

A ROUND ROBIN TEST OF ROCKWELL B SCALE HARDNESS

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Abstract: A round robin test of Rockwell B scale was carried out among the calibration class laboratories and testing class laboratories in Japan. Block calibration laboratories and general class machines are participated to the round robin test. The common indenter holder is prepared to investigate the indenter holder effect. Indenter ball (Tungsten carbide ball) is also provided and each participant uses the new ball for common and each-laboratory's holder, respectively. Blocks used are 30, 60, and 90 HRB and two blocks from different manufacturer is used for each level. The materials of the blocks are brass for 30 and 60 HRB and steel for 90 HRB, respectively. The variation of the test was about ± 0.5 HRB for 60 and 90 HRB blocks, about ± 1 HRB for 30 HRB hardness level, however, the some laboratory has large discrepancy.

In addition, the hardness difference between steel (S) ball indenter and tungsten carbide ball indenter (W) is also investigated. The calculated hardness difference (S-W) is shown in Table 1. $H_{S-W} = 0.76$ HRB for 90 HRB, $H_{S-W} = 0.67$ HRB for 60 HRB block, $H_{S-W} = 0.90$ for 30 HRB. The calculated standard deviations are 0.22, 0.26 and 0.41 HRB for 90, 60 and 30 HRB, respectively.

Keywords: Rockwell B scale hardness, round-robin test, Tungsten carbide ball indenter

1. INTRODUCTION

A Rockwell B scale hardness test is one of popular Rockwell hardness test. In recent years Japan has not been done round-robin test excepting Rockwell C scale hardness. It is important that to know the situation in Japan after indenter material changed from steel ball to tungsten carbide ball. Participants of the round robin test including Block calibration laboratories and manufacturer or maintenance companies. Additionally indenter ball material effect was also investigated in NMIJ.

In this paper, we introduce the overall trend of round robin test. We describe the details of the hardness changes before and after the round robin and indenter material effect, that is measured in NMIJ.

2. DESIGN OF ROUND ROBIN TEST

Twenty-three laboratories are participated in the round robin test. Participants are divided into 5 groups; one group uses the same block set to decrease the hardness change with increasing number of indentation. NMIJ is participated to all groups as key laboratory and tested first and last of the round robin.

Five indenter holders are chosen and are used as common indenter-holder for each group. The common indenter holder was shown in Fig. 1. Tungsten carbide ball indenter is provided from the same lot. Each participant installs new ball indenter to both of the common and own indenter-holder. Hardness reference blocks for 30, 60, and 90 HRB blocks from two manufacturers are used. Materials of blocks are brass for 30 and 60 HRB, steel for 90 HRB. Test surface are divided to 5 areas. Two set of blocks are used for common and own indenter holder measurement. The Each participants measure the 60 points: 2 indenters, 2 set of 3 hardness levels blocks and 5 points for each blocks. Test cycle and other testing conditions are in accordance with the ISO standard.

NMIJ participate as key laboratory using primary machine, SHT-32. Spot anvil with 12 mm in diameter is used to decrease the hardness change due to blocks deformation with increasing the number of indentations.



Fig. 1: indenter holder which is used in this round robin test.

3. RESULTS AND DISCUSSTION

3.1 Round robin test

NMIJ measured the first and last of the test. The hardness difference obtained by the round robin is shown in figs. 2, 3 and 4 for 90 HRB, 60 HRB and 30 HRB, respectively. Each result is indicated as a hardness difference from the first NMIJ's measured value. Five measurement groups and two blocks are indicating in the same figure. The grouping is A:1-4, B:5-9, C:10-14, D:15-18 and E:19-22 in laboratory number. NMIJ is indicated No. 0 and No. 0' that means first and last measurement of round robin, respectively. The range of the ordinate of the figures are ± 1.0 and ± 2.0 , ± 3.0 HRB for 90, 60 30 HRB blocks, respectively. The results for block A and B are indicated by closed and open circle. The standard deviation of the measured value is indicated by error-bar. We estimated the number of indentation less than 60 including NMIJ in the planning, however, the returned blocks have more than 70 indentations.

Firstly, we describe the hardness stability between first and last measurement, performed by NMIJ. The hardness difference is about 0.1 HRB for 90HRB blocks, excepting +0.3 HRB for block A of common indenter of Group C. The difference is almost within 0.3 HRB for 60 HRB blocks, excepting +0.6 HRB for block A of common indenter of Group C. The difference is within 0.6 HRB for most of 30 HRB blocks. Exceptions are found is that; for common indenter, Group A of both blocks and group A (about +1 HRB), Group D of block B (about +1.4 HRB).

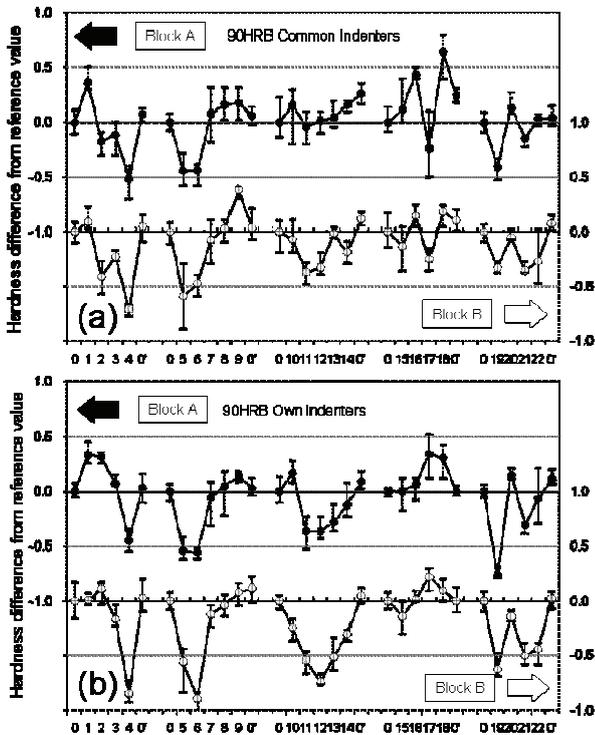


Fig. 2 hardness variation for 90 HRB, (a) common indenter and (b) own indenter.

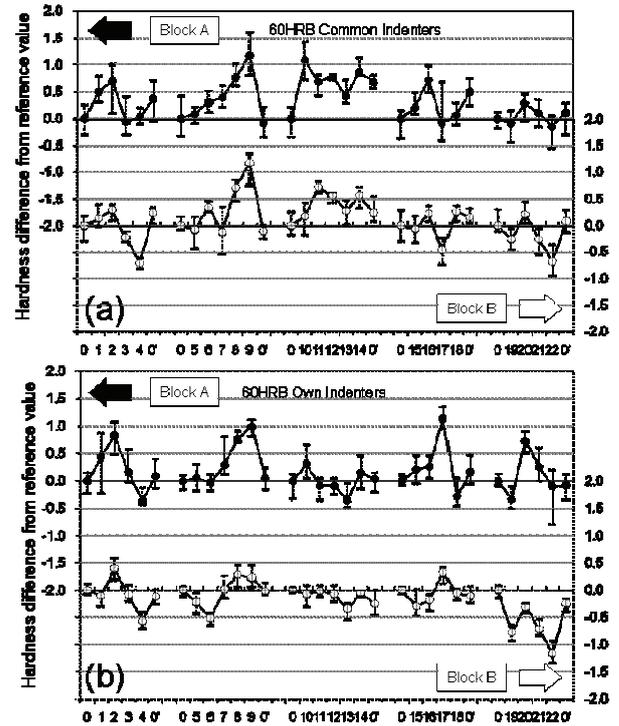


Fig. 3 hardness variation for 60 HRB, (a) common indenter and (b) own indenter.

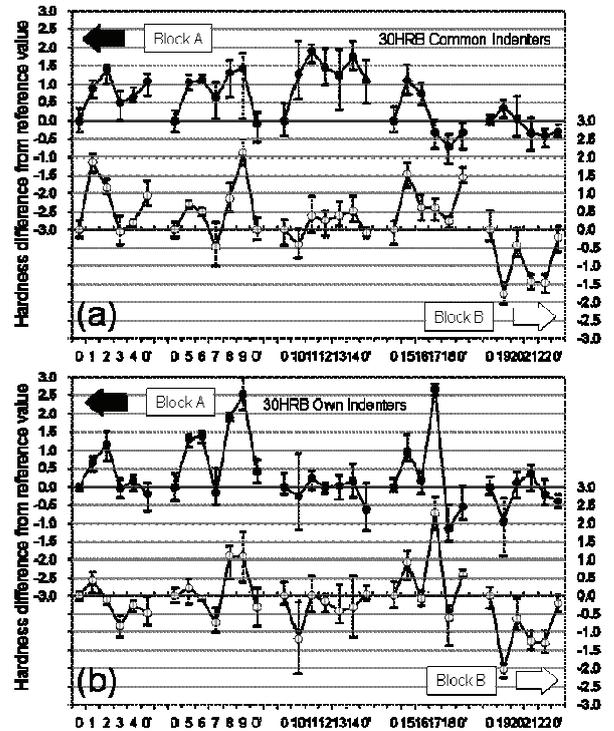


Fig. 4 hardness variation for 30 HRB, (a) common indenter and (b) own indenter.

Typical hardness variation among the participants is about ± 0.5 HRB for 60 and 90 HRB blocks, about ± 1 HRB for 30 HRB block, but some laboratory shows more large discrepancy. Looking at the curve of the measurement results by the same indenter, it can be seen that there is a similar trend in the A blocks and B. In addition, some participants, there is a trend in the measurement if block has the same hardness level are similar even with different indenter. The participants have reported a lower hardness value at almost all levels of hardness, especially in the laboratory No. 4 and 22.

The test using flat anvil is also investigated after finishing all round robin measurement. It is very difficult to find out indentation points. We briefly described the results. No hardness difference was found in 90 HRB (variation is -0.1 to +0.2 HRB). About 0.5 HRB in 60 HRB (variation -0.6 to +0.8 HRB), about 1 HRB in 30 HRB (variation -0.6 to +1.5 HRB), respectively. It may be depend on indent location; however, the standard deviation and variation between blocks are much larger than that of measured using spot anvil. It may be comes from the contact condition between anvil and the block. Number of measurements for one sample is small in the normal sample testing. On the other hand, number of measurement for reference block is large. Spot anvil is most useful in the sample with large number of repeated measurement such as reference block used in daily check.

3.2 Indenter ball material effect

To investigate the hardness difference between steel ball and tungsten carbide ball, additional test was carried out in NMIJ after the round robin test. Three indenter holders are used in this experiment. That is the same indenter which is used the common indenters in round robin test. The hardness difference between tungsten (W) and steel ball (S) is measured.

Three repetition are carried out in the same block. New indenter ball was installed in each attempt. We measured two times using 95 HRB control block after install a new ball to check the indenter condition. Two indenters are installed W ball first, the other one S ball first to decrease hardness bias due to block bending. The order of experiment for an indenter is W-S; first attempt, W-S, the second, S-W the last, for example. The weighted mean with taking into account the order was used to decrease the effect. Unfortunately, the difference between simple average and weighted average was very small compared with its measurement standard deviation.

Hardness variation depending holders observed by the measurement of control block are shown in fig 5. Three holders; A, B, C; and three repetitions; 1, 2, 3; are used in the figure. A new ball was used in all tests with the exception of NMIJ indenter. No significant difference was not observed among these indenter set (ball/holder) for

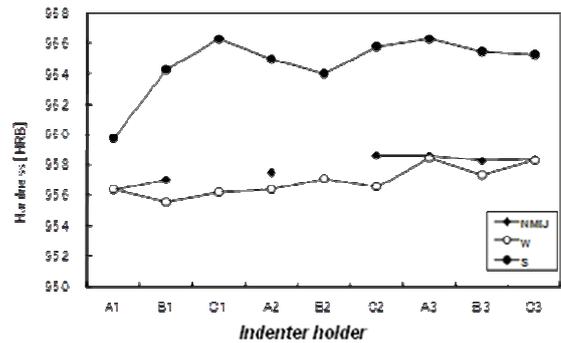


Fig. 5 Hardness variation between indenter holders. Square shows NMIJ's own holder with tungsten carbide ball indenter. Open and closed circle shows tungsten carbide ball and steel ball indenter, respectively.

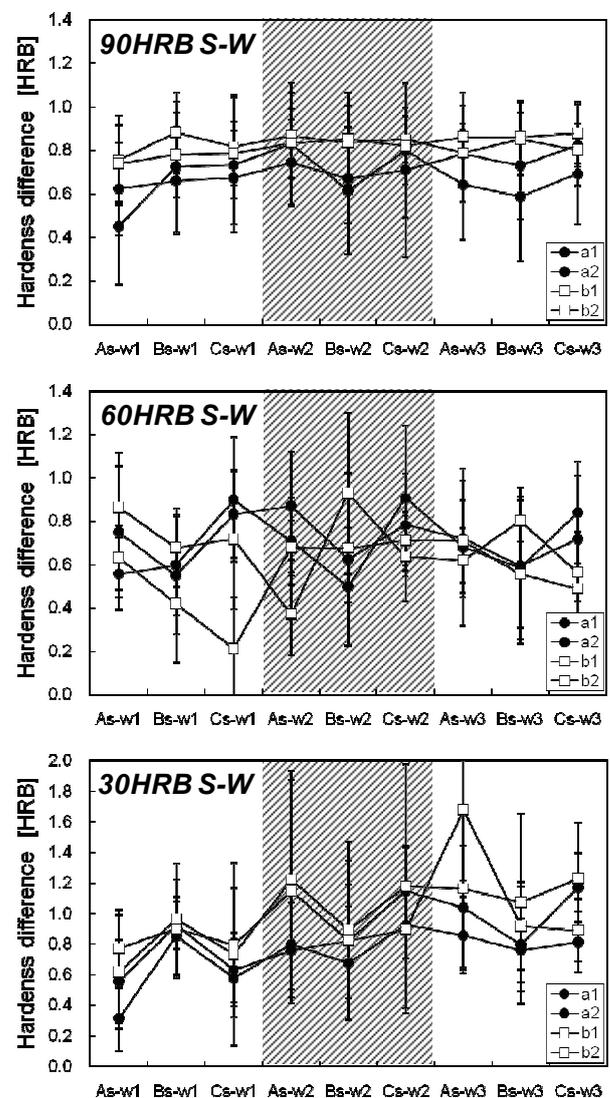


Fig. 6 The hardness difference between Steel ball indenter and tungsten carbide ball indenter. Hardness of tungsten subtracted from hardness of steel (S-W) is indicated.

tungsten carbide ball. In contrast, slightly variation was observed for the steel ball indenters.

Hardness difference between steel ball and tungsten carbide ball (S-W) is shown in the fig. 6. All results shows the hardness from steel ball is higher than that from tungsten carbide ball. though we designed the order of measurement considering the hardness change due to number of indentations, the result shows small difference (less than 0.05 HRB) compared with the scatter of measurement (0.3 HRB typ.) between simple averaged result and weighted with considering the order of measurements. The error bar indicating the standard deviation which is calculated from the standard deviation of each measurement;

$$\sigma_{S-W}^2 = \sigma_S^2 + \sigma_W^2.$$

The standard deviation for each hardness level is below.

90 HRB: 0.15 HRB for W ball and 0.17 HRB for S ball.

60 HRB: 0.19 HRB for W ball and 0.18 HRB for S ball.

30 HRB: 0.30 HRB for W ball and 0.27 HRB for S ball.

The calculated hardness difference (S-W) is shown in Table 1. $H_{S-W} = 0.76$ HRB for 90 HRB, $H_{S-W} = 0.67$ HRB for 60 HRB block, $H_{S-W} = 0.90$ for 30 HRB. The calculated standard deviations are 0.22, 0.26 and 0.41 HRB for 90, 60 and 30 HRB, respectively. This standard deviation shows that the obtained hardness difference (S-W) may have large uncertainty. Therefore, it can be said that the difference is about from 0.5 to 1 HRB for 90 and 60 HRB blocks, is about from 1 – 1.5 HRB for 30 HRB block.

4. SUMMARY

We introduce the results of round robin test of Rockwell B scale among laboratories. We also investigated the hardness difference between steel ball indenter and tungsten carbide ball indenter. The standard deviation of the measurement was very large. The difference is about from 0.5 to 1 HRB for 90 and 60 HRB blocks, is about from 1 – 1.5 HRB for 30 HRB block.

ACKNOWLEDGMENT

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Table 1 Hardness difference between Steel ball and tungsten carbide ball indenter and its calculated standard deviation.

Hardness	Difference [S-W]	Standard deviation
90 HRB	0.76 HRB	0.22
60 HRB	0.67 HRB	0.26
30 HRB	0.90 HRB	0.41