THE INFLUENCE OF MICROSTRUCTURE HOMOGENEITY ON THE UNIFORMITY OF HARDNESS STANDARD BLOCKS

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ABSTRACT: The aim of this work is to correlate the homogeneity of the microstructure of two certified hardness standard blocks, both with the same hardness value range, with its uniformity hardness values. In order to identify the morphological characteristics of the blocks studied, as grain size distribution, an automatic image analysis system with software based on ASTM E112 and ASTM E1382 standards was employed. The hardness measurements were carried out in industrial hardness tester machine, in three different regions of the blocks. The results obtained for both blocks showed that, for the regions where coarsed grains were observed as islands of microstructure non-homogeneity, the hardness values dropped compared with those mentioned in the calibration certificates. The microstructure homogeneity plays therefore an important role on the uniformity of hardness values for reference blocks.

Keywords: hardness blocks, microstructure homogeneity, hardness uniformity

1. INTRODUCTION

In the routine of an accredited hardness laboratory, the employment of certified standard blocks during the indirect verification is very usual, in order to estimate the repeatability and error of the machine.

In some occasions, it was observed local hardness changes compared to the hardness values mentioned in the calibration certificate of the blocks. As the preliminary microstructure evaluation of these blocks have showned some regions of coarsed grains, it was decided to investigate the relationship between these hardness values deviations and the blocks microstructure. These evaluations were performed via automatic image analysis. So, based on a large experience in metallography and metallic material properties, the microstructure of two certified Rockwell B hardness standard blocks were studied, to confirm our theory that the microstructure homogeneity has a direct influence on the uniformity of hardness values for reference blocks.

2. EXPERIMENTAL PROCEDURE

In the present work, two certified Rockwell B hardness standard blocks named A and B in the same hardness range (60-80 HRB) were studied.

2.1 Microstructure Evaluation

An appropriate metallographic procedure was performed on both samples, in order to assure a good contrast between matrix and grain boundary. In automatic image analyses, this type of defect can lead to an erroneous result, because the equipment works with gray levels for the detection of the boundaries in the matrix. The metallographic etchings used were Nital 2% , for both samples, to reveal the microstructure of the blocks.

2.1.1 - Coarsed grain quantification

In order to identify and quantify the coarsed grains area (islands), a procedure was developed using an automatic analyzer image system with software based on ASTM E112 and ASTM E1382 standards, with the application of the *Live Image, Snapshot Image, Edit Plane Draw, Binary Filling, Feature Measure* and *Field Measure* filters [1-2].

2.1.2 Grain size homogeneity evaluation

Another procedure was developed to evaluate the grain size homogeneity, to enhance the contrast matrix / boundary, using the *Sharpen*, *Histogram Equalization* and *Gray Contrast Adjustment* filters. After that, the grains were segmented through *Threshold Image* in order to disconsider(?) the boundaries. It was then possible to count the grains with *Field Measurement* for each field analyzed, and measure the area of each grain using *Feature Measure.* The segmentation of the grains in its several sizes was obtained including in the procedure limits of mean area of the grains, according to the ASTM E 1382 standard (table 2), to allow the comparison of the grain area with the related ASTM grain size number [3].
The statistical calculations were stored in the *Post Sample* for compilation of the data for the different fields of each analyzed sample, for both procedures described in 2.1.1 and 2.1.2.

2.1.3 Hardness evaluation

In order to evaluate the hardness distribution in the different regions of the microstructure, fifteen Vickers hardness indentations (HV 0.5) were performed in the matrix, in the coarsed grain region (island) and in an adjacent region of the island, resulting in forty five indentations for each sample.
Rockwell B hardness measurements were carried out on the coarsed grains regions (islands) and in the matrix to better understand the influence of the homogeneity microstructure on the uniformity of hardness values of reference blocks. Such operation was possible using the objective (70X) of the Brinell method, to localize these regions on the microstructure for both samples.

3. RESULTS AND DISCUSSION

The figures 1 and 2 present micrographs of the reference blocks A and B, where both microstructure are constituted predominantly by ferrite and some regions with pearlite. The regions with coarsed grains (islands) are delineated.

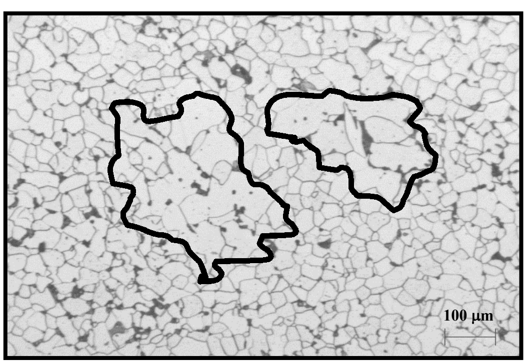


Figure 1 - Microstructure of reference block A Magnification: 100X

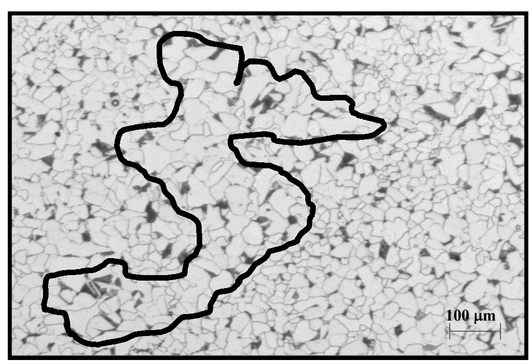


Figure 2 - Microstructure of reference block B Magnification: 100X

The table 1 presents the result obtained with the procedure described in 2.1.1

Table I - Quantification of islands with coarsed grains

	Reference Block A	Reference Block B
Number of islands detected	78	27
Total area (A_T)	250,9 mm^2	217,6 mm^2
Total coarsed grain area (A_{CG})	4,38 mm^2	2,58 mm^2

During an indirect verification of a hardness test machine, the probability of the indentation occuring in one coarsed grain region of the reference block is express by the equation 1. For ***n*** indentations the total probability is expressed by equation 2.

$$P = \frac{A_{CG}}{A_T} \quad (1) \qquad\qquad Ptotal = \sum_{n=1}^{n} \frac{A_{CG}}{A_T} \quad (2)$$

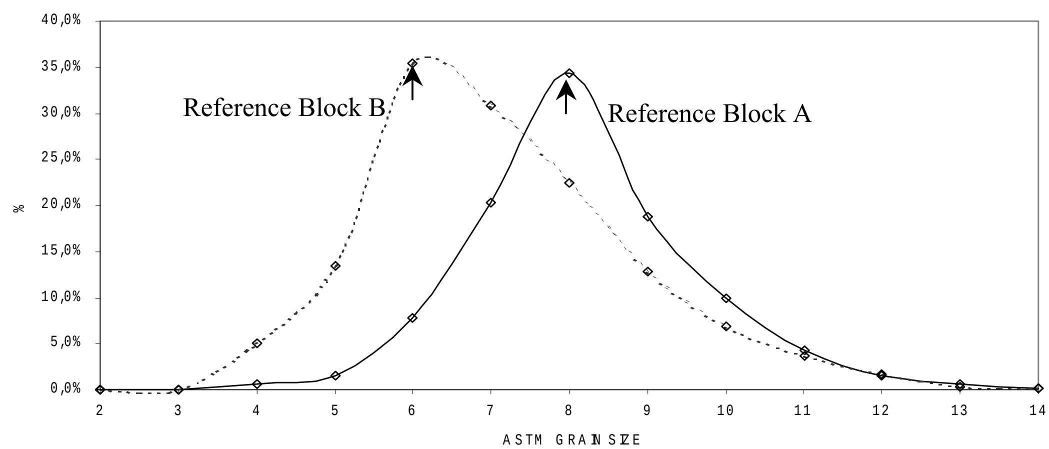
where, A_{CG} - total coarsed grain area

A_T - total area

Five (5) indentations were performed for each reference blocks, according to the international standards, and the resulting total probability is expressed by the equations 3 and 4.

$$P_A^{total} = \sum_{n=1}^{5} \frac{4.38}{250,9} = 8.72\% \quad (3) \qquad P_B^{total} = \sum_{n=1}^{5} \frac{2.58}{217,6} = 5.93\% \quad (4)$$

Figure 3 shows the ASTM grain size distribution of the total area analyzed for each sample, in accordance with the procedure described in 2.1.2. It could be observed that the reference block A presented the highest concentration of ASTM grain number, around ASTM 8 (34.4%). The concentration of ASTM grain number for the reference block B were around ASTM 6.2 (35%).



Figures 3 - Comparison of ASTM Grain Size Distribution for the blocks A and B

Figures 4 and 5 present the ASTM grain size distribution for the coarsed grain regions of the reference blocks A and B, respectively. A similar behaviour of both curves can be noticed, with a concentration of ASTM grain number 4 and 5 indicated by arrows. However, the curve for the reference block B presented a high percentage of ASTM grain number 4 (10.7%) and 5 (6.2%) when compared to the block A, 7.6% and 1.7%, respectively.

Based on the figures 3, 4 and 5 it can be said that the reference block A presented the highest difference between ASTM grain number of the coarsed grain regions (ASTM 4) and the matrix (ASTM 8). This is the probabley reason for the high non-uniformity (%) in hardness measurements obtained for the reference block A, when compared with that obtained for the reference block B.

The influence of the coarsed grain regions is not the only significant parameter for the highest non- uniformity values, but also the range of the mean ASTM grain number between matrix and coarsed grain regions.

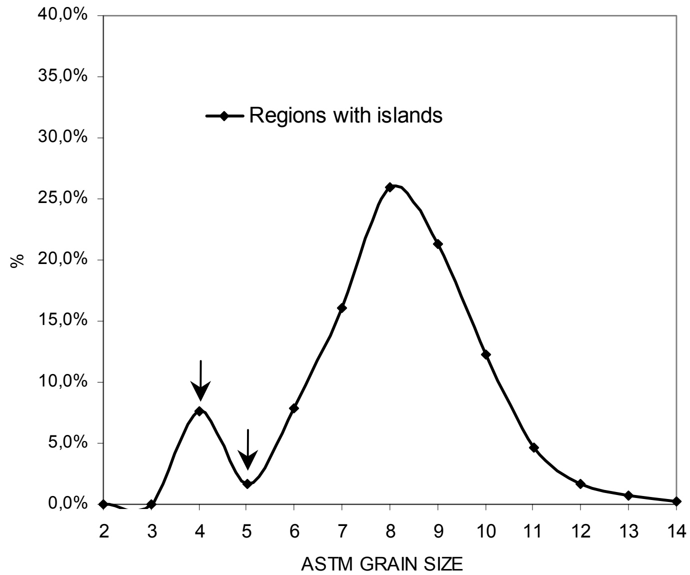


Figure 4 - ASTM grain size distribution for the coarsed grain regions of the reference block A

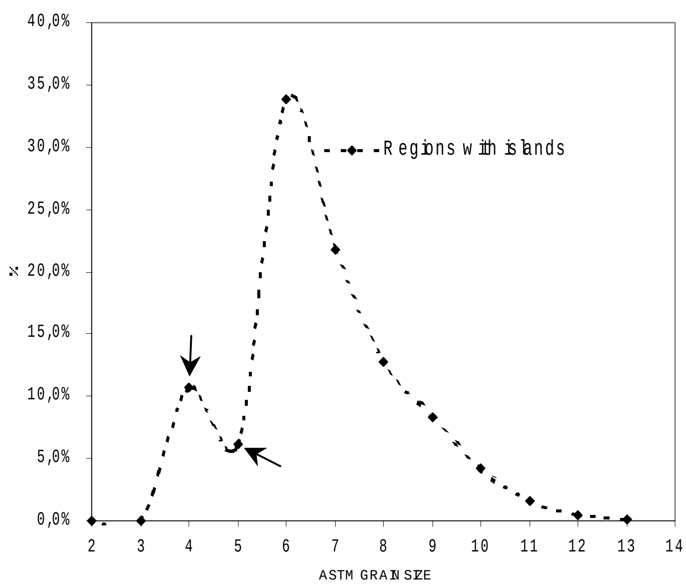


Figure 5 - ASTM grain size distribution for the coarsed grain regions of the reference block B

The table II shows the hardness values obtained in the reference block A, in the matrix and in the coarsed region (island), where it can be observed that all the hardness measurements obtained inside the island were lower than the values for the matrix, confirming the theory that the non-homogeneity of the microstructure leads to a variation in the hardness values of a reference block [4-5].

Table II - Results of Rockwell B hardness measurements in the reference block A

Indentation	Hardness Value		Hardness difference	
	island	matrix	Absolute	%
1	58,8	62,8	-4,0	-6,37
2	59,7	63,4	-3,7	-5,84
3	60,8	63,5	-2,7	-4,25
4	59,8	62,9	-3,1	-4,93
5	62,1	63,6	-1,5	-2,36
Average	60,2	63,2	-3,0	-4,74

The non-uniformity of hardness is defined according to international standards as the difference between the highest and the lowest indentation depth. For the Rockwell B method, the limit defined in these standards is 3% related to the mean indentation depth.

The table III presents the indentation depth related to the hardness values measured and the non-uniformity for each region studied (matrix and island) of the reference block A. The non-uniformity obtained in the heterogeneous region (island) is above the limit defined by the standard while for the homogeneous region (matrix) the non- uniformity was in accordance with the standard.

Table III - Non-uniformity obtained for reference block A

Indentation	Indentation depth	
	Island	Matrix
1	0,1424	0,1344
2	0,1406	0,1332
3	0,1384	0,133
4	0,1404	0,1342
5	0,1358	0,1328

Non-uniformity	0,0066	0,0016
Limit	0,0042	0,0040
Non-uniformity %	4,7%	1,2%

Similar methodology was performed for the reference block B and the table IV and V present the results of Rockwell B hardness measurements and non-uniformity, respectively. However, in this case, the non-uniformity for both regions (island and matrix) is in accordance with the international standards.

Table IV - Results of Rockwell B hardness measurements in the reference block B

Indentation	Hardness Value		Hardness difference	
	island	matrix	Absolute	%
1	62,1	64,2	-2,1	-3,27
2	63,0	63,8	-0,8	-1,25
3	62,9	63,9	-1,0	-1,56
4	63,2	64,3	-1,1	-1,71
5	63,1	63,7	-0,6	-0,94
Average	62,9	64,0	-1,1	-1,75

Table V - Non-uniformity obtained for reference block B

Indentation	Indentation depth	
	Ilhas	Matriz
1	0,1358	0,1316
2	0,1340	0,1324
3	0,1342	0,1322
4	0,1336	0,1314
5	0,1338	0,1326
Non-uniformity	0,0022	0,0012
Limit	0,0040	0,0040
Non-uniformity %	1,64%	0,91%

4. CONCLUSION

- Based on the results of this investigation, it can be concluded that inside the coarsed grain regions, the hardness values are lower when compared with those mentioned in the calibrated certificates.
- Two parameters that influence the non-uniformity of the hardness blocks are: total coarsed grain areas (%) and the difference of the ASTM grain number between matrix and coarsed grain regions.
- In the present study, the difference between matrix/coarsed grain regions ASTM grain number had greater influence than the amount of coarsed grain regions.

5. REFERENCES

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