

Investigation of Influence Factors on Hardness Change of 25 and 40 HRBW Reference Hardness Blocks

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Abstract: National institute of metrology (Thailand), NIMT studied behavior of hardness change on 25 and 40 HRBW. There is not only number of indentations but also other several influences cause to stability of hardness measurement. Some dominance factor such as diameter size of anvil, block thickness and indenting pattern were taken into account for scope of experiments. Set of 25 and 40 HRBW reference hardness block were provided, consisting of 6, 8.5, 10.5 and 11 mm thickness. Hardness tested on one with various anvil sizes, 6, 12 and 60 mm diameter. The tests proceeded on different indenting patterns, spread and huddle patterns respectively.

Investigations exposed that stability of hardness measurement is mainly affected from several factor that mention above. Each indentation pattern makes hardness change with uniquely increasing and steadying trends for spread and huddle patterns. Amounts of hardness change seem to be inversely proportion to hardness level. Besides, the number of indentations make bottom surface of block becomes more and more concave. However, the blank block is generally produced slightly convex surface. Thus, at first several test results showed unexpected trend meanwhile, bottom surface is still convex. In additional, anvil size is not more effect. As found that on the huddle patterns, the results of those three groups by using various anvils 6, 12 and 60 mm are not significantly different. On the other hand, results using 60 mm have smaller hardness change than one when testing with spread patterns.

Thickness of block also effect on stability. However, for the group of spread pattern showed similar result between in the groups of various thickness blocks. Meanwhile, test result of 11 mm thickness block is more stability than other thickness for huddle pattern.

Keywords: Reference block, hardness change and bending.

1. INTRODUCTION

Based on the previous experimental study of “A stability of hardness change on 25 HRBW reference hardness block due to the number of indentations” [1], it is shown that there are several significant factors which affect the hardness value of 25 HRBW such as the number and the pattern of indentations, the thickness of reference block and the diameter size of anvil. However, there is still no evidenced information of the influenced factors on the

hardness change for other hardness levels. This paper provides more experimental data to investigate the influence of such factors at other hardness levels. Hardness value of 40 HRBW is considered for investigation and comparison with the results of 25 HRBW. Additionally, in practice, a certified reference block could be operated under a variety of anvil sizes. In the study, we also investigate the effect of anvil size (small or large anvil size relatively compared to reference block) on hardness change.

2. EXPERIMENTAL PLAN

A set of 40 HRBW reference block consists of four different block thicknesses at 6, 8.5, 10.5 and 11.5 mm produced by ASAHI GIKEN CO., Ltd. The four different thicknesses of reference blocks are divided by two groups for two different indenting patterns of “spread pattern” and “huddle pattern”. For each block within the set of each indenting pattern, the blocks are operated with the various anvil sizes of 6, 12 and 60 mm in order to explore the influence factors of hardness change on measurement stability as has been described before in the previous research of 25 HRBW reference block [1]. Numbers of test pieces used in each experiment conditions are shown in Table1. The hardness change of 40 HRBW under a variety of conditions will be investigated for comparisons to 25 HRBW. Each indenting pattern is classified as follows:

2.2.1 Pattern A, the spread pattern: the indentation was performed at the possibly farthest distance from the previous indentation.

2.2.2 Pattern B, the huddle pattern: the indentation was performed at the possibly nearest distance from the previous indentation.

The mean hardness value of each block is determined by the average of five hardness values that indented from each five area distributed over the surface block as the specified indenting pattern. Changes in hardness values are estimated by observing a stability of 18 mean hardness values.

Table 1: The experiment conditions and Numbers of test pieces used

Block thickness (mm)	Diameter of anvil (mm)					
	Huddle pattern			Spread pattern		
	6	12	60	6	12	60
6	1	1	1	1	1	1
8.5	1	1	1	1	1	1
10.5	1	1	1	1	1	1
11.5	1	1	1	1	1	1

The sections divided on block surface of the both indenting patterns are shown in Fig.1.

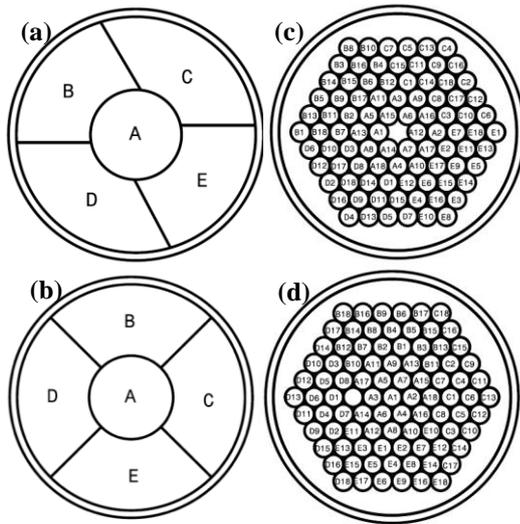


Fig. 1, Sections divided on block and layout of indentation of (a), (c) for spread pattern and (b), (d) for huddle pattern.

Furthermore, another 40 HRBW reference hardness block at 10.5 mm thickness is indented other than the two described previous patterns to clearly observe the effect of indenting pattern on hardness change. In order to study the bending deflection of reference block occurred during the experiment under specified conditions as shown in Table 1, bending degree of the bottom surface is measured after each hardness mean is taken, by surface roughness measuring device, model: S-3000, manufactured by Mitutoyo. Also we investigate 80 HRBW in the two thicknesses of 10.5 mm. and 11.5 mm. to observe the effect of hardness level.

3. EXPERIMENTAL RESULTS

At each condition for spread and huddle indenting pattern, the experimental results of 25 HRBW and 40 HRBW are presented in Fig. 2 and Fig. 3. Based on these overview results, we observed that hardness change relates

to the different specified conditions. The effect of each influenced factor on the hardness change is described below.

3.1 Influence of indenting pattern

In this study, we separate the experimental results for two indenting patterns which can play a specific effect on the hardness change as detailed following;

3.1.1. Spread indenting pattern

It is observed that the trend of hardness change can be classified by three intervals as presented in figure 2.

- The first interval is between the 1st mean hardness value and 4th mean hardness value. The trend exhibits an increase in hardness value for the thick reference block and using the large anvil. However, the rate of increasing hardness change will decrease as the block get thinner and the anvil size get smaller until the thickness of the block is 6 mm and the anvil size is smaller than 12 mm, the trend tends to decrease again.

- The second interval is between the 5th mean hardness value and 14th mean hardness value. The trend exhibits an increase in hardness value with increasing anvil size and the thickness of reference blocks. The constant trend of hardness value is found when using the anvil size 12 mm or smaller and the thickness of reference block 10.5 mm or thinner.

- The third interval which is over 15th mean hardness value clearly shows the highest increasing rate compared to all intervals, no matter how size of anvil or how thick of reference block.

3.1.2 Huddle indenting pattern

It is also found that we can classify the trend of hardness change into three different intervals as presented in figure 3.

- The first interval which is between 1st and 4th mean hardness shows the increasing trend in hardness value except when using the reference block at thickness 6 mm or using the anvil size at 6 mm.

- The second interval which is between 5th and 14th mean hardness shows the constant trend for all anvil sizes or all thickness of reference blocks.

- The third interval which is over 15th mean hardness shows the opposite trend to the second interval. The trend tends to decrease for all anvil sizes or all thickness of reference blocks.

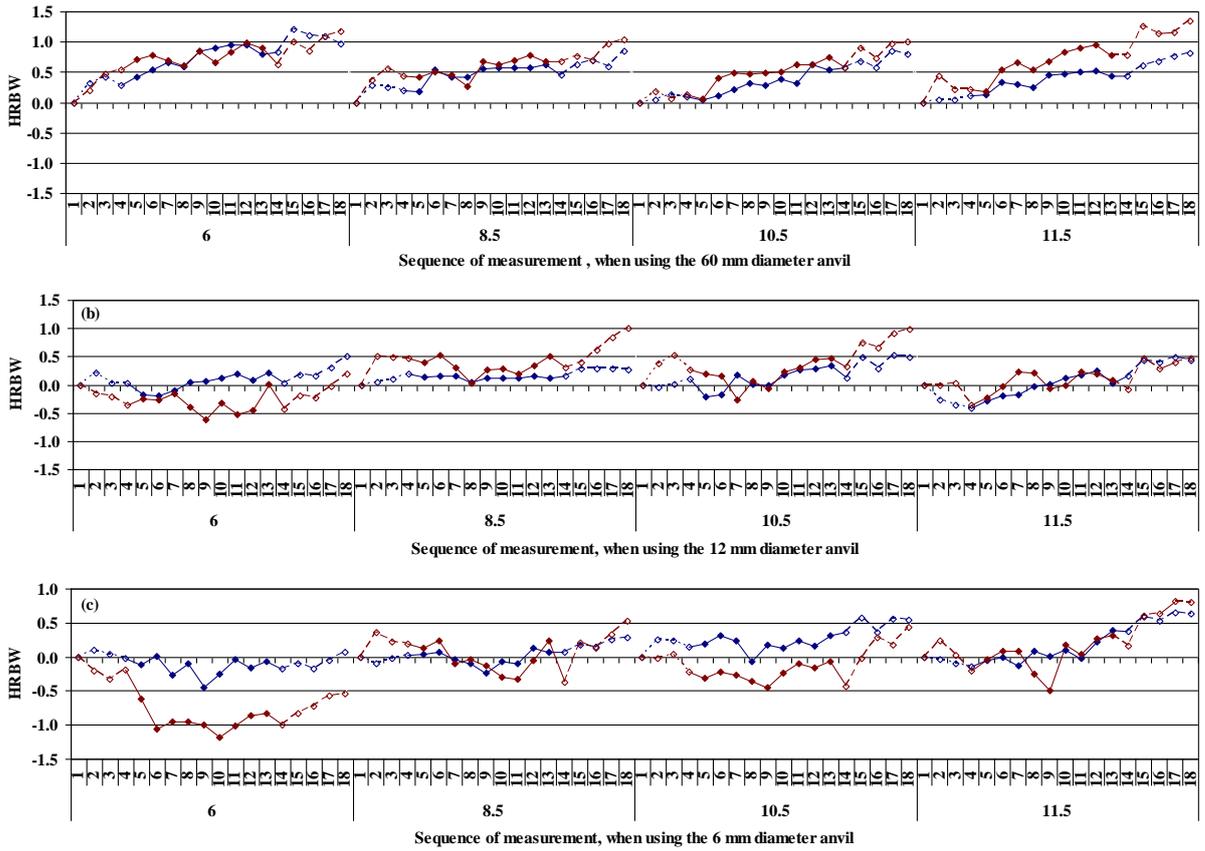


Fig.2, Experiment results of spread pattern. (brown line for 25 HRBW, blue linefor 40 HRBW)

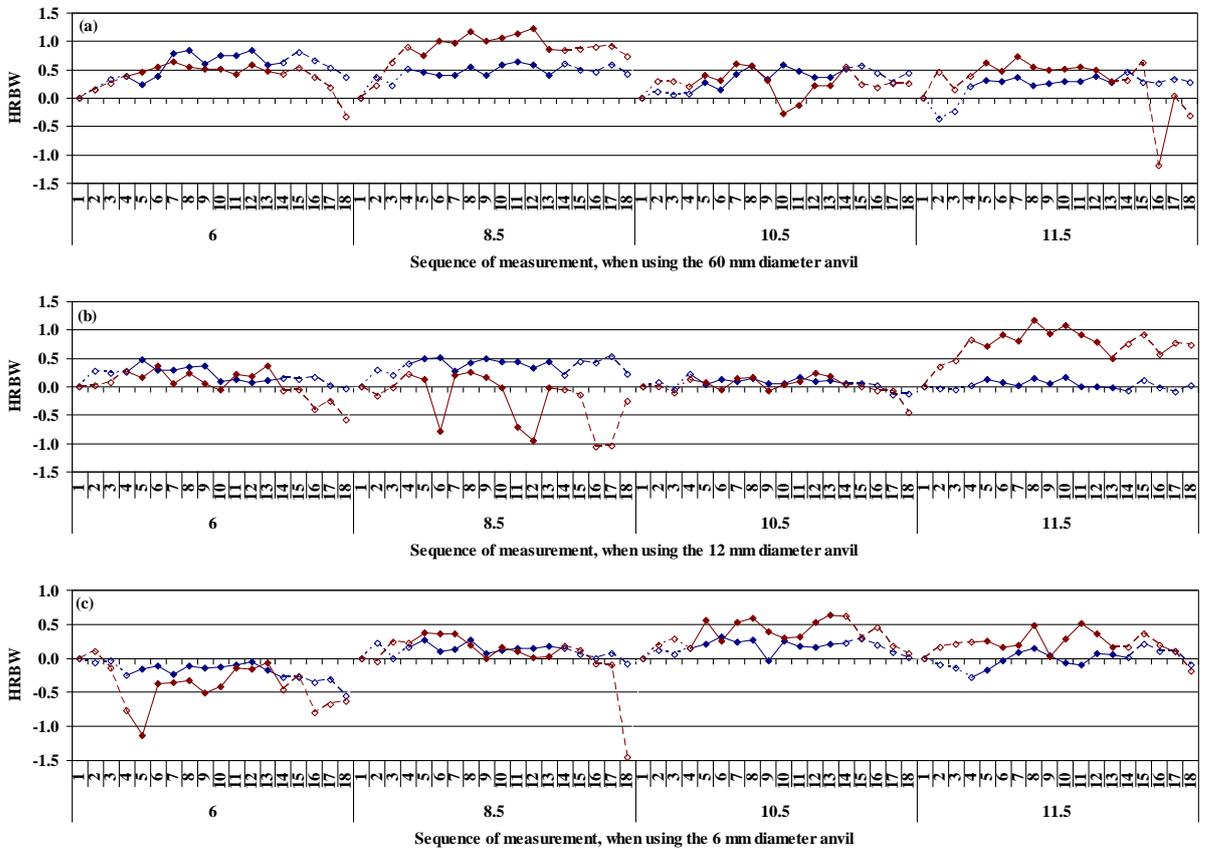


Fig. 3, Experiment results of huddle pattern. (brown line for 25 HRBW, blue linefor 40 HRBW)

3.1.3 Other indenting pattern

In order to explore the possible trend of hardness change, another indenting pattern which is between spread and huddle indenting pattern is investigated on 40 HRBW for only the thickness of reference block at 10.5 mm using anvil size at 60 mm.

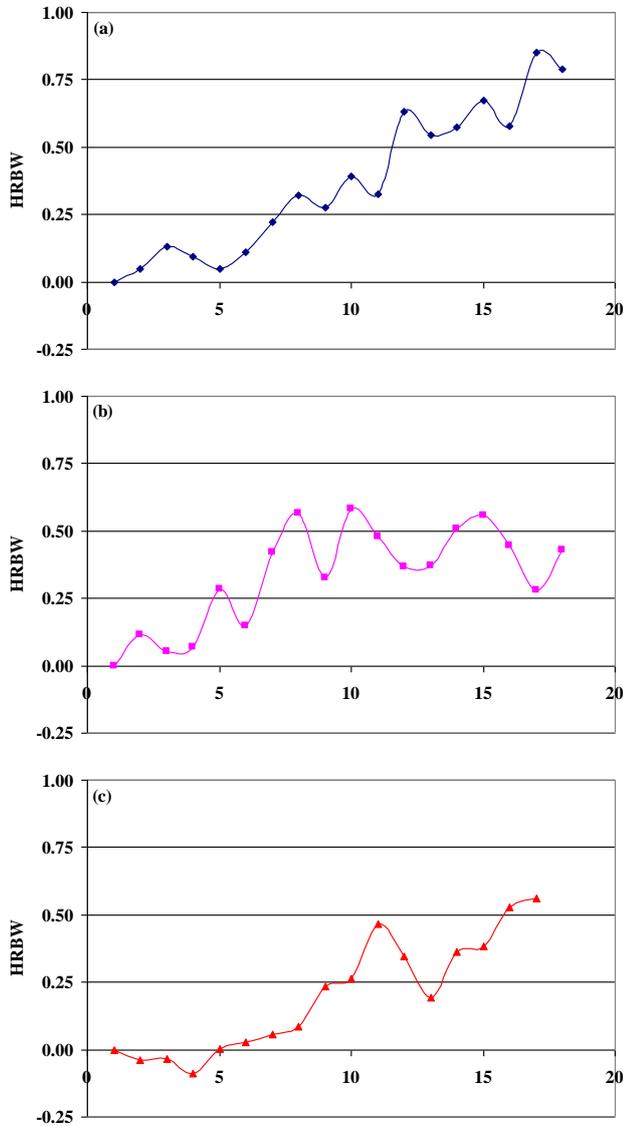


Fig. 4, The hardness change of 40 HRBW block using anvil 60 mm. diameter when measure with (a) spread, (b) huddle and (c) other indenting pattern

The results among three different indenting patterns are compared at the same conditions as shown in Fig. 4.

The measurement results show that the trend of hardness change by performing spread indenting pattern increase through all hardness values. While the trend of hardness change by Huddle indenting pattern shows an increase in hardness until the 8th mean hardness value and then exhibits constant trend. However, the trend of hardness change by the other indenting pattern exhibits different from the two patterns. The trend is observed with constant rate at

the beginning until 8th mean hardness value, and then the hardness change increases after that.

3.2 Influence of hardness level

Fig. 2 and Fig.3 previously showed that the hardness change of the reference blocks demonstrates the particular pattern related on the measurement conditions. However, the comparison of hardness change between 25 HRBW and 40 HRBW for all 24 conditions shows a few difference since the hardness level between two blocks are quite small, only 15 HRBW. In order to clearer understand the effect of hardness level on the hardness change, a reference block of 80 HRBW at 11.5 and 10.5 mm in thickness is investigate in the case of the spread pattern and using 60 mm diameter flat anvil. The trend of hardness change on hardness level from 25 HRBW to 80 HRBW is presented in Fig. 5.

The effect of hardness level on hardness change is evident. When the hardness level is low, the amount of hardness change increase compared to the higher hardness level. The results indicate the trend of hardness change with hardness level is inversely proportional.

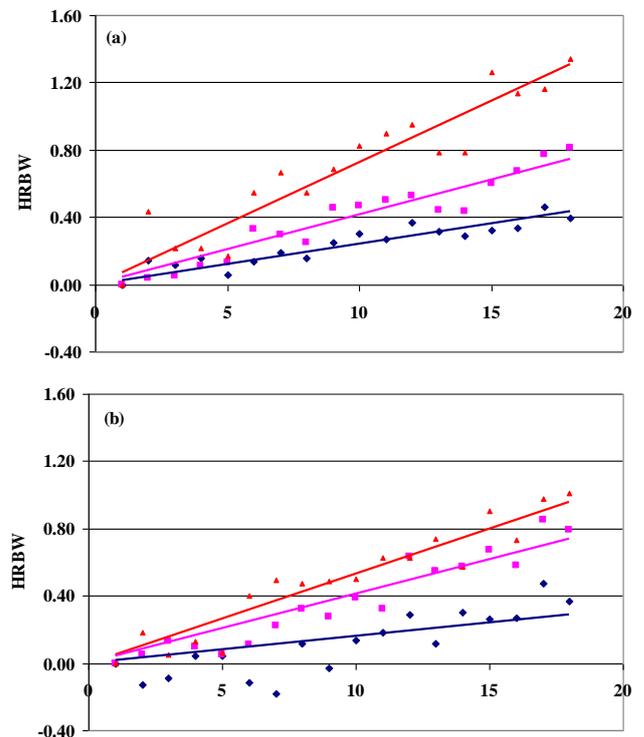


Fig. 5, The hardness change comparing between 25 HRBW (red), 40 HRBW (pink) and 80 HRBW (blue), when measured on (a) 11.5 mm and (b) 10.5 mm block thickness

3.3 Influence of Anvil size & block thickness

It has been difficult to examine the effect of anvil size or block thickness by only one parameter. However, in case of the measurement with spread pattern, using the larger anvil size and the thicker block can give more significant effects on the hardness change than using the smaller anvil size and the thinner block as shown in Fig. 6.

While the results of the measurement with Huddle pattern show that the relationship between hardness changes is irrelevant to the anvil size or block thickness.

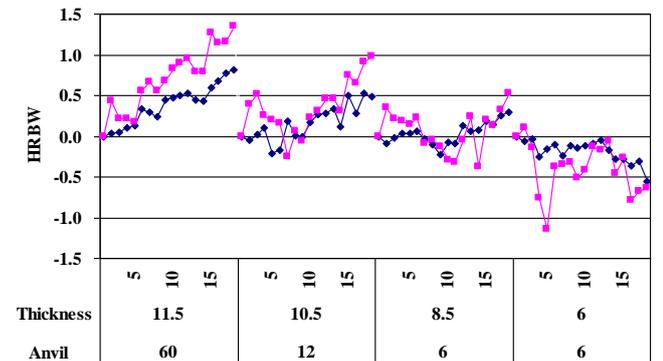


Fig. 6, The hardness change effected by block thickness and anvil size, when blue line for 40 HRBW and pink line for 25 HRBW

In practice, a reference block is probably indented by a variety size of available anvils until it is fully indented all over the block surface. This circumstance is simulated by using three reference blocks of 40 HRBW at 10.5 mm thickness. These blocks are indented by both indenting patterns of Spread pattern and Huddle pattern. The measurement is conducted by three intervals and each interval comprised of 6 data is performed with the difference of anvil sizes.

Fig. 7 shows the hardness change with various conditions, where the behaviour of hardness change is determined related on the indenting pattern and anvil size for certain conditions.

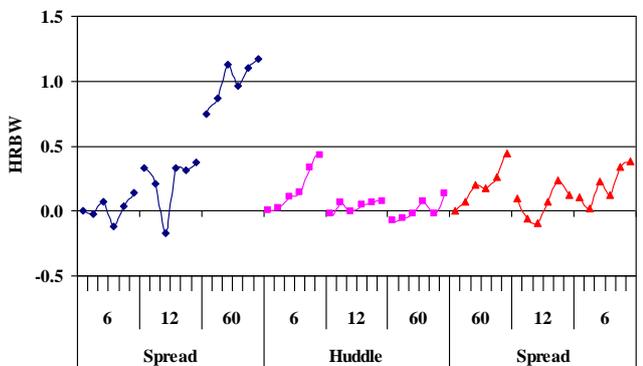


Fig. 7, The hardness change due to using various anvil sizes

3.4 Influence of large notched anvil

In the study, not only the typical flat anvil of 6, 12 and 60 mm is used but “large notched anvil”, commonly used in the calibration lab, is also used to explore the effect of hardness change. The size of the large notched anvil is much larger than the diameter of reference block which can support the total area of the bottom of the block during all indentations. However, the surface of the anvil is a v-shape cut, rather than smooth surface as presented in Fig. 8. Unfortunately, there are a few studies of the large notched anvil on hardness change. Therefore, National Physical Laboratory, NPLI has investigated the measurement by using large notched anvil to better understand the effect on hardness change. The measurement of NPLI is operated by Hardness standardized machine model: HSM HR/HV 2007-07 and S/N: 2007/07 as presented in Fig. 9.



Fig. 8, Large notched anvil



Fig. 9, Hardness standardized machine of NPL (India)

The measurement results are determined by the regional comparison on hardness measurement, Rockwell scale B (APMP. M.H.-S3) by using the same spot anvil size at 10 mm [2]. Then, NPL hardness lab has remeasured a set of artefacts 25 HRBW-100HRBW reference blocks for by using the large notched anvil, instead of spot anvil.

Fig.10 shows the overview results of comparison on Rockwell scale B, code number APMP.M.H-S3. The

deviation from the group average when all participants using spot anvil is within +0.8 HRBW to -0.6 HRBW.

Whereas the deviation from the NPLI when using the large notched anvil instead of 10 mm spot anvil is within -2.64 HRBW and -0.13 HRBW at the hardness level of 25 and 100 HRBW respectively as shown in Fig.11. Therefore, it is proven that using the large notched anvil always results in an attendant decrease in hardness level and also be particular sensitive to the lower hardness value than the higher one.

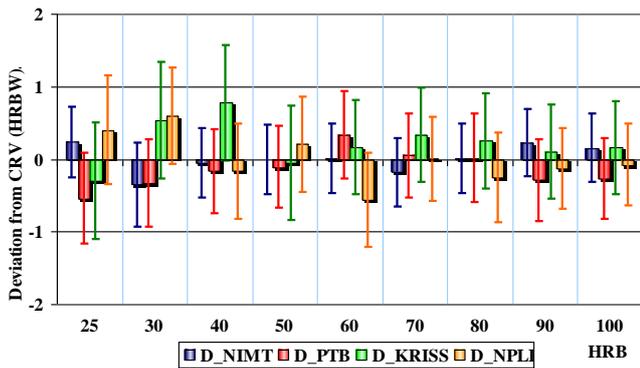


Fig. 10,APMP. M.H.-S3comparison result on Rockwell scale B

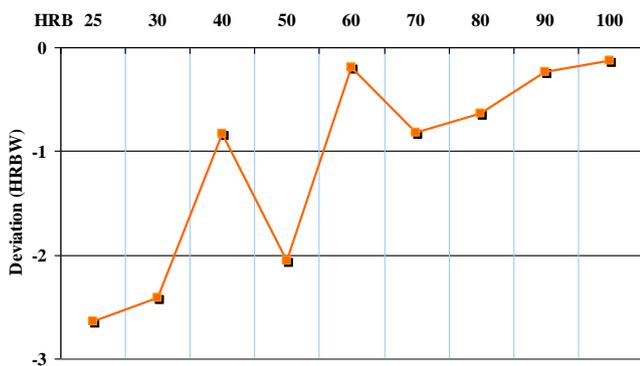


Fig. 11, Deviation value when using large notched anvil reference from using 10 mm anvil diameter

The information of regional comparison of APMP.M.H.-S3 is studied again as a representative example by using the measurement results of all participants with spot anvil except only one result which use large notched anvil instead. It is shown that the result is not consistent to others and become a cause of larger deviation from the group at +1.09 HRBW to -1.71 HRBW as presented in Fig. 12.

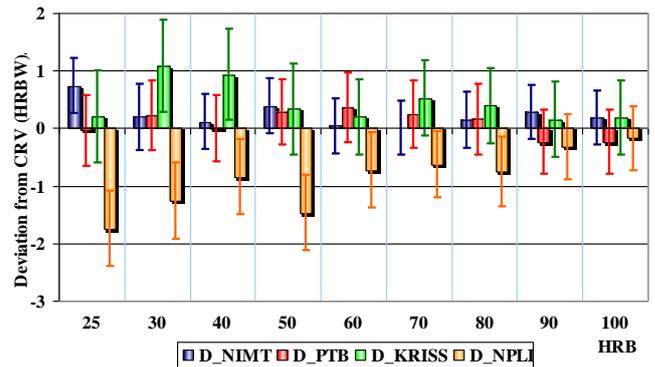


Fig. 12,Re-investigation of APMP. M.H.-S3with result of using large notched anvil (orange bar)

This measurement results are confirmed that inter-laboratory comparison on Rockwell scale B should carefully consider the size and appearance of anvil and define as a technical protocol in order to minimize the measurement error due to the different types of anvil

3.5 Influence of Bending Deflection

Bending deflection of 40 HRBW reference block is consistent to the previously discussed results of 25 HRBW reference block. The effect of the bending deflection of reference block is not relatively influenced by indenting pattern and anvil size, but resulting from both of thickness of reference block and number of indentations. Bending deflection is inversely proportional to the thickness of reference block as presented in Fig 13. It is seen that using 6 mm thickness block can cause the highest deflection at 48 um, while using 11.5 mm shows the least bending deflection at only 9 um. In case of comparison of bending deflection for two hardness level, 40 HRBW clearly exhibits the less bending deflection than 25 HRBW reference block. However, there is no significant relationship between the bending deflection and hardness change.

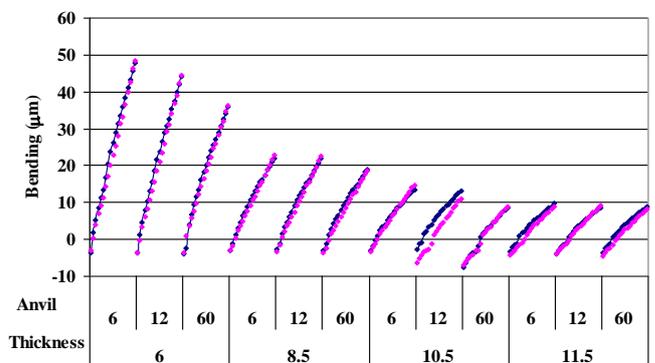


Fig. 13, Bending of block from spread pattern (pink line) and huddle pattern (blue line)

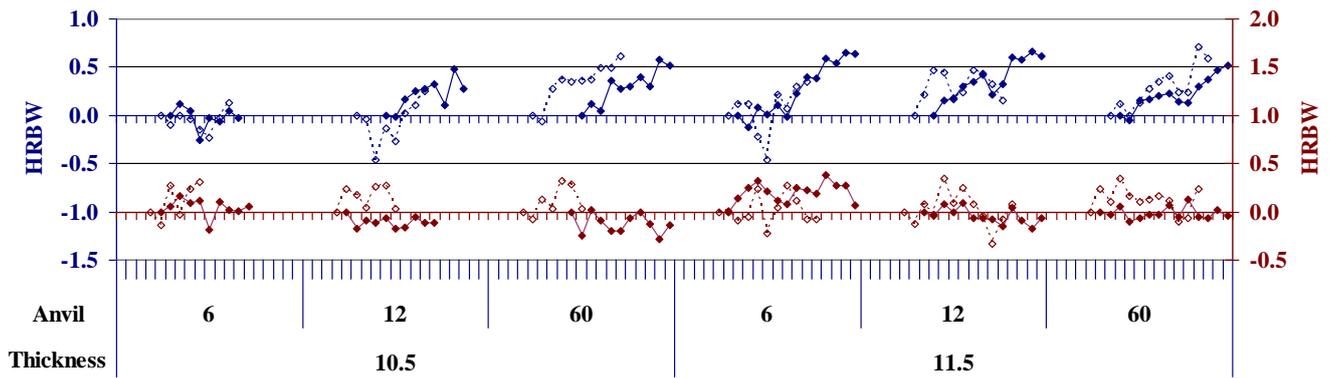


Fig. 14, The stability of 25 HRBW (dash line) and 40 HRBW (solid line) reference blocks, measuring under surface flatness not more than 10 μm ; Where blue line represent spread pattern and brown line represent huddle pattern

According to the requirement of ISO 6508-3 (2005): Metallic material-Rockwell hardness tester-Calibration of reference blocks allows the flatness of the blocks surface shall not over than 10 μm and the bottom of the blocks shall not be convex [3].

However, in practice, once reference blocks are manufactured, the appearance bending has already occurred at approximately 3-4 μm without any indentations based on the results in figure 13. Therefore, the bending deflection and convex of the block can be considered as the limitation to the maximum number of indentations. It is also defined the number of pre-indentations in order to provide the block reach to concave or flat within 10 μm condition. Based on the limitation above, the average number of indentations for 40 HRBW reference block at each different specified condition are shown in Table 2.

Table2,Maximum number of mean values of 40 HRBW block comply with ISO 6508-3:2005 requirements

Block thickness (mm)	Maximum number of mean values					
	Huddle pattern			Spread pattern		
	6	12	60	6	12	60
6	2	2	2	3	3	4
8.5	5	5	6	6	6	7
10.5	10	10	11	9	9	10
11.5	14	13	14	12	12	12

The table shows that the average numbers of indentation at each specific condition is relatively consistent to the prior study of 25 HRBW. The results also shows that the blocks having thickness of 6 and 8.5 mm give the least average number of indentation which is not sufficient to practical use. While the block having thickness of 10.5 and 11.5 mm can provide the average number of indentation at 10 to 14 which is suitable for practical use. Fig. 13 presents that 40 HRBW reference block at 11.5 mm thickness perform the bending deflection less than 10 μm all over the

block surface with any indenting patterns. This observation suggests that the reference blocks should be produced at thickness at least 11.5 mm to assure that the change of physical performance of the blocks is still conform to the requirement of ISO6508-3:2005 during operation.

Considering the hardness change for 25 HRBW and 40 HRBW reference blocks in the acceptable range conformed to the requirement of ISO 6508-3:2005, the 25 HRBW and 40 HRBW with spread indenting pattern shows range of hardness change within 0.81 HRBW and 0.76 HRBW, respectively. On the other hand, huddle indenting pattern shows range of hardness change within 0.67 HRBW and 0.39 HRBW, respectively as presented in Fig. 14.

4. CONCLUSION

A few researches [1] and [4], have investigated the influenced factors on stability of reference block for Rockwell scale B. One of the influence factors on hardness change is indenting pattern. For example, the trend of hardness change with spread indenting pattern exhibit increase with constant rate, while the trend of hardness change with Huddle indenting pattern tends to constant for all ranges. Thus, it is possible to expect that other indenting patterns can give the interesting different trend of hardness changes.

The change in hardness value relates to the hardness level, which is inversely proportional relationship. Furthermore, it is observed that using the thicker blocks and larger anvil size can give significantly higher effect on hardness change than using the thinner blocks and smaller anvil. Moreover, the investigation of using large notched anvil is also interesting since it shows the different behaviour, which is primarily a result of a decrease in hardness value than using spot anvil at approximately -2.64 HRBW to -0.13 HRBW. It is clear that a reference block

using the different size of anvils can vary a trend of hardness change and also provide a change in hardness value.

The bending deflection of a reference block is inversely proportional to its thickness. Then, when considering the flatness of the block for 40 HRBW at bottom surface is not exceed 10 μm , the block at 11.5 mm thick shows that the bending deflection is not more than the range of acceptable standard measurement during indentations over the block surface. These results are clearly show the thickness of reference block should be manufactured at least 11.5 mm thickness. By considering the standard ranges of measurement for bending deflection, the hardness change is within 0.76HRBW over 13 mean values and 0.39 HRBW over 14 mean values for spread pattern and huddle pattern, respectively.

5. ACKNOWLEDGEMENT

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6. REFERENCE

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