A Study of Hardness Change on 25 HRBW Reference Block due to the Number of Indentations

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Abstract

Reference hardness blocks may have measurement uncertainty as low as 0.45 Rockwell units. However, in case of Rockwell scale B hardness blocks, changes in hardness over the test surface caused by indentations could be as high as 2 HRBW or more which exceed its measurement uncertainty and thus, directly affect the accuracy of hardness measurement. To study the behavior of hardness change due to indentations, two groups of 25 HRBW test specimens of reference hardness blocks were studied one group in the spread patterns and the other in the huddle patterns, respectively. Each group of the test specimens consists of 3 sets of reference hardness blocks of 6, 8.5, 10.5 and 11 mm thickness in order to match the 60, 12 and 6 mm anvil's diameters.

The results of the study showed that indentations caused the reference blocks bending deflections. The bending deflection was inversely proportional to the diameter of used anvil and the thickness of reference block. When using a 60 mm diameter anvil, for every thickness of reference blocks, the hardness values always increased over 1 HRBW. While anvils having 12 mm and 6 mm diameters produced positive hardness change rates. The hardness change rate tended to decrease when the diameter of the anvil was increased and increased when the thickness of the reference block is decreased. Especially, for the 6 mm thickness block, the hardness change rate was in the negative direction. Moreover, tests carried out in the huddle pattern gave more stable results than those tests carried out in the spread pattern.

From the results, it cold be concluded that the hardness change could be minimized by selecting appropriate thickness of the reference block, diameter of the anvil used, and indenting pattern. However, those factors influence the bending of the reference block. Therefore, the maximum number of indentations should be carefully considered by taking into account, not only the distance between the indentations but also the tolerance of the surface flatness of the reference block.

***Keywords**:* Reference block, hardness change, bending.

1. Introduction

Number of indentations is an important factor to be considered for usage of reference hardness block nowadays, due to the fact that hardness value is changed by number of indentation [1]. However, in case of Brass

Rockwell B scale reference block, there is additional influence factor from bending of the reference block, which affects to a measurement stability. The effect is obviously observed when a large flat anvil is used. As described in a research work on “Effect of bending in brass Rockwell B scale test blocks” [2], performed by Samuel Low and James Fink, bending in a reference block is greater by increasing number of indentation. However, the experiment was just carried out by 9.5 mm diameter spot anvil and 9.4 mm thick reference block. In order to study the behavior of changes in hardness of Rockwell B scale reference block in wider view, the experiment was done under different specified conditions with the variation in the factors that is expected to have an effect on hardness value, such as block thickness, indenting pattern and anvil diameter.

2. Experiment Plan

2.1 Experiment conditions

Hardness value of 25 HRBW was chosen for the experiment due to it is the lowest level that is available in HRBW scale and also with the fact that low hardness level can provide high sensitivity, which is good to observe its behavior under test conditions. Thirty pieces of 25 HRBW reference block with thickness of 6 mm to 11.5 mm were specially manufactured by ASAHI GIKEN CO., Ltd. Japan. The reference blocks were divided into 2 sets in order to study the measurement result under different specified conditions in indenting pattern. Each set was experimented under sub-conditions, which were the variations in reference block thickness and diameter. Numbers of test pieces used in each experiment condition experiment conditions are described in Table. 1.

Table. 1 Numbers of test pieces

	Huddle pattern			Spread pattern		
	Diameter of anvil (mm)			Diameter of anvil (mm)		
Block thickness	6	12	60	6	12	60
6	1	1	1	1	1	1
8.5	1	1	1	1	1	1
10.5	2	2	2	2	2	2
11.5	2	2	2	2	2	2

2.2. Indenting pattern

To ensure that the distance between the center of two adjacent indentations are at least four times of 1.2 mm, which is the diameter of indentation on 25 HRBW test piece, and the distance from the center of indentation to the edge of test piece are at least 2.5 times of 1.2 mm, the indenting positions on a whole surface were specified as a layout. As a result of the layout, 90 indentations were the maximum numbers of indentations that could be performed on the block surface. With reference to ISO 6508-2 (2005): Metallic materials - Rockwell hardness test - Verification and calibration of testing machines (scale A, B, C, D, E, F, G, H, K, N, T) [3], *hardness value shall be determined from the mean of five indentations that are uniformly distributed over the test surface*, therefore the indenting position layouts were specified by dividing the test surface into five sections for five indentations, in other words, for one hardness mean. Maximum numbers of hardness means were 18 values (where each value obtained from a mean of 5 indentations), are corresponding to maximum number of indentations that is 90 indentations. Changes in hardness values were estimated by observing a stability of 18 hardness mean values. The indenting patterns in each divided section were specified 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.

Both indenting patterns are shown in Fig.1.

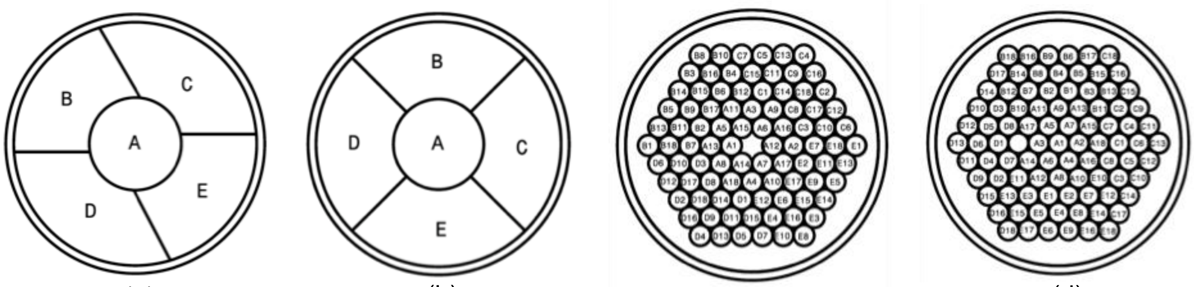
In order to study the bending deflection of reference block occurred during the experiment under specified conditions as shown in Table 1, bending degree of the bottom surface was measured after each hardness mean was taken, by surface roughness measuring device, model: S-3000, manufactured by Mitutoyo.

3. Experiment Result

3.1 Experiment Result from Spread Indenting Pattern

The overview of results shows that when performing the indentations as the spread pattern, the trends in hardness changes are observed as 3 intervals along 18 sequences of hardness mean determination. The characteristics and changing points of the trend depend on the sizes of used anvils.

3.1.1 When using the 60 mm diameter anvil: The measurement results are shown in Fig. 2(a). The first interval of the trend is observed between the 1st and the 4th sequence of measurement, that is to say, hardness mean.



(a) (b) (c) (d)

Fig. 1 Sections divided on block surface of (a) spread pattern (b) huddle pattern and layout of indenting positions of (c) spread pattern (d) huddle pattern

The trend exhibits an increase in hardness of about 0.5 HRBW through 4 mean values, with an abrupt shift of first two mean values. The second interval of the trend is observed between the 5th and the 14th hardness mean, with an increase in hardness of about 0.8 HRBW, 0.7 HRBW, 0.4 HRBW and 0.3 HRBW through 10 mean values for reference blocks having a thickness of 11.5 mm, 10.5 mm, 8.5 mm and 6 mm, respectively. The third interval starts from the 15th hardness mean with an increase in hardness of about 0.6 HRBW through 5 mean values.

3.1.2 When using the 12 mm diameter anvil: The measurement results are shown in Fig. 2(b), the first interval of the trend is observed between the 1st and the 4th mean hardness. The trend exhibits the constant in value with a fluctuation of about ±0.5 HRBW along 4 mean values. The second interval of the trend is observed between the 5th and the 14th mean hardness, with the constant in value fluctuating within ±0.5 HRBW along 10 mean values. The third interval starts from the 15th mean hardness with an increase in hardness of about 0.7 HRBW through 5 mean values.

3.1.3 When using the 6 mm diameter anvil: The measurement results are shown in Fig. 2(c). The first interval of the trend rather varies between ±0.4 HRBW along 4 mean values. The second interval of the trend shows an increase in hardness of about 0.7 HRBW through 10 mean values for reference blocks having a values is observed for reference block having a thickness of 10.5 mm, and decreasing trend of -0.5 HRBW is observed for reference blocks having a thickness of 8.5 mm and 6 mm, respectively. The third interval shows an increase in hardness of about 0.9 HRBW though 5 mean values.

3.2 Experiment Result from Huddle Indenting Pattern

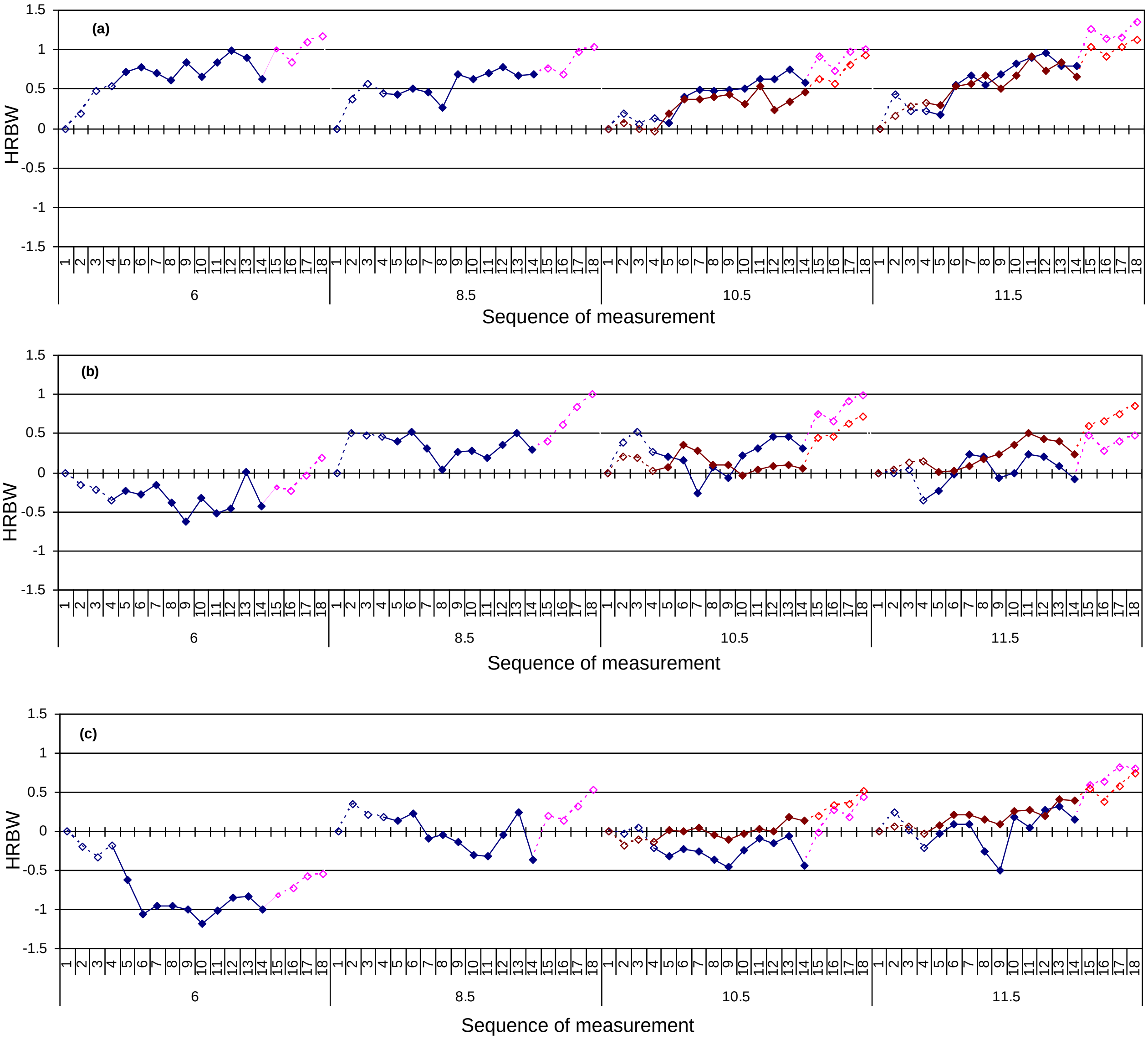


Fig. 2 Experiment results from spread indenting pattern (a) when using the 60 mm diameter anvil (b) when using the 12 mm diameter anvil c) when using 6 mm diameter anvil

thickness of 11.5 mm, whereas a constant trend with a fluctuation of ±0.4 HRBW along 10 mean

The overview of results obtained from huddle indenting pattern also shows the trends in hardness changes as 3 intervals. The first interval of the trend is observed between the 1st and 4th hardness mean, while the second interval is observed between the 5th and 14th hardness mean and the third interval is observed from the 15th hardness mean.

3.2.1 When using the 60 mm diameter anvil: The measurement results are shown in Fig. 3(a). The trend exhibits an increase in hardness of about 0.5 HRBW through 4 mean values. The second interval shows the constant trend with a fluctuation of approximately ±0.3 HRBW along 10 mean values. The trend in third interval tends to decrease by -0.5 HRBW to -1 HRBW through 5 mean values.

3.2.2 When using the 12 mm diameter anvil: The measurement results are shown in Fig. 3(b). There is no separation (changing point) between the first and second interval of the trends for reference blocks having a thickness of 6 mm, 8.5

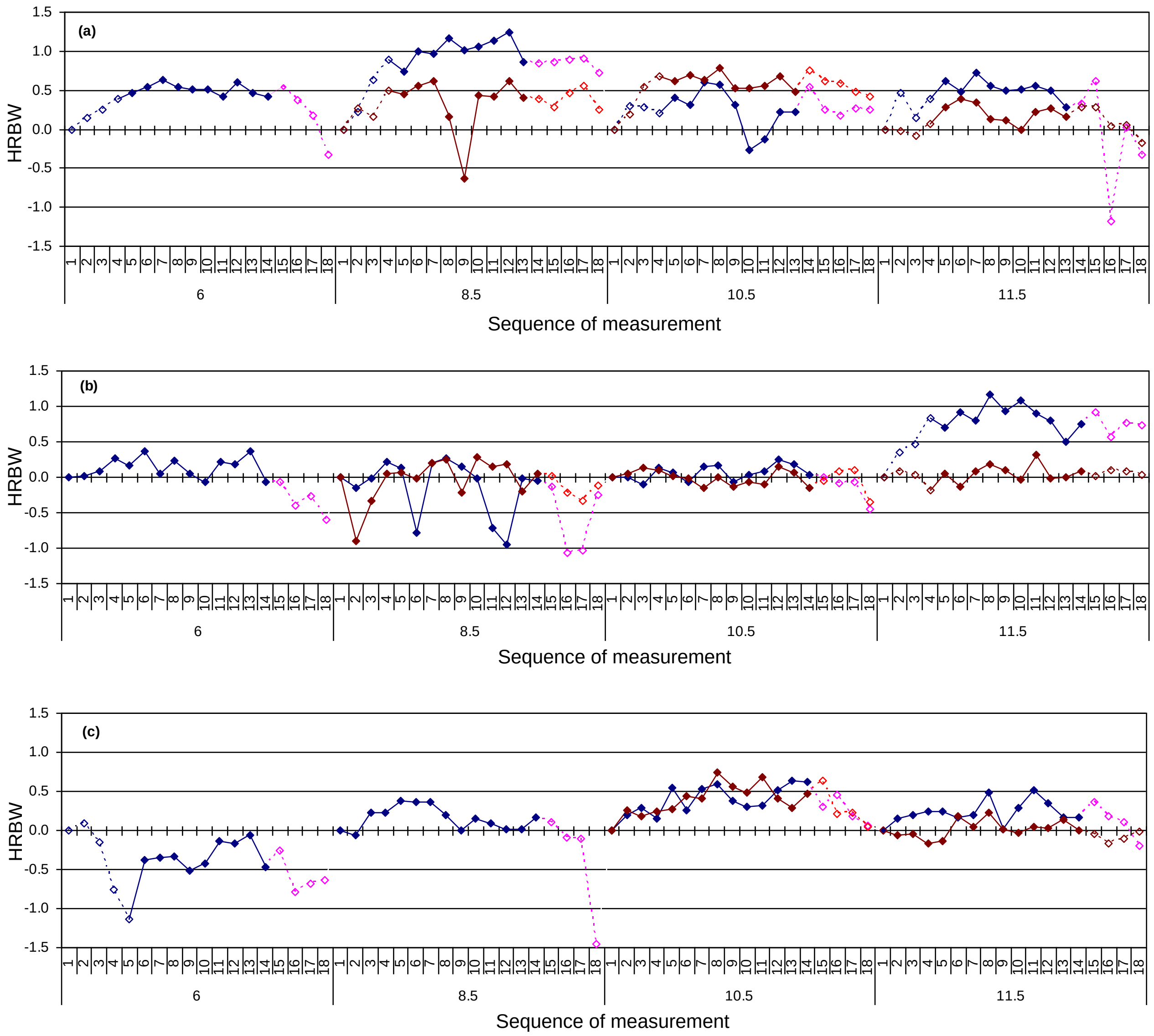


Fig. 3 Experiment results from huddle indenting pattern (a) when using the 60 mm diameter anvil (b) when using the 12 mm diameter anvil c) when using 6 mm diameter anvil

mm and 10.5 m. Hardness seems to be steady within these two intervals fluctuating within ±0.25 HRBW. However, for only 8.5 mm thickness reference block measured by 12 mm diameter anvil, the result exhibits a variation in hardness as high as ±1 HRBW along 10 measurements. For 11.5 mm thick reference block, the trend in the first interval increases about 0.8 HRBW through 4 mean values, whereas the steady trend fluctuating within ±0.35 HRBW along 10 mean values, is observed in the second interval.

3.2.3 When using the 6 mm diameter anvil: The measurement results are shown in Fig. 3(c). The first interval of the trend is observed between, approximately the 1st and 5th hardness mean with an erratic trend of a large variation in hardness. The second interval shows a steady trend fluctuating within ±0.5 HRBW along 10 mean values. However, the trend tends to decrease in the third interval.

3.3 Bending Deflection of Reference Block with the Numbers of Indentations

It could be observed that bending deflection occurs such that the bottom of the block becomes concave more and more with the numbers of indentations. There is a correspondence in bending effects resulting from both indenting patterns. The use of 60 mm diameter anvil gives less effect in bending than one obtained from smaller anvils in order, i.e., 12 mm and 6 mm diameter anvils. Furthermore, it is seen that thicker blocks gives less bending deflection than thinner ones. Fig. 4 shows the bending of reference block resulting from both indenting patterns with respect to thicknesses of the blocks and sizes of the anvils.

With the consideration of requirement in ISO 6508-3 (2005): Metallic materials – Rockwell

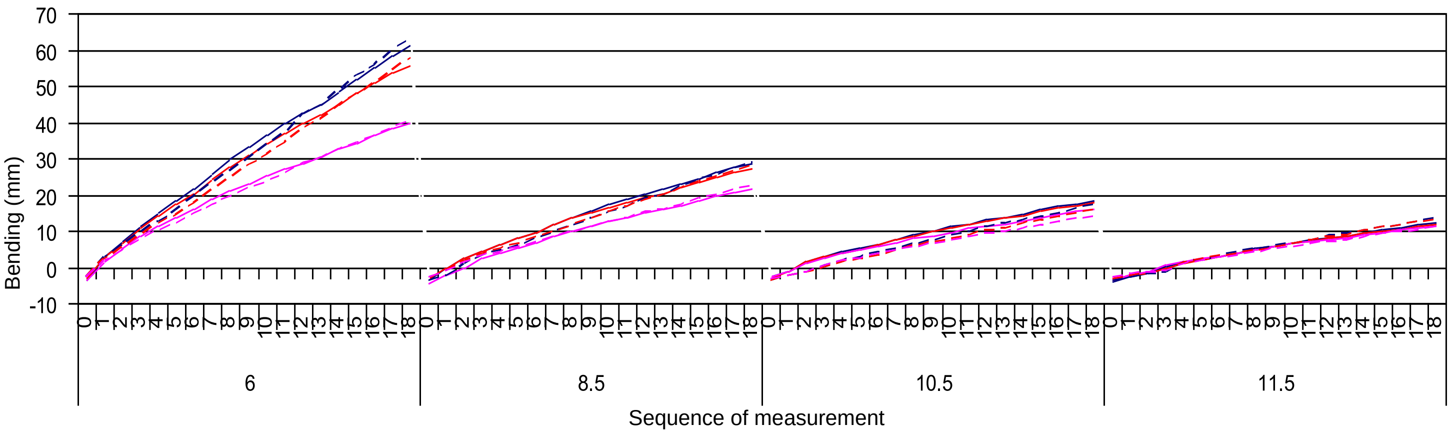


Fig. 4 Bending of reference block resulting from both indenting patterns (where dash line and solid line represent for spread pattern and huddle pattern, respectively) with respect to thicknesses of the blocks and sizes of the anvils (where blue, red and pink line represent for 6, 12 and 60 mm diameter anvils, respectively)

hardness test – Calibration of reference blocks (scales A, B, C, D, E, F, G, H, K, N, T) [4], that is, *flatness of the block surfaces shall not exceed 10 µm and the bottom of the blocks shall not be convex*, as a result, maximum numbers of mean values obtained from different specified conditions are limited to the numbers presented in Table. 2.

Table. 2 Maximum numbers of mean values obtained from each specified conditions

	Huddle pattern			Spread pattern		
	Diameter of anvil (mm)			Diameter of anvil (mm)		
Block thickness	6	12	60	6	12	60
6	2	2	3	3	3	4
8.5	6	6	8	7	7	8
10.5	9	9	10	11	12	13
11.5	14	15	16	14	14	17

However, at the initial state that is not any indentation has been made on the block, the bottom surface is observed to be convex within 3 to 4 µm in degree. Therefore in order to observe the measurement result when the bottom of the block becomes flat, at least 1 mean value, 2 mean values, 3 mean values and 4 mean values has been measured for block having thicknesses of 6 mm, 8.5 mm, 10.5 and 11.5 mm, respectively. Mean values taken outside the acceptable measurement ranges (ranges prior to sufficient numbers of indentations have been performed), shall not be used as the measurement results, due the block conditions are not conforming to ISO 6508-3 (2005). The acceptable ranges of measurement are indicated in Table. 3.

Table. 3 The acceptable measurement ranges for each specified conditions

	Huddle pattern			Spread pattern		
	Diameter of anvil (mm)			Diameter of anvil (mm)		
Block thickness	6	12	60	6	12	60
6	1(2)	1(2)	2(2-3)	2(2-3)	2(2-3)	3(2-4)
8.5	4(3-6)	4(3-6)	6(3-8)	5(3-7)	5(3-7)	6(3-8)
10.5	6(4-9)	6(4-9)	7(4-10)	8(4-11)	9(4-12)	10(4-13)
11.5	10(5-14)	11(5-15)	12(5-16)	10(5-14)	10(5-14)	13(5-17)

It could be seen that although the block is slightly convex, even with a small degree of 2-3 µm, the measurement results obtained from this measurement range show a large variation as high as 0.63 HRBW. By considering of the acceptable measurement ranges for specified conditions in Table 3, the limit on numbers of indentation on the block could be obtained. It is observed that 6 mm and 8 mm thick reference blocks measured by both indenting patterns are limited on indentation numbers to a maximum 6 mean values. Thus, these blocks may not worth to use as a certified reference hardness block.

Fig. 5 shows the stability of an increase in hardness mean obtained when the bottom surface of block conformed to the requirement in ISO6508-3 (2005), where the minimum indentation numbers, which are determined when anvil's size and indenting pattern are assumed to be unknown), are considered, i.e., 6 mean values for the 10.5 mm thick block and 10 mean values for 11.5 mm thick block.

By performing a spread indenting pattern on the block when its bottom surface conforms to ISO requirement, it is seen that this indenting pattern provides the trend with an increase in hardness value. When using 60 mm diameter anvil, an increase observed is 0.5 HRBW through 6 mean values for 10.5 mm thick reference blocks and is 0.8 HRBW through 10 mean values for 11.5 mm thick reference block. While with the use of 6 mm and 12 mm diameter anvils, hardness values seem to be steady with a fluctuation of ±0.5 HRBW along 6 mean values for 10.5 mm thick reference block a fluctuation of ±0.5 HRBW along 10 mean values for 11.5 mm thick reference block.

While the measurement performed with the huddle indenting pattern within the same measurement range, the steady trend is observed with the fluctuation within ±0.4 HRBW along 6 mean values for block having thickness of 10.5 mm and within ±0.5 HRBW along 10 mean values for block having thickness of 11.5 mm.

4. Conclusions and Discussions

The measurement results show that the changes in hardness value relate to the size of used anvil, thickness of the block and indenting

interval and decrease abruptly in the third interval, when perform the measurements with huddle indenting pattern. On the other hand, hardness tends to increase in the second interval and rapidly increase in the third interval, in case of spread indenting pattern. It is observed that bending of the block directly relates to the block thickness. Due to the fact that the 6 mm and 8.5 mm thick blocks give narrow ranges allowed for the measurement (when the flatness of bottom surface is not exceed 10 µm.), thus the these blocks are not suitable to use as a reference block. While the 10.5 mm thick blocks gives a range allowed for measurement only 6 mean values, therefore if the blocks have been certified for 1 mean value, there will be only 5 mean values remaining for later use. The 11.5 mm thick blocks provides a range for measurement as much as 10 mean values, therefore there is still 9 mean values remaining for later use after it has been certified for 1 mean value.

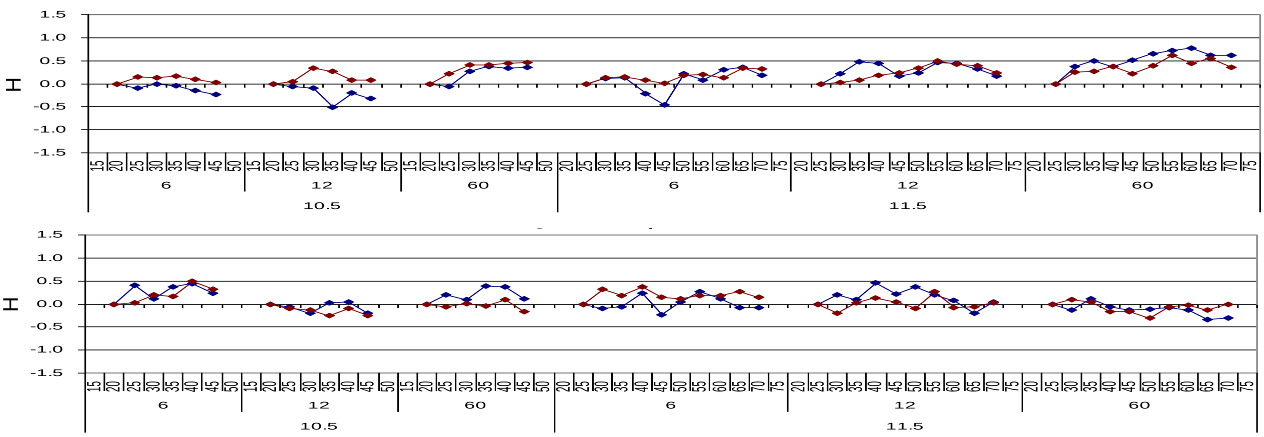


Fig. 5 the stability of an increase in hardness mean observed by (a) Spread indenting pattern and (b) Huddle

pattern. The trends of changes in hardness of 25 HRBW are observed as three intervals. The first interval obtained from both indenting patterns, shows an unpredictable trend however relating to the convexity of bottom surface of the block. Hardness changes in this interval could be as much as ±0.5 HRBW to ±1 HRBW. Then hardness values seem steady in the second

However, there is no difference in hardness change rate per one mean value, i.e., in case of spread indenting pattern, +0.083 HRBW/one mean value for 10.5 mm thick block and +0.073/one mean value for 11.5 mm thick block, while in case of huddle indenting pattern, hardness is seemly steady at ±0.5 HRBW along 6 mean values for 10.5 mm thick block and ±0.5

HRBW along 10 mean values for 11.5 thick block.

5. Acknowledgement

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6. References

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