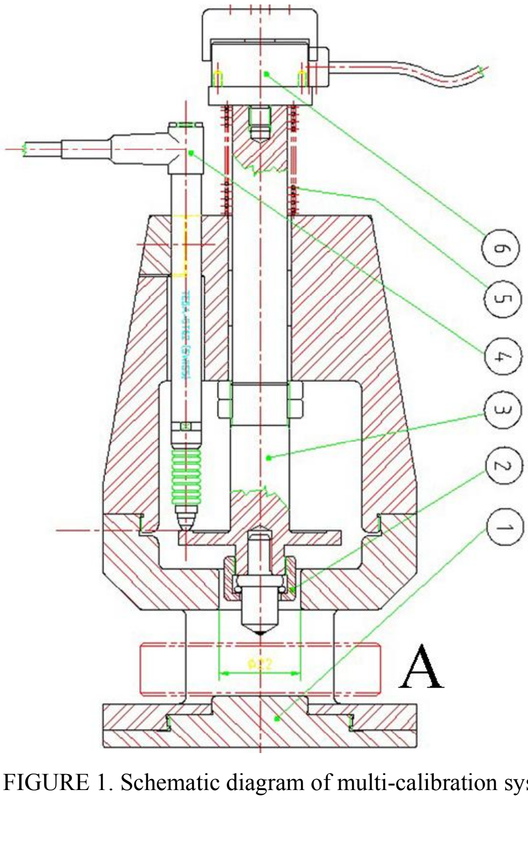

FIGURE 1. Schematic diagram of multi-calibration system

2. MULTI-CALBRATION SYSTEM

2.1. Structure and operation of test cycle-calibration system

A schematic diagram of test cycle-calibration system is shown in Figure 1. The system is made up of structural hardware and data processing software. The structural body has a main axial shaft at the centre. It is composed of an indenter plunger, a load cell, and a length measuring sensor on the body. Also, an anvil is located at the bottom of the body to house the hardness reference blocks. The distance between indenter and reference block can be adjusted to maintain a same value by using a special part as indicated by A. The testing forces are transferred to the indenter along the main shaft and the displacement of indenter is measured by the length sensor parallel to the axial shaft. The shaft is made from specially heat-treated hard materials which have a displacement less than 0.2 μm under a force of 1500 N to avoid an effect of the shaft strain on the hardness values. It is proved that the concentricity (deviation from a center of circle) of axial shaft is important to measure the Rockwell hardness using the displacements measured from the length sensor. The concentricity can be adjusted for the range of 5 ~ 8 μm . At the bottom of main shaft, a spring is installed to prevent the weight of shaft from being added to the total load, i.e. playing a role of counterbalance. Actually, application load of main shaft with the weight of 300 g is reduced to 50 g due to the spring constant. A detailed specification of test cycle-calibration system is listed in Table 1.

TABLE 1. Specification of new calibration system for Rockwell hardness machine

Item	Specification	Remark
Calibration parameter	Loads (preliminary test force, additional test force), dwell time, application time	Starting and ending points are detectable
Main shaft working range	± 2.5 mm	
Hardness scales	A, B, C, D	
Data acquisition time	0.1 second/point	
Data processing	PC based software	
Uncertainty ($k = 2$)	0.43 HRC	Indirect calibration using reference blocks

The data processing is carried out by a PC which is connected to the sensors of load cell and length measuring system. The calibration items of test cycle-calibration system are preliminary testing force and additional testing force, the application times of them, the dwell times, and final reading time. The output signals coming from the load cell and electronic micrometer are synchronized by PC clock and saved every 0.1 second. The accuracy of load cell and the time resolution of length are 0.1 % and 0.01 μm, respectively.

As described above, the calibration system has a typical feature of measuring and calibrating the load, time and length at the same time unlike other calibrating instruments.

TABLE 2. Results of performance evaluation of the new calibration system using reference blocks

Hardness (HRC)	Meas. (HRC)	Deviation (HRC)	Std. error	Uncertainty (k=2)
60.12 uncertanty 0.40 HRC	60.4	0.28	0.03 HRC	0.40 HRC
	60.3	0.18		
	60.3	0.18		
	60.2	0.08		
	60.3	0.18		
41.64 uncertanty 0.41 HRC	41.9	0.26	0.04 HRC	0.42 HRC
	41.8	0.16		
	41.9	0.26		
	41.7	0.10		
	41.9	0.26		
29.51 uncertanty 0.41 HRC	29.4	-0.11	0.06 HRC	0.43 HRC
	29.7	0.19		
	29.6	0.09		
	29.5	-0.01		
	29.7	0.19		

In order to estimate the performance of the calibration system, the Rockwell hardness testing machine which satisfies the condition of ISO 6508-2 and the reference blocks with an uncertainty of about 0.4 HRC which were certified by KRISS standard machine were employed. The experimental results are shown in TABLE 2. The maximum deviations were 0.28, 0.26, and 0.19 HRC, respectively, for each hardness level, and the uncertainties were 0.40, 0.42, and 0.43 HRC, respectively. Although the maximum uncertainty (0.43 HRC) is slightly larger than the uncertainty (0.4 HRC) of reference block, the uncertainty from repeated measurements is very small and this implies that the multi-calibration system is stable and reliable. Therefore, the present multi-calibration system affords to calibrate the on-site Rockwell hardness testing machines.

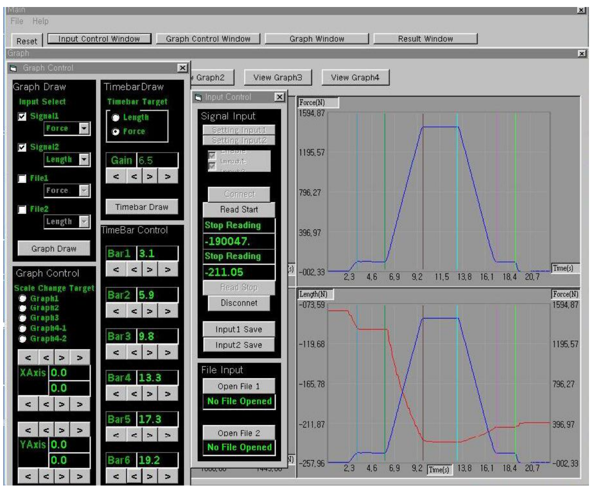

FIGURE 2. Main screen of multi-calibration system

2.2. Application to on-site calibration

On-site calibrations were conducted by using the multi-calibration system (IT5P) for an automatic Rockwell hardness machine, which is composed of an electric motor actuator and load cell. It is an automated instrument of which a test cycle can be adjusted arbitrarily so that it is suitable for the present calibrating experiment.

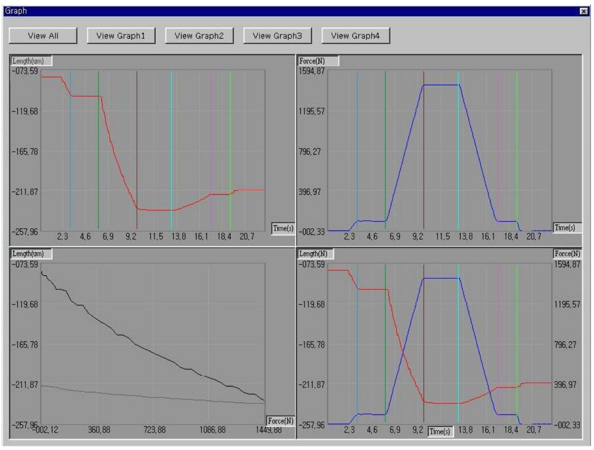

FIGURE 3. Variations of depth (left), force (upper right), and their merged data (lower right) with time.

The test cycle of on-site hardness machine was set with following test conditions, i.e., the dwell time of preliminary force 3 seconds, the application time of additional force 4 seconds, dwell time of additional force 4 seconds, final reading time 2 seconds. A reference block (45 HRC) was used for this experiment.

A main screen of data-processing software is shown in Figure 2. Several parameters are required to fill before calibration. After installing the reference block on the anvil, the multi-calibration system is put on the anvil of on-site Rockwell hardness machine. And then the testing cycle is measured following a usual hardness measuring test.

In Figure 3, it is shown that the force and length varies with the time elapsing, simultaneously. They can be zoomed out for further analyses. In the graphs, movement of the indenter with the application of force can be easily observed, i.e. if they are linear or nonlinear with time, whether the force is transferred to the reference block according to the applied load or not can be found and also if the depth varied properly with time without any abrupt change due to, if any, certain holes or inclusions can be known.

FIGURE 4. Photo of calibration results after a run of multi-calibration system for a testing cycle of Rockwell hardenss

Figure 4 shows the list of calibration results which appeared in the monitor. For example, the application time of preliminary force is 3.9 seconds (T_ap), i.e. 6.2 *μm/sec*. The application time of additional force is 3.9 seconds (T_aa), which is slightly lower than the set value (4 seconds). The dwell time of test force is 3.5 seconds (T_dl), which is quite different from the set value of 4 seconds. The results also show that the indented depth is 112.5 *μm* and hardness is 43.7 HRC. Thus, the calibration of testing cycle is summarized as shown in TABLE 3.

TABLE 3. Example of calibration results for on-site Rockwell hardness machine

Calibration items	Nominal Value	Result of calibration
Preliminary Force	98.07 N	95.36 N
Test force	1471 N	1449.2 N
Preliminary Dwell time	3.0 sec.	3.0 sec.
Application time of additional load (T_aa)	4.0 sec.	3.9 sec.
Dwell time Test force (T_dl)	4 sec	3.5 sec.
removal time of Additional load	none	1.9 sec.
Final reading time	2.0 sec.	2.0 sec.

3. CONCLUSION

A new concept multi-calibration system for on-site direct calibration of Rockwell hardness machine was developed and evaluated. It was proved that it could calibrate easily and efficiently the test cycle of Rockwell hardness machines according to ISO 6058-2. This calibration system is expected to be useful for the enhancement of reliability of hardness measurement.

REFERENCES

[1] ISO 6508-1, Metallic materials-Rockwell hardness test-part 1: Test method (2005)
[2] ISO 6508-2, Metallic materials-Rockwell hardness test-part 2: Verification and calibration of testing machines (2005)
[3] EA 10-16, Guidelines on the Estimation of Uncertainty in Hardness Measurements (2001)
[4] S. R. Low, "Rockwell hardness measurement of metallic materials", National Institute of Standards and Technology, Spec. Publ. 960-5, Washington, CA, 2001.

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