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BEHAVIOR OF INTRADENDRITIC AND INTERDENDRITIC MICROHARDNESS OF AN ALUMINUM-SILICION ALLOY DIRECTIONALLY SOLIDIFIED

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Abstract. *The microhardness is a mechanical property that can represent the resistance of some phase or precipitation, inclusion or defect included on the material structure to be penetrated. In metal alloys that are exposed to various phase modifications, as those which are produced by unsteady-state solidification, the variation of the microhardness promotes an anisotropy that are not convenient for the performance of the material. In the case of non-ferrous alloys of the aluminium-silicon system, the morphology of the silicon in the interdendritic region could promote a non-uniform microhardness in the ingot, which could shows different properties on each millimeter distance from the metal-mold interface. This paper aims to present the evaluation of the interdendritic microhardness of the Al-11wt.%Si alloy solidified in a directional horizontal device, in order to verify the influence of the morphology of the silicon on the microhardness of the specimen, based on the distance of the metal-mold and cooling rate applied in its solidification. The results conclude that the silicon morphology does not significantly influence the increase or reduction of the microhardness of the casting, even with its eutectic modification in the solidification process.*

Keywords: *Horizontal solidification, Al-Si alloy, microhardness, interdendritic, intradendritic.*

1. INTRODUCTION

The effect of silicon on the aluminum matrix produces a family of highly attractive alloys for engineering applications. Such alloys are widely used in automotive industry due to their excellent foundry characteristics and good mechanical properties, like corrosion performances, machinability and castability. These alloys also have other advantages such as light weight, low thermal expansion coefficient, good formability and low cost (Chen *et al.*, 2014; Yang *et al.*, 2012).

Peres *et al.*, 2004 exposed that the increase of silicon in aluminium matrix could be related to the decrease of the interfacial heat transfer coefficient, as well as the thermal diffusivity and the initial solidification temperature, i.e., the liquidus temperature. However, primary and secondary dendritic arm spacing is supposed to decrease with the increase of silicon quantity.

The microhardness of a material is an important mechanical property, which can provide essential data as to the quality of a casting process. However, it is known that the quality of a molten material depends on several factors such as its morphology, composition, grain size, among others. Thus, an investigation is needed which connects the factors of the solidification process with the results of the mechanical properties. Therefore, this study aims to present the evaluation of the interdendritic microhardness of Al-11wt. % Si solidified in a horizontal directional device in order to verify the influence of the silicon morphology on the microhardness of the specimen, with respect to the metal-mold distance and the cooling rate applied in its solidification.

2. EXPERIMENTAL PROCEDURE

The casting assembly used in transient horizontal directional solidification experiments was designed in such a way that the heat was extracted only through a water-cooled system placed in the lateral mold wall. The casting was sectioned along the longitudinal direction and the macrostructure was revealed (2 mL HCl; 10 g FeCl3 and 100 mL H2O). An etching solution of 92% (vol.) CH3OH, 5% (vol.) HNO3 and 3% (vol.) HCl applied during three seconds was used to reveal the microstructures. Longitudinal sections of the directionally solidified specimens were examined. Microhardness measurements in this study were carried out using a 25 gf load and a dwell time of 10 s. The adopted vickers microhardness was the average of at least 20 measurements on each sample. Were collected the positions 2, 5, 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140 and 145 mm from the metal-mold interface in order to establish sufficient amount of data for the mathematical analyzes.

3. RESULTS AND DISCUSSION

The microstructure of the studied alloy is exposed in the Fig. 1. It clearly be seem that the silicon morphology changed during the solidification, while the aluminum dendrites became large and bulky. To emphasize, white dendrites are mainly composed of aluminum, while the black background (or gray) are mainly composed of silicon. The tonality of silicon is strongly related to the time of revealing. For times of 3 seconds or less, primary silicon and its particles can be seem more sharply; For more than 3 seconds, aluminum dendrites can be seen with more clarity and definition of contour.

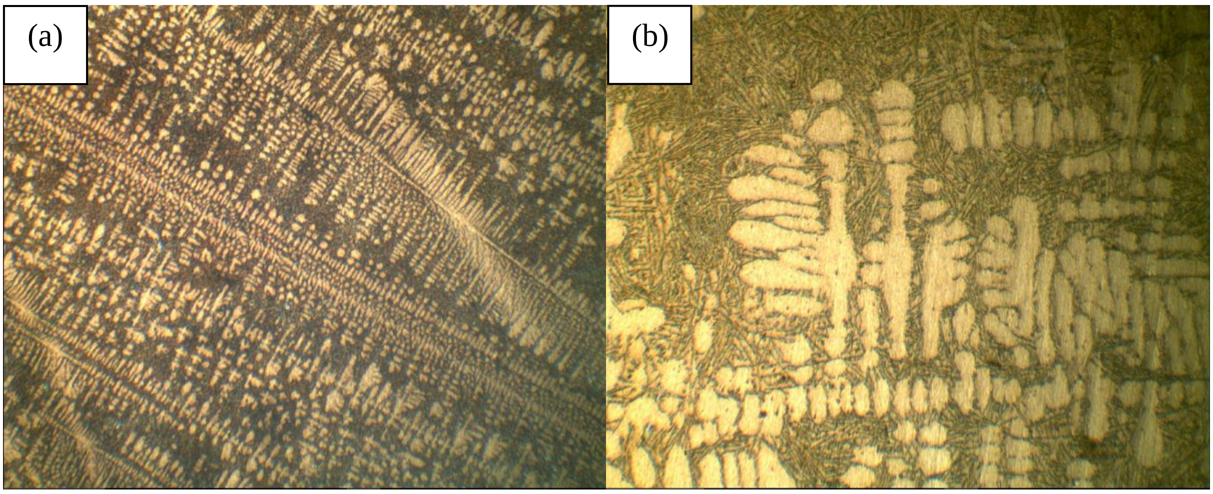

Figure 1. Dendrites on (a) 4 mm and (b) 140 mm from the metal-mold interface.

The rapid solidification of close positions from the metal-mold interface promotes a state of non-equilibrium, providing high microhardness in that region, as seem in Fig. 2 (a), while positions that are more distant from the cited interface tend to present smaller microhardness. Clearly can be seen that, in Fig. 2 (b), the behavior of the interdendritic microhardness does not follow a non-linear fit or a function that describes the increase or decrease of the mechanical property. The inclusion of that data in the intradendritic microhardness, expressed in Fig. 2 (c), can compromise the linear fit of the property, masking the analysis. Fig. 2 (b) and (d) shows that interdendritic microhardness are is quite random in its behavior based on the cooling rate and the metal template interface distance.

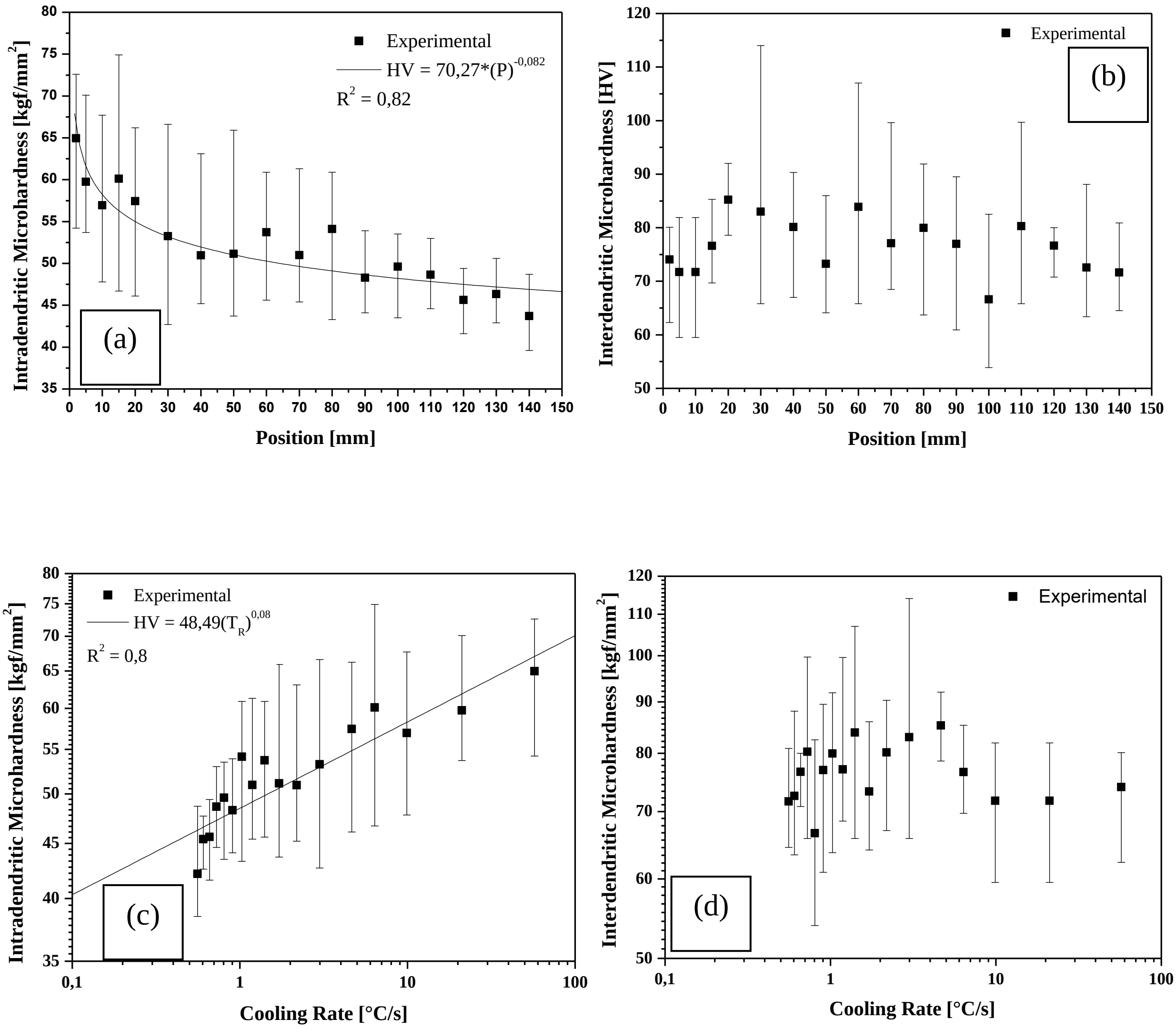

Figure 2. Evaluation of the microhardness with respect of position in the (a) Intradendritic region and (b) interdendritic region. Relation of the cooling rate on the (c) intradendritic and (d) interdendritic microhardness.

According to Goulart *et al.* (2006), the improvement of the mechanical characteristics of cast structures having smaller dendrite spacings are due largely to the shorter wavelength of the periodicity of the microsegregation.

The Figure 3 exposes the macrostructure of the cited alloy. As shown, even the columnar-to-equiaxed transition (CET) occurred between the positions 45 and 75 mm from the metal-mold interface, no relevant or perceptible change happens on the interdendritic microhardness. By Fig. 2 (b), on that interval, the interdendritic microhardness increase and decrease randomly, exactly similar to the other ranges of the curve, and it is not possible to determine any mathematical conclusions in terms of function or specificity.

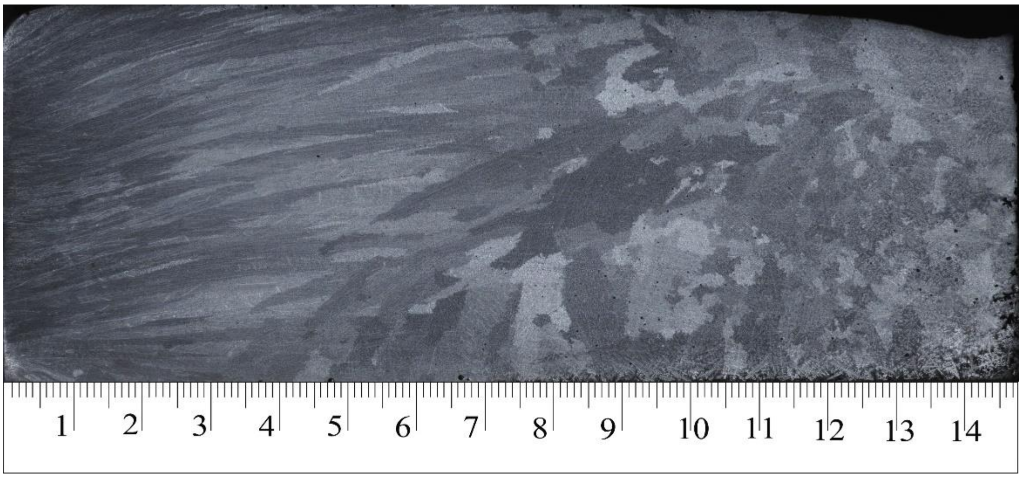

Figure 3. Macrostructure of Al-11%wt. Si solidified horizontally.

4. CONCLUSIONS

From the results exposed above, the interdendritic region appears to have a random microhardness when compared with the intradendritic area, even with the modification of silicon morphology. The intradendritic region can be mathematically described as a function of the cooling rate and position in an allometric aproach, which presents great linear ajustment coefficient. No relevant alterations was seem with respect to the interdendritic microhardness and the CET.

5. REFERENCES

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