

# THE INFLUENCE OF THICKNESS ON THE NON UNIFORMITY VALUES OF ROCKWELL B HARDNESS STANDARD BLOCKS

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*Abstract: In the present work, the influence of thickness variation and of the microstructural aspects on the hardness uniformity of Rockwell B standard blocks is discussed. In order to correlate the results, two different heat treatments were performed on the steel employed to manufacture the standard blocks. Three different thickness ranges were studied for each of the two heat treatments conditions applied to the standard blocks material. The microstructural characteristics were studied by means of optical microscopy. The hardness measurements were carried out in hardness testing machines belonging to the three Brazilian Institutes involved in the present study. The results indicate that the non-uniformity hardness values are directly affected by the resulting microstructural changes due to the applied heat treatments. However, a relationship between thickness variation and hardness values has not yet been entirely understood.*

## 1 INTRODUCTION

The present work is part of a project which is being developed in partnership between INMETRO, ITUC/PUC-Rio and INT since 1995. Its main purpose is the establishment of a national metrological system with hardness scales, whose procedures and standards must have traceability to metrological institutes recognized worldwide [1-3].

The reasons for the manufacturing of national standard blocks are the increase in demand by research institutes and national industries, at the moment estimated in 20,000 blocks/year, and the lack of production of hardness standard blocks in Brazil. The Brazilian market uses imported blocks, whose prices for the national consumer are very high, as well as the time for delivery, which decreases the time of its use because of the expiration of the validity date on the calibration certificate.

Previous studies, concerning the development of standard hardness blocks for three Rockwell C ranges [3], showed that the hardness values were directly related to the microstructural aspects of the block's material. Oil quenching was considered to be the most suitable heat treatment to achieve lower non-uniformity levels.

The purpose of this work is to discuss the influence of thickness variation and of the microstructural aspects on the hardness non-uniformity values of 60-70 HRB and 70-80 HRB standard blocks ranges. In order to correlate the results, two different heat treatments were performed on the steel employed to manufacture the standard blocks. The material has been supplied by a national enterprise and contains a very low level of phosphorus and sulfur.

Three different thickness values were studied for each of the two heat treatments conditions applied to the standard blocks material.

## 2 EXPERIMENTAL

The low carbon steel employed to manufacture the standard blocks has been supplied in the form of 670 mm cylindrical bars. The bars were cut and machined to the final dimensions of the standard blocks studied, e.g, 650 mm in diameter and 06, 12 and 16 mm in thickness.

To achieve the desired hardness ranges (60-70 HRB and 70-80 HRB) and also the uniformity of the measurements, two heat treatments were performed in a furnace under argon atmosphere, adopting different heat treatment and tempering temperatures and cooling rates. All the specimens were austenitized for half an hour. For each condition of heat treatment, three specimens were studied in order to evaluate the reproducibility of the entire process. Three different thickness values were studied for each of the two heat treatments conditions applied to the standard blocks material.

In order to correlate the hardness results to the microstructure of the heat treated blocks, the microstructural characteristics were analysed by means of optical microscopy and the hardness measurements were carried out in hardness testing machines belonging to the three Brazilian Institutes involved in the research. The non-uniformity of hardness values was calculated according to ISO 6508-3 standard [4].

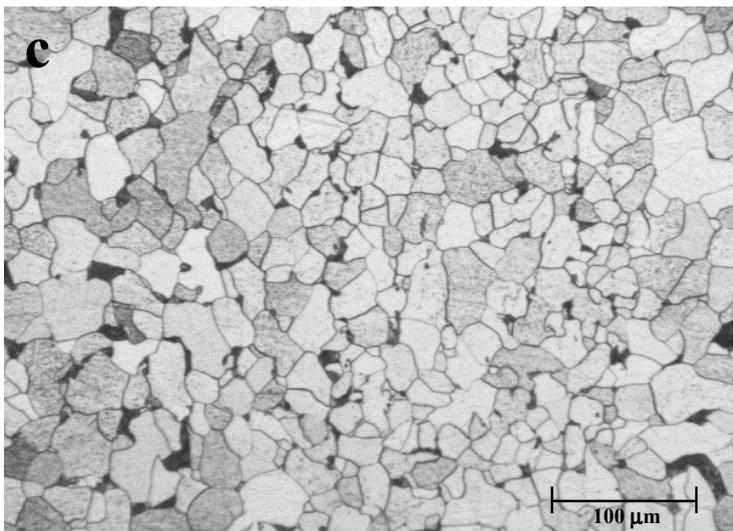
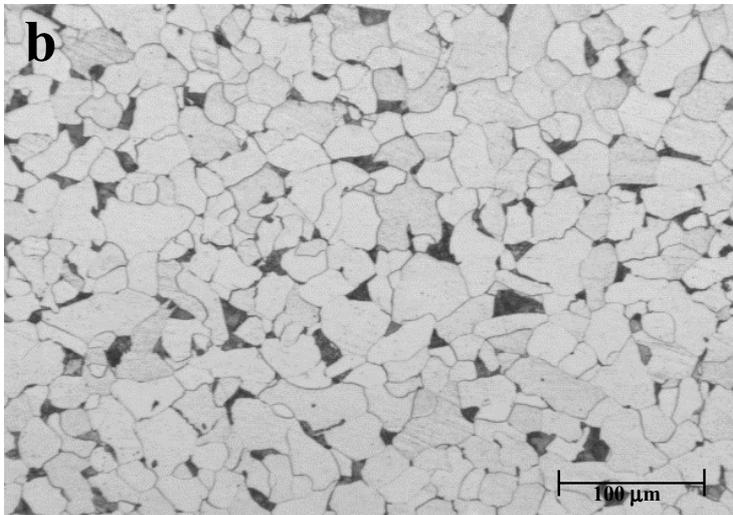
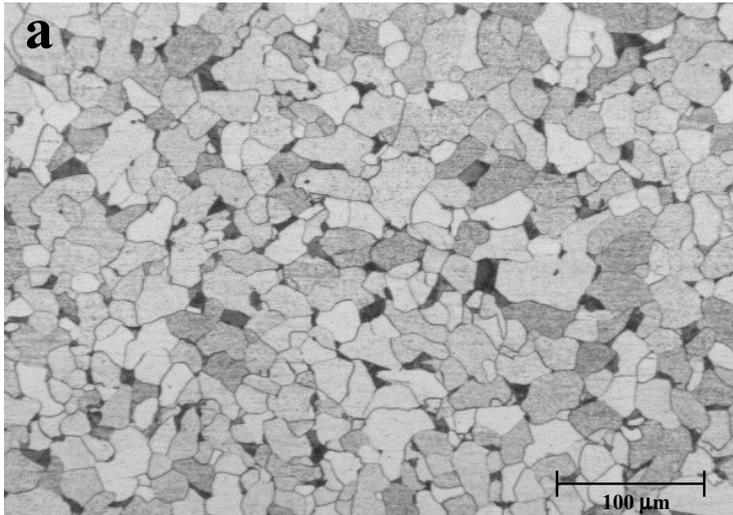
## 3 RESULTS AND DISCUSSION

The hardness values of the blocks and the indentation depths, obtained for the different heat treatments and thickness, are shown in Table 1 and 2, as well as the non-uniformity values and the maximum non-uniformity permissible.

**Table 1.** Hardness average values and indentation depth, applied heat treatments and non-uniformity percentages used to manufacture the blocks.

Hardness Range (HRB)	Thickness (mm)	Heat Treatment	Hardness Values (HRB)	Depth (mm)	Maximum Permissible Non-Uniformity (%)	Non-Uniformity (%)
60-70	6	normalized	64.44	0.1311	3.0	2.13
60-70	12	normalized	63.24	0.1335	3.0	2.20
60-70	16	normalized	61.44	0.1371	3.0	2.38

Figures 1 a, b and c show the characteristic microstructure of the 60-70 HRB range for the three different thickness values studied. The hardness and non-uniformity values presented in Table 1 for these blocks are in accordance with the microstructural features observed. The normalization heat treatment produced an homogeneous distribution of equiaxed polygonal ferrite grains along the thickness of the blocks, leading to lower non-uniformity values than that permissible in the international standards [4-6]. One can also notice that the hardness values showed an inverse relationship to the blocks thickness values. This effect is probably related to the deformation resistance of the blocks material. Further studies are necessary though, to confirm this tendency.

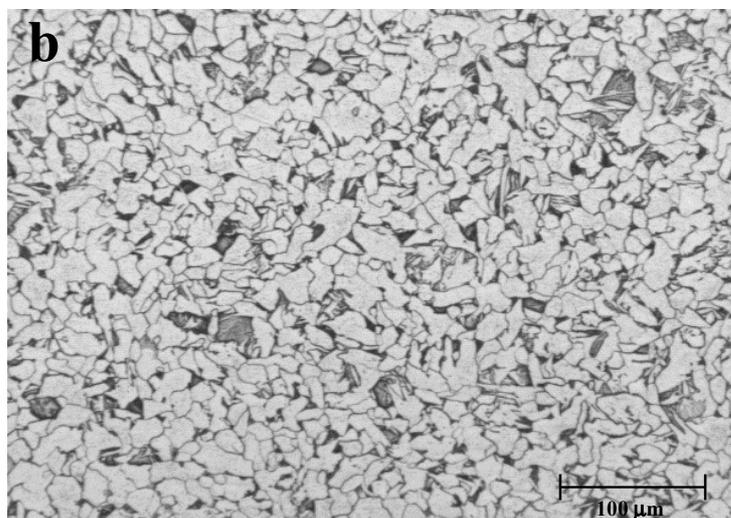
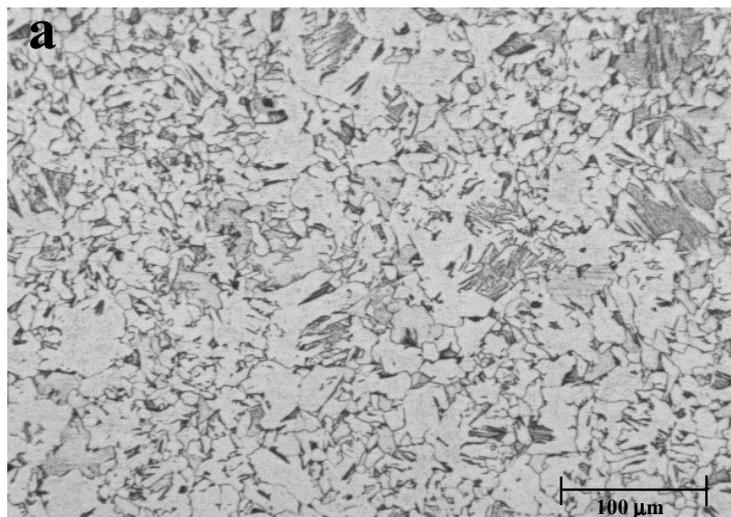


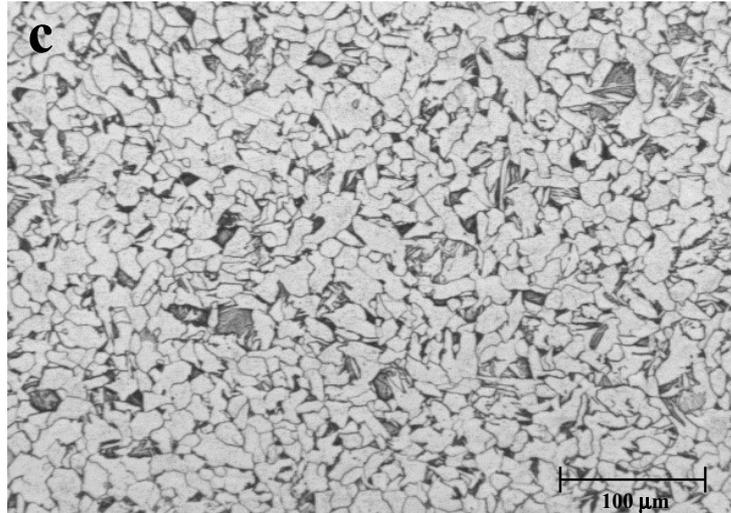
**Figure 1.** Microstructure characteristics of the 60-70 HRB range. (a) 6mm, (b) 12 mm and (c) 16mm.

**Table 2.** Average of hardness values and indentation depth, applied heat treatments and non-uniformity percentages used to manufacture the blocks.

Hardness Range (HRB)	Thickness (mm)	Heat Treatment	Hardness Values (HRB)	Depth (mm)	Maximum Permissible Non-Uniformity (%)	Non-Uniformity (%)
70-80	6	oil quenched	73.34	0.1133	3.0	13.77
70-80	12	oil quenched	75.62	0.1087	3.0	10.10
70-80	16	oil quenched	74.14	0.1177	3.0	8.59

The micrographs related to the blocks in the 70-80 HRB range for the three thickness studied are illustrated in Figure 2. The microstructure resulting from the oil quenching heat treatment, for the low carbon steel employed in the manufacture of the blocks, was very heterogeneous, presenting a mixture of constituents as irregular polygonal and acicular ferrite grains and the presence of superior bainite, which led to a very high non-uniformity hardness values [4-6]. The morphological and compositional microstructural heterogeneities were more significant than the thickness variation of the blocks, not allowing to correlate the hardness results to the thickness values studied.





**Figure 2.** Characteristic microstructure of the 70-80 HRB hardness range. (a) 6mm, (b) 12 mm and (c) 16mm.

#### 4 CONCLUSIONS

- The results achieved for the blocks in the range 60-70 HRB indicate that the non-uniformity hardness values are directly influenced by the homogeneous resulting microstructure, showing the suitability of the heat treatment parameters to the studied hardness range blocks.
- The developed blocks in the 70-80 HRB range presented a high microstructural heterogeneity for oil quenching heat treatment, leading to non-uniformity hardness values much higher than that specified by the international standard. Thus, one can conclude that the material and the heat treatment employed are not adequate to the development of standard blocks for this hardness range.
- Regarding the 60-70 and 70-80 HRB blocks, the microstructural features are more significant than the thickness variation on the non-uniformity hardness values.
- The results obtained for the 60-70 HRB suggest that the hardness values may be correlated to the thickness variation. However, further studies are necessary to investigate this tendency.

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