

Characterization of Rockwell ball indenter holder shape and properties, and its effect on hardness

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Abstract: Although ball indenter plays a key role in the measurement of Rockwell hardness, its verification procedure, which is essentially required to provide reliable data, has not been adequately detailed in ISO 6508; only the requirements for ball size are described. When considering the ball indenter is composed of two main parts, the ball and the ball holder, these insufficient requirements for the ball indenter can give rise to unorganized measured data and consequently result in an increase of uncertainty. In fact, many problems regarding the reliability of measured data are widely being reported in industries, as various types of ball holders are now being used due to the absence of their standard requirements. In this study, therefore, the influence of the ball holder on the hardness measurement was investigated. Four preferred types of commercial ball holders in the industry were selected and their shape and hardness were characterized. The role and importance of the ball holder in terms of hardness measurement were discussed in relation to the alignment of the ball indenter and plastic deformation of the ball holder. It was found that plastic deformation of the ball holder was caused by the difference in hardness between the ball and ball holder during indentation and this results in a large scattering of data.

Keywords: Rockwell hardness, Ball indenter

1. INTRODUCTION

Regarding the ball indenters for the Rockwell hardness B scale, when the ISO 6508-1, 2, and 3 were revised in full scale, the overall contents including materials, the allowable limit of the indenter diameter, the manner of expressing the hardness, etc. were significantly changed from the previous version. In particular, indenters made of tungsten carbide were added with the suffix 'W' to be used for the unit of hardness so that they can be distinguished from the steel ball indenters. Generally, a ball indenter for the Rockwell hardness scale consists of the 1.5875 mm ball, which presses the test specimen and the ball holder that supports the ball.

The diamond indenters for Rockwell hardness and the associated holders are generally accepted as industry standards that are used by manufactures and industries. However the ball indenters and the ball holders are not standardized in terms of their shapes and the hardness characteristics, which in effect have become the cause of increase in deviations and uncertainties. As for the hardness characteristics of diamond indenters, ISO 6508-2 specifies that the verification of hardness indicating deviation should be made through indirect verification, which refers to the comparison between the reference indenters and the indenters to be tested for their hardness values. However, for the ball indenters, there are no such procedures and thus currently there is no way of verifying the hardness characteristics associated with holders or with the combination of holders and balls. This obviously implies that improvements are required for enhancement of accuracy and reduction of uncertainties in measuring the B scale hardness. This paper reports the results of comparative analysis between the hardness characteristics of the Rockwell hardness B scale indenters available on the market, with four categories depending on the manufacturer and the shape of the ball holder, and those of the ball indenters that KRISS (Korea Research Institute of Standards and Science) possesses. The procedure for the Rockwell diamond indenter has been followed.

2. BALL INDENTERS FOR ROCKWELL HARNESS B SCALE

Fig. 1 shows the ball indenters that are commonly used in the industry. As shown in the figure, it can be found that the ball holders, except for the plungers, vary according to different manufacturers.



Fig. 1 Ball indenters of Rockwell hardness for B scale

The ball holder should be structured so that it can hold the ball firmly and at the same time the ball should be able to press the specimen in the precisely correct vertical direction. If the ball holder interferes with pressing against the specimen, or if, while the indentation information is conveyed to the indicator of the hardness tester, the data on the indentation depth is distorted or modified by the ball holder, then unexpected problems may occur regardless of how precise the hardness tester is. To investigate the heat treatment history of the ball holders that are thought to have close relationships with the performance and hardness characteristics of the ball indenters we measured the hardness of the holders. The hardness measurement was made in the sequence of M, A, W and L manufacturers and the measurement results showed 60, 24, 24, and 40 HRC respectively. The indenters should have sufficient rigidity since their role is to convey the test load equivalent to 980 N to the test specimen during hardness tests. The fact that the hardness is not consistent for different manufacturers may mean that they do not have sufficient rigidity. This may affect the hardness characteristics and eventually induce systematic errors. To evaluate the hardness characteristics of the ball holders of the said manufactures, hardness tests were made for comparison. The test method employed was to compare the hardness values with that of the reference indenter of KRISS. The size of the ball was at a fixed value since different sizes might affect the hardness characteristics during the tests. The range of the hardness applied to the hardness characteristics comparison was 30 ~ 90 HRBW. Three test specimens were used for each manufacturer. The test results are summarized in Fig. 2.

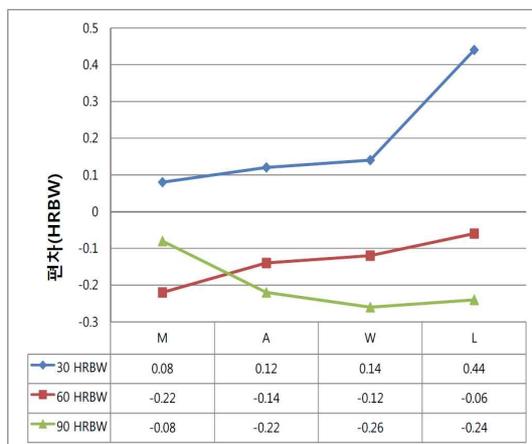


Fig. 2 Hardness deviations for different all holders

Test results show that all the deviations of manufacturers M, A, W, and L are consistently within the range of ± 0.3 HRBW except for the deviation for the nominal hardness 30 HRBW of manufacturer L, which is 0.44 HRBW bigger than those of other manufacturers. The magnitude of contribution to the uncertainty for the hardness measurement is found to be approximately 0.1 HRBW when estimated based on the test results, excluding those from manufacturer

L. This value does not excessively exceed what was initially anticipated. Nonetheless, measurement laboratories where multiple indenters are operated should implement periodic inspections to monitor the variations of indications for different ball indenters and the observations should be utilized for correction of hardness measurement data and for calculation of uncertainties. Deficient ball indenters should be identified by way of hardness characteristics verification together with shape verification in the same manner that the Rockwell hardness diamond indenters are verified as specified in the ISO 6508-2. For reference, one of the institutes worldwide that provides the services of verifying the ball shapes and the ball hardness characteristics although the latter is not addressed in the ISO 6508-2 is MPA NRW in Germany. At this institute, two kinds of hardness reference blocks, one 20 HRBW and the other 100 HRBW, are used for verification of hardness, and the allowable limit applied is ± 0.4 HRBW. It is recommended that in the future the verification procedure that is used at MPA NRW should be reflected in the ISO 6508-2. In effect by doing so, it is expected that the measurement reliability of Rockwell B scale could be greatly enhanced. One aspect that should be taken into consideration is the fact that the verification procedure used by MPA NRW is only for the holders of the specific ball indenters produced by MPA NRW, which means supplementation is necessary for incorporation into the standard. The hardness characteristics that appear in the test certificates are those obtained from the tests with the specific balls mounted on the ball holder. Thus, if the balls are delivered to job sites and used by mounting on different ball holders, they may show hardness characteristics that differ from the test certificates. Therefore, a more desirable method is to define a ball and holder set together, and to publish the hardness characteristics obtained from this set. Additionally, it is necessary to standardize the ball holders that currently have extreme varieties of shape and hardness.

3. REFERENCE INDENTERS FOR ROCKWELL B SCALE

The balls used for the ball indenters are a type of product that should be replaced when the number of usages exceeds the limit or they are damaged. On the contrary, the ball holders can be used for long periods of time unless they are damaged. They determine many aspects of the hardness characteristics as explained above. Considering all such aspects, it can be said that as one of the components of the ball indenter, the ball holder is more important than the ball as far as hardness is concerned. It is known that a ball holder, which does not change in terms of integral hardness characteristics even when the ball is replaced, is of higher quality. In other words, if the replacement ball is complying with the standards, the overall hardness characteristics deviation after replacement should be equal to or less than it was before replacement. In this regard, a supply of balls that meet the requirements of the current standards is important but not sufficient. If reference ball holders for which the hardness characteristics have been verified are supplied, then the reliability of hardness measurements can be more improved than the current one. Figure 3 shows the reference

ball holders that are manufactured for such a purpose. These two types of ball holders involved are based on the ball holders that are most commonly used in the domestic industry for hardness test equipment. Figure 4 shows the sections of the reference ball holders- type B.



a) Type A reference ball holder b) Type B reference ball holder

Fig 3 Reference ball indenters manufactured

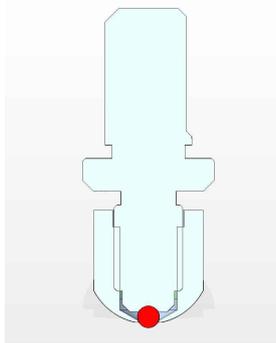


Fig. 4 Section diagram of reference ball holder type B

Though details are not given for the sake of brevity, the critically important aspects of mechanical processing that govern the performance of the ball holders include the degree of alignment of the center lines of the ball, the area where the ball contacts the ball holder, and the cap that supports these. It is found that the maximum allowable error in center line alignment is 0.02 mm and violation of this limit drastically deteriorates the hardness characteristics. If the error of center line alignment exceeds the allowable limit, the deviation of hardness could reach as high as approximately 4.5 HRBW with a specimen of nominal hardness of 90 HRBW. Several specimens were randomly selected from the stock of manufactured ball holders and the hardness tests were made in the same manner as stated above in comparison with the KRISS reference ball indenters. The test results are shown in Fig. 5. Analyzing the comparative measurement results, it is observed that the maximum deviation (absolute value) is smaller than 0.14 HRBW, which implies improvements compared with the four indenters stated above. The impact of these indenters on the uncertainties of the hardness measurements is a maximum of 0.06 HRBW.

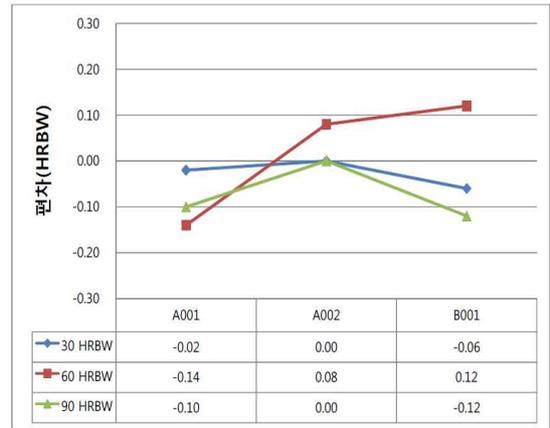


Fig. 5 The performance verification results of a trial product for ball indenters

4. CONCLUSIONS

It is demonstrated that, in the Rockwell hardness system, the hardness measured by use of ball indenters varies depending not only on the shape and material of the balls but also on the property of the ball holders. The hardness characteristics of the Rockwell hardness B scale of four ball indenters manufactured by four different manufactures were examined. The results showed that the maximum deviation was 0.44 HRBW, a value that is quite large and thus cannot be disregarded. To devise a method to overcome such shortcomings, reference indenters were manufactured and the hardness characteristics were comparatively analyzed. The results showed that the maximum deviation improved to 0.14 HRBW and the uncertainty due to the ball indenter also significantly improved from 0.1 to 0.06 HRBW. The current version of ISO 6508-2 and ISO 6508-3 specify the implementation of indirect verification for the hardness characteristics of diamond indenters but do not specify similar provisions about the ball indenters. It appears necessary that for the future of ball indenters, in the same manner as for the diamond indenters, the hardness characteristics should be verified by way of indirect verification and thus the reliability of hardness measurement can be upgraded.

5. REFERENCES

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