



24th COBEM - 2017



24th ABCM International Congress of Mechanical Engineering
December 3-8, 2017, Curitiba, PR, Brazil

COBEM-2017-2428

GRAPHITE SIZE AND DISTRIBUTION OF NODULAR CAST IRON OBTAINED BY CONTINUOUS CASTING

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Abstract. During the solidification of the nodular cast iron the cooling rate induces several macrostructural changes, such as: carbide precipitation, casting defects and a notable variation in nodule count, which consequently changes the size of nodules and the spacing between them. The present work studies the effect of the cooling rate on a nodular cast iron bar, the influence of the variation of the number of nodules, nodules size, spacing between nodules and hardness. The nodular cast iron samples were drawn from a round bar obtained by the FUCO® continuous casting process in the following positions: bar surface (higher cooling rate), half bar radius (intermediate cooling rate) and center bar (lower cooling rate). The microstructural characterization was performed using an optical microscope and the measurements were performed using a SEM (Scanning Electron Microscope). Through the results it was possible to identify the variations and a constant ratio between the spacing between nodules and the diameter of the graphite nodules.

Keywords: Nodular Cast Iron, Tool wear, Sheet metal stamping.

1. INTRODUCTION

Nodular cast iron is widely used in the automotive industry, specifically in the construction of stamping dies for forming conventional sheet metal, mainly because of its excellent lubricating properties from the graphite nodules present in its metal matrix (L. Figueiredo et al. 2011 and Y. Qiu et al. 2016). During the forming, the initially flat metal sheet is formed by deep drawing in a defined matrix shape such as doors, ceilings, bumpers, among other parts for framing a vehicle body. During stamping, the entry radius of the dies is subjected to wear due to the sliding contact between the nodular cast iron die and the metal sheet. Based on a forming process of the automotive industry, the objective of this work is to investigate the influence of the cooling rate on the number of nodules, nodule size, nodule spacing and nodular cast iron hardness.

2. EXPERIMENTAL PROCEDURE

The nodular cast iron samples were extracted from a round bar made by the FUCO® continuous casting process (Catálogo Fundação Tupy 2007). A cross section with 120 mm diameter and 12 mm thickness was made from the bar. The cross section was divided in three positions, as seen in Figure 1. The divisions are: (S) - surface, (HR) - half radius and (C) - center. (Casagrande 2003).

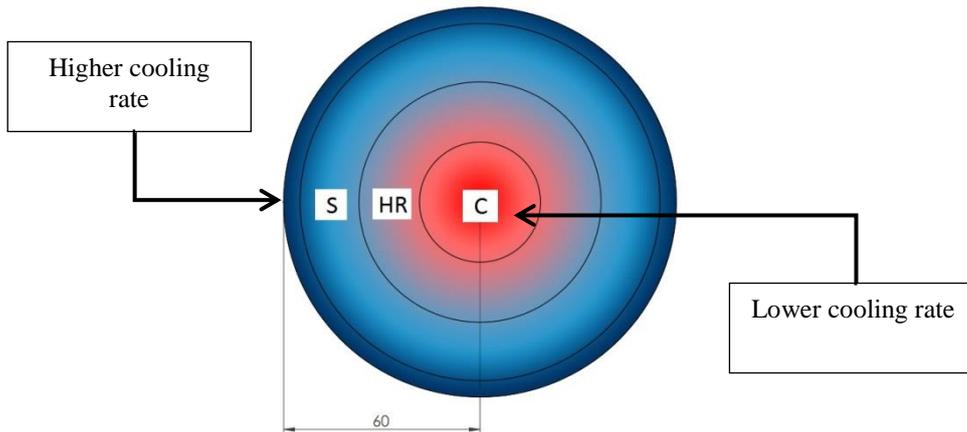


Figure 1: Location of the samples drawn from the cross section of the bar.

The characterization was performed according to ASTM A247-67, using an optical microscope and Olympus analySIS Image Processing software. The diameter and spacing between nodules were measured using a TESCAN-VEGA3 scanning electron microscope (SEM), from the Electronic Microscopy Laboratory of PUC-PR. The hardness test was performed on a Brinell scale (HB), based on the NBR 6394-80 standard.

3. RESULTS AND DISCUSSION

Table 2 shows experimental results by extracting samples in different positions of the FUCO® bar, the number of nodules varied between 518 and 827 nod/mm². The mean nodule diameter varied from 32,61 µm to 55,37 µm, figure 2 (a). A mean nodule spacing from 125,34 µm to 208.48 µm, figure 2 (b). Figure 2 (d) shows an increase of hardness from the surface to the center of the bar. The number of nodules is lower when there is a higher cooling rate exhibited in the center - (C) position, but the nodules are larger and more spaced. The opposite happens in the surface - (S) position, where the nodules are smaller, but in greater quantity and closer together. A consistent ratio can be defined between the spacing and the diameter of the nodules according to figure 2 (c).

Table 2 – Identification of quantity, diameter, nodule spacing and hardness at each position of the nodular cast iron bar.

<i>Position</i>	<i>Quantity (Nod/mm²)</i>	<i>Mean Spacing L (mm)</i>	<i>Mean Diameter D (mm)</i>	<i>Ratio (L/D)</i>	<i>Hardness (HB)</i>
S	827	0.12534	0.03261	3.84	231
HR	628	0.17140	0.04476	3.83	244
C	518	0.20848	0.05537	3.77	248

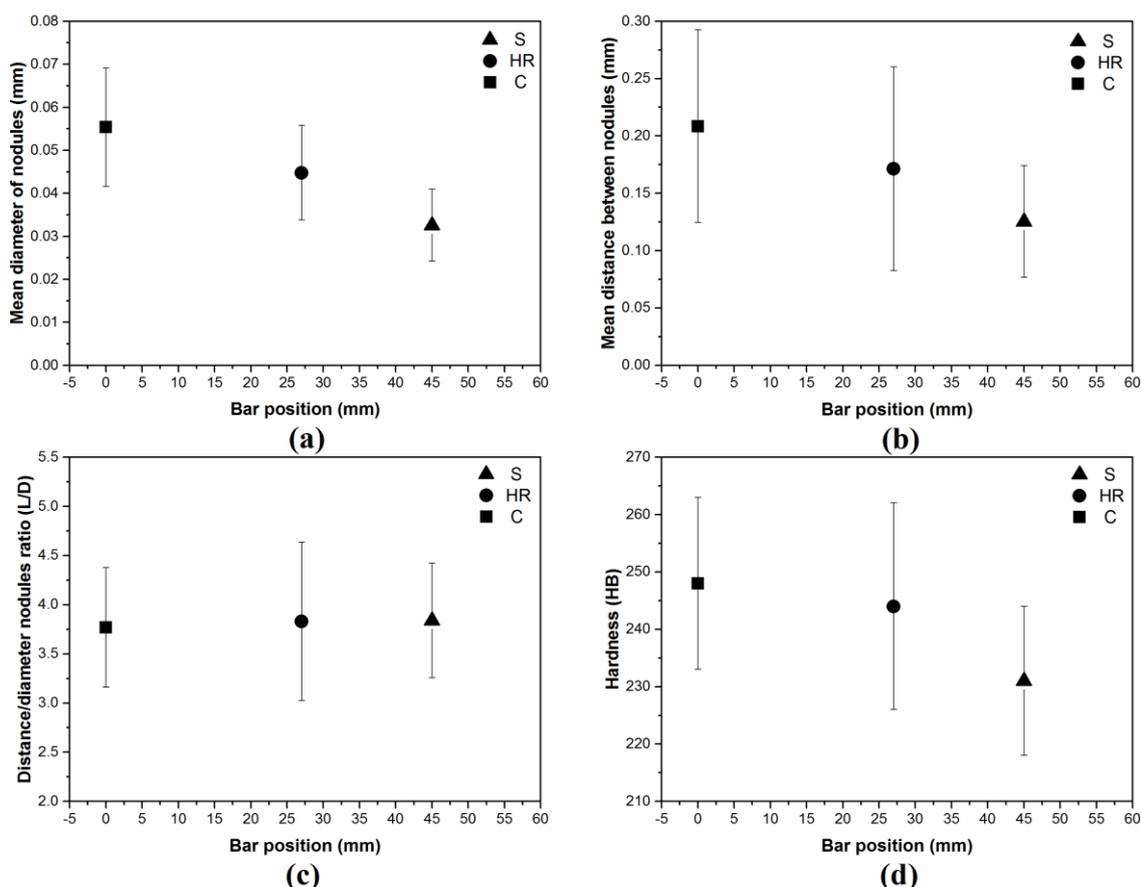


Figure 2: Influence of solidification of the cast iron bar nodular position S, HR and C; (a) Size of the nodules; (b) Spacing between the nodules; (c) Distance/diameter nodule ratio (L/D); (d) Hardness variation.

4. CONCLUSIONS

The formation of graphite in nodular cast irons is mainly determined by the solidification cooling rate. The cooling rate determines the time available for carbon diffusion to occur in the eutectic reaction, which defines the formation of graphite in terms of size and number of nodules. In this study, it was shown that on the surface, where a higher cooling rate occurs, the number of nodules is larger and the distance between them is smaller, since the time available for diffusion is shorter. In the center, where a slower cooling rate occurs, the number of nodules is smaller and the space between them is larger because the time available for the diffusive processes is longer. Since the carbon content remains uniform, the number of nodules is higher at the surface and lower at the center, consequently a constant ratio between the distance and the diameter of the nodules, was observed in the three different positions, and can be applied for wear reduction studies and lubricating effect of graphite nodules for sheet metal forming dies.

5. ACKNOWLEDGMENTS

To the Graduate Program in Mechanical Engineering of the Pontifícia Universidade Católica do Paraná. The authors also thank CAPES/FA for the financial support, as well as Tupy Fundições LTDA, for supplying the nodular cast iron bar.

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