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INFLUENCE OF COPPER CONTENT IN THE MICROSTRUCTURE AND MICROHARDNESS OF AL-SN SYSTEM ALLOY SOLIDIFIED BY PRESSURE

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Abstract. *Al-Sn alloys have been widely used in the manufacture of bearings due to their mechanical strength, good formability and wear resistance. The present work aims to analyze the influence of copper content variation on microstructure and hardness of pressure solidified Al-Sn alloys. The results show that the microhardness values of the compositions decrease with the application of pressure possibly due to the shear of the interdendritic copper plates, caused by the high pressure exerted on the metal.*
Keywords: *Al-Sn alloys, Copper, Microhardness.*

1. INTRODUCTION

Pure aluminum has properties that are part of a movement of high density, about 2.7 g / cm³, high resistance to corrosion, good electrical and thermal conductivity. In addition, the aforementioned metal may combine with most of the engineering metals, making them aluminum alloys more attractive for industrial applications. Elements such as copper, for example, substantially improve the hardness and mechanical strength of the alloys, either in the crude melt condition or after heat treatments, making the field of application of these metals even more extensive (BALDAM, 2013). The tin is usually used in motorcycle industry due to its non-stick functional excellence, minimizing wear through its selflubricating effect. Al-Sn alloys have been widely used in the manufacture of manufactured goods due to their good property mechanics, good formability and wear resistance. Seeking the higher speed of the engines, that was added as a turn-off for increased resistance and fatigue resistance.

In general, in the solidification of aluminum alloys, the resulting microstructure is related to the shape of the interface between the solid and the liquid (S/L). In the thermal and constitutional parameters of the metal-liquid system encountered during solidification and rejection of the solute or solvent at the solid / liquid interface, create a thermal gradient at the front of the interface smaller than the thermal gradient of the liquid line profile, resulting in a Super Cooling Constitutional and causing an instability of this interface and consequently a gradual degeneration of the flat front. These modifications give rise to more complex morphologies called cell and dendritic structures. As the degree of constitutional super cooling increases, higher order instabilities occur and the hexagonal cell structure changes to dendritic, in the form of a malta cross; with the primary crystallographic branches in crystallographic directions near the direction of heat flow and with the continuity of solute rejection, the secondary arms appear perpendicular to the primary branches (GARCIA, 2007).

A microstructural scale representative of each morphology is defined by centers of cells and branches or dendritic denominators of intercellular and interdentritic spaces, which are used to associate the solidification processes of a formed microstructure (JUNIOR, 2017). The mechanical properties of the cast products are strongly dependent on the intercellular and interdendritic spacing. Smaller spacings allow the microstructure to be characterized by a better uniform distribution of the microscopic segregation that exists between the cellular or dendritic branches, favoring the mechanical behavior, since in this case eventual reinforcement phases contained in the intercellular or interdendritic regions are distributed more evenly along the microstructure, constituting a more effective blockade to the movement of disagreements. Therefore, the correct specification of the thermal parameters that control these spacings during solidification is extremely important (FARIA et al., 2015).

The objective of this work is to analyze the solute (Cu) variation in the microstructural formation and microhardness of Al-Sn-Cu alloys solidified by the squeeze casting process. The variation of the copper content tends to favor the appearance of intermetallic $Al2Cu$ that increase the microhardness, on the other hand with the increase of copper concentration in the alloy the dendritic spacings tend to decrease.

1.1. MICROSTRUCTURES

The microstructures present in the composition of a metal alloy resulting from the solidification process are related to the shape of the interface between solid and liquid. Under ideal thermodynamic conditions, this interface should remain flat, but changes in the constitutional and thermal parameters of the metal / mold system that occur during solidification cause this interface to become unstable. These instabilities are induced by the occurrence of a process called constitutional overcooling (SRC), which consists of overcooling at the solid / liquid interface due to solute redistribution caused by outof-equilibrium solidification, as increasing solute concentration tends to decrease. the melting point of the melt, hence the solidification front may change from planar to cellular or dendritic. Cell growth is defined by the occurrence of elongated grains with low growth velocity and perpendicular to heat flux (GARCIA, 2007).

Secondary dendritic arms depend on the cooling rate. They are formed near the dendritic tips and with few evenly spaced branches, being strongly influenced by the cooling rate, ie, according to the rate of solidification, the secondary dendritic spacing decreases as the cooling rate increases. It is, the faster the solidification process, the smaller the spacing, and for hypoeutectic alloys the increase in solute content causes a decrease in the secondary spacing (CANTÉ, 2009).

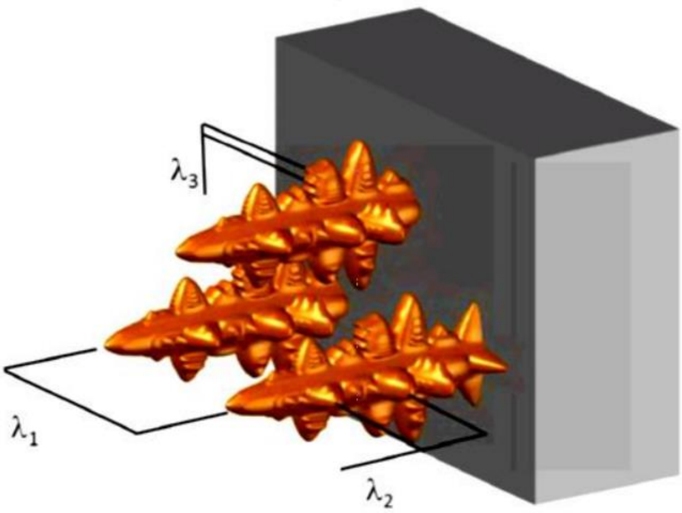


Figura 1. Schematic representation of primary, secondary and tertiary dendritic branches.

1.2. VICKERS MICROHARDNESS

For the quality control of a product, it is very common to use mechanical tests to check the hardness of a material. Hardness is a mechanical property that consists of measuring the resistance of a material to localized plastic deformation when an indentation is applied to it and is directly related to the atomic structure of each material (GARCIA, 2007). The general principle of indentation is to apply a known standardized load on the smooth surface of a material and then measure the residual plastic deformation (LIMA et. Al., 2010).

One of the main reasons for using the hardness test is that it is a simple and relatively inexpensive, non-destructive test and corresponds to a magnitude directly proportional to other mechanical properties, such as the tensile strength limit and the limit strength. flow of a material (CALLISTER, 2007).

There are several hardness measurement techniques, we can mention the Rockwell, Brinell and Vickers (microhardness) scales that differ according to the geometry of their spherical, conical or pyramidal indentors. Among the mentioned methods, Vickers microhardness proves to be a more versatile method than the others, being able to meet the needs of increasingly demanding and sophisticated industrial processes when compared to the others.

2. MATERIALS AND METHODS

2.1. GENERAL CONSIDERATIONS

This chapter presents the experimental procedures used as well as the materials and equipment necessary to perform this work. The experimental script following the development of this work is summarized in the flowchart of figure 2.

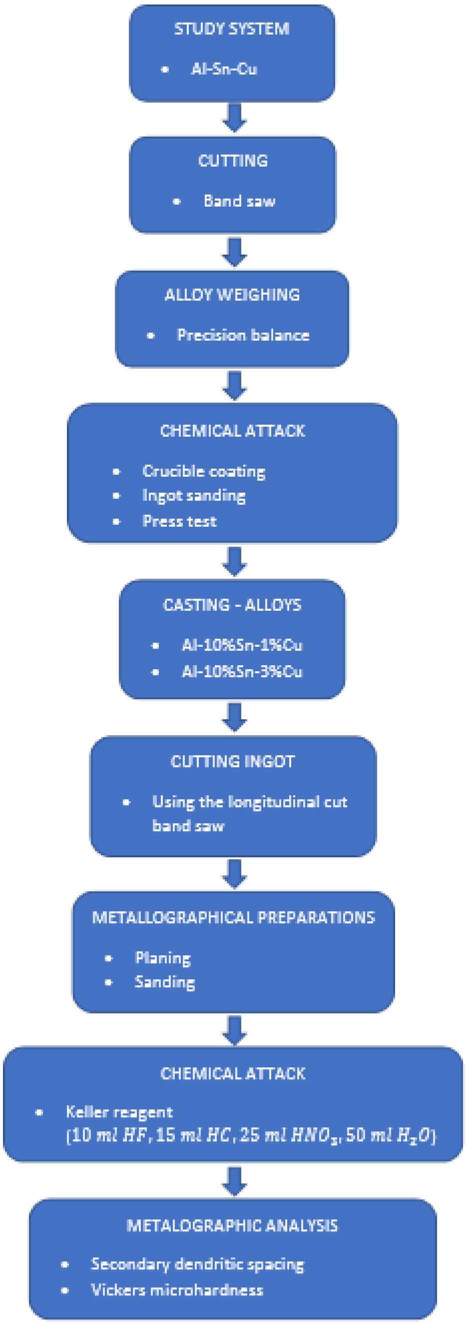


Figure 2. Flowchart of the methodology used.

2.2. OBTAINING ALLOYS

In this work, alloys were used of Al-10% Sn-1% Cu and Al-10% -3% Cu by weight. The aluminum, tin and copper used are commercially pure metals. All materials were cut on the AGRA SBS band saw and weighed on the SHIIMADZU scale model UX6200H. After weighing the material was deposited in a silica carbide crucible coated with a protective layer of alumina.

The oven was muffle type, Jung model 4213, heated by an output resistance generator of 6KW. The alloy was poured at a temperature of 720ºC, which corresponds to 10% of TL (Liquidus temperature). The temperature was monitored by a K-type thermocouple. Upon Tv (pouring temperature), the alloy was leaked in a steel ingot 1020 with dimensions according to Fig. 4 (a).

After the solidification, 10 cross-sections were made obtaining 10 pieces represented in Fig. 4 (b), where each piece has a thickness of approximately 1cm. From the parts obtained, parts 1 and 10 were discarded due to the fact that they could be influenced by heat extraction from the drive and the base of the ingot.

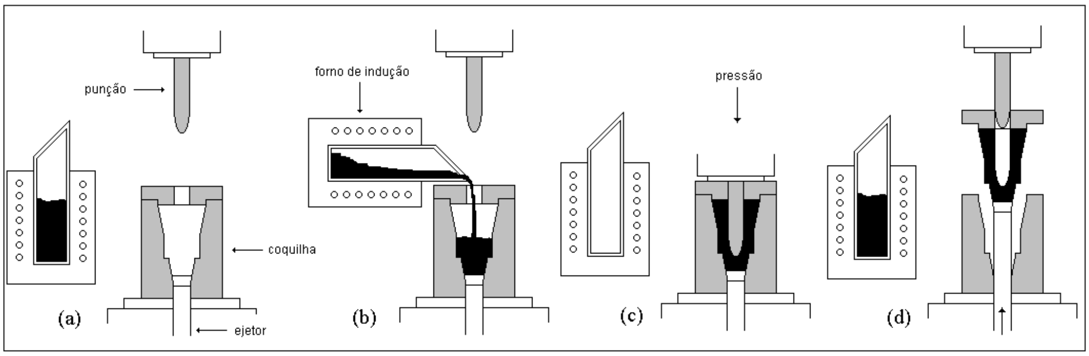


Figura 3. Squeeze casting process scheme

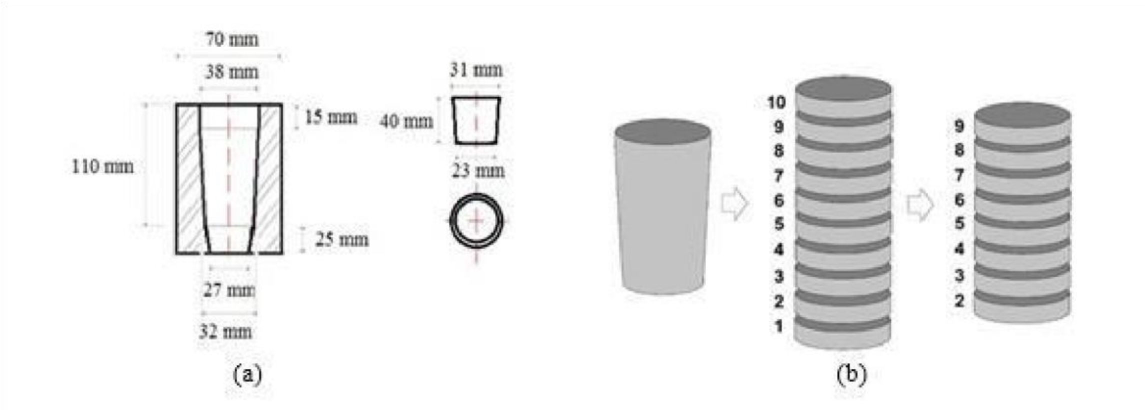


Figure 4. (a) Dimensions of the ingot; (b) Schematic of ingot cuts.

2.3 MICROSTRUCTURE

For the microstructural analysis, the selected pieces were sanded using granulometry of 100 to 1200 mesh with variation of 90 ° between the sandpaper change. Then the pieces were polished in a PLF model polishing machine using 1μm diamond paste, ¼μm diamond paste and alumina. To reveal the microstructure the chemical reagent hydrofluoric acid was used in 95% water and 5% hydrofluoric acid solution, with a permanence time of 10 seconds of drip and 10 seconds of scrubbing.

The part was divided into 4 mm sections in order to analyze the modification of the secondary dendritic spacing from the metal / mold interface to the center of the part fig. 5. Position 1 was considered to be the 1mm distance from the metal / mold interface and the following positions were established by advancing to the center of the part. The images were analyzed using an OLYMPUS CORPORATION BX41RF-LED optical microscope connected to a 10x magnification computer, allowing the measurement of secondary dendritic spacing (λ_2) through the AnalySIS Imager program (6).

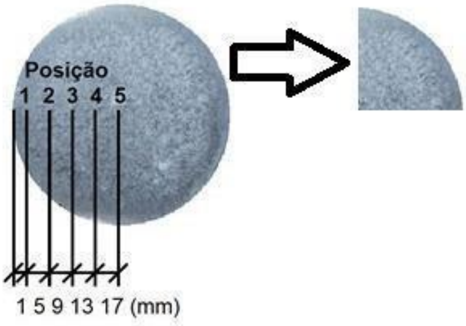


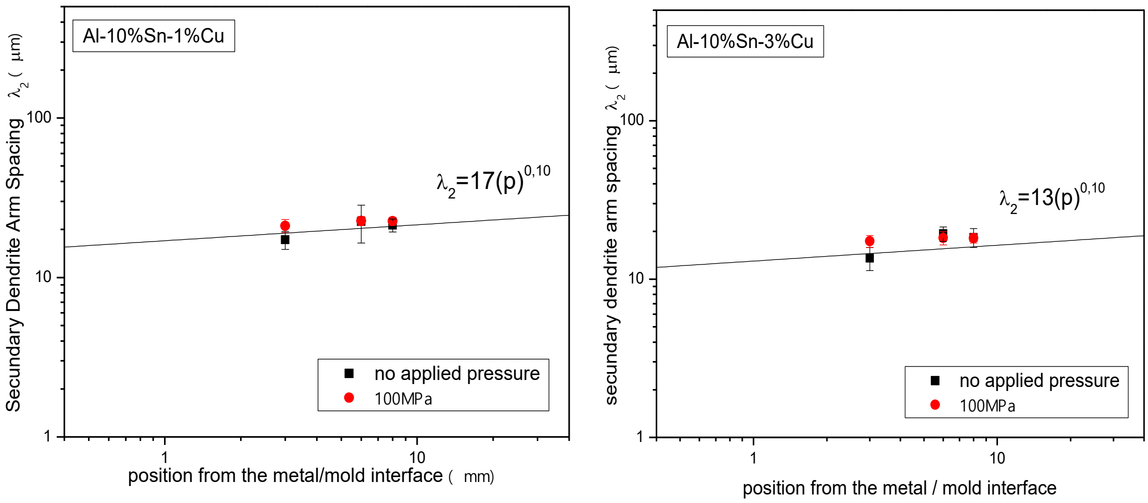
Figure 5. Scheme of the position of the measurements of the positions of each piece.

2.4 MICRODURE

For the microhardness test, a quarter of the total workpiece was used as shown in figure 5. We used the Insize micro durometer model ISH DV1000, with load of 200g, where 10 prints were made for each sample for 15s in the superficial section.

3 RESULTS AND DISCUSSION

The graphs of figure 6 shows the variation of the secondary dendritic spacing by the position from the metal / mold interface for Al-10%Sn-1%Cu and Al-10%Sn-3%Cu alloys at ambient pressure and 100MPa. By comparing the graphs of the parts of the two compositions with and without pressure, it is possible to note that the secondary dendritic spacings have a slight tendency of growth from the metal / mold interface to the center of the ingot. We can see that there are no significant changes in the spacing values due to the application of pressure to the two compositions. The Al-10%Sn-1%Cu composition ingot has secondary dendritic spacing values slightly higher than the Al-10%Sn-3%Cu composition ingot (figure 7). This behavior is observed, according to (LIMA, 2014), as the solute content increases in the alloy, possibly due to a higher solute rejection during solidification resulting in larger amounts of lateral protuberances (OLIVEIRA FILHO, 2017).



(a) (b)

Figure 6. Graphs of the secondary dendritic spacing as a function of position from the metal / mold interface. a) Al10%Sn-1% Cu b) Al-10%Sn-3%-Cu.

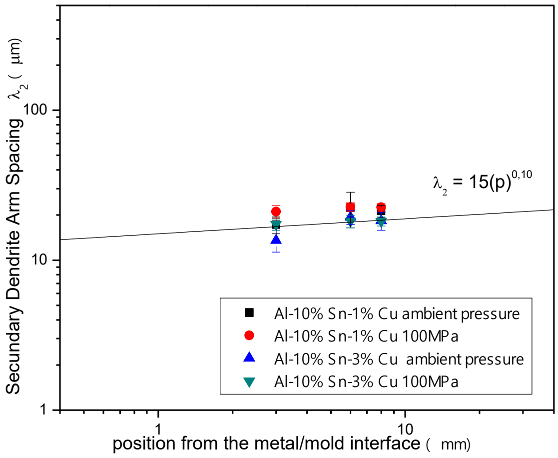
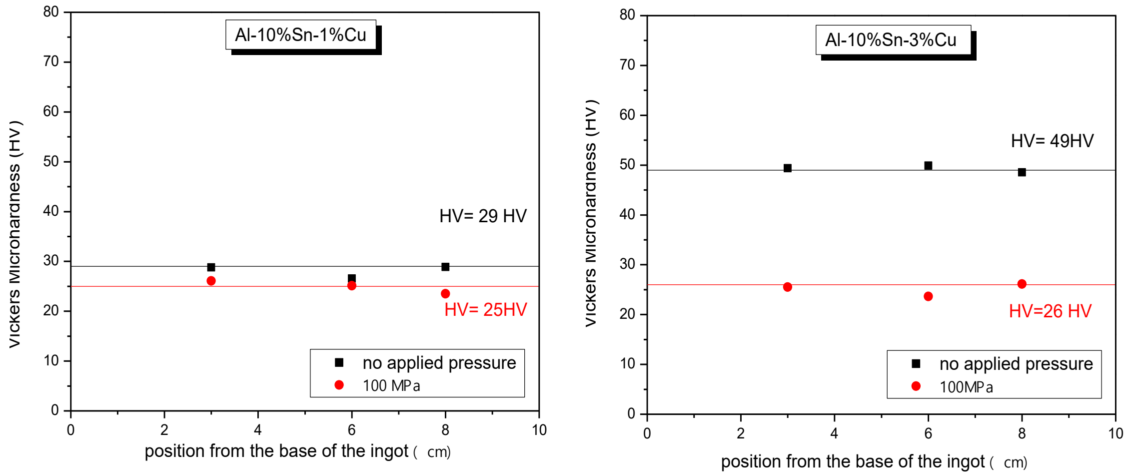


Figure 7. Comparison of secondary dendritic spacings as a fuction of part number.

In Figure 8, the data concerning the microhardness variation as a function of the position of the ingot base for Al10% Sn-1% Cu and Al-10% Sn-3% Cu alloys are presented. It is possible to observe that the microhardness values of Al-10% Sn-1% Cu ingot show a small decrease in microhardness with increasing pressure. It is best observed this decrease in the Al-10% Sn-3% Cu ingot, as the microhardness values minimized with increasing pressure. Possibly this happened due to the shearing of the interdendritic silicon plates, caused by the high pressure exerted on the metal (SOUISSI et al., 2012).



(a) (b)

Figure 8. Graphs of Vickers microhardness depending on the position from the bottom of the ingot. a) Al-10% Sn1% Cu b) Al-10% Sn-3% Cu.

4 CONCLUSION

Comparing the graphs of the parts of the two compositions shown in figures 8.a) and 8.b), we can understand that the Al-10% Sn-1% Cu composition ingot has lower microhardness values than the composition ingot Al-10% Sn-3% Cu. This behavior is observed due to the increase in the copper content of the alloy.

Therefore, it is possible to conclude that there is no significant variation of the secondary dendritic spacing with the application of pressure. The ingot with lower copper content has slightly higher dendritic spacing values, possibly due to a higher solute rejection during solidification resulting in larger amounts of lateral protrusions.

The microhardness of the Al-10% Sn-1% Cu and Al-10% Sn-3% Cu ingots has decreases in microhardness with increasing pressure, possibly due to shear of the interdendritic silicon plates, caused by the high pressure exerted on the metal.

5. REFERENCES

BALDAM, R. Fundição: Processos e tecnologias correlatadas. 1. ed. São Paulo: [s.n.]

FARIA, J. D. et al. Influência na microestrutura e na microdureza decorrente da adição de 4%Ag na liga Al-4%Cu solidificada unidirecionalmente. Revista Materia, v. 20, n. 4, p. 1–16, 2015.

GARCIA, A. Solidificação: fundamentos e aplicações. 2. ed. Campinas: [s.n.].

JUNIOR, A. A. D. C. Parâmetros Térmicos de Solidificação , Microestrutura e Propriedades em Tração de Liga Ternária Al-Sn-Cu Parâmetros Térmicos de Solidificação , Microestrutura e Propriedades em Tração de Liga Ternária Al-SnCu. 2017.

LIMA, R. A. DE. Influência de parâmetros operacionais na macroestrutura e propriedades mecânicas de ligas do sistema Al-Zn solidificadas através do processo squeeze casting. joão Pessoa: [s.n.].

OLIVEIRA FILHO, R. M. Universidade Federal da Paraíba Centro de Tecnologia Programa de Pós-Graduação em Engenharia Civil e Ambiental - Mestrado e Doutorado - - ALUNO REGULAR - Universidade Federal da Paraíba Centro de Tecnologia Programa de Pós-Graduação em Engenharia Civil e. n. 83, p. 9630, 2017.

CRUZ, K. S. et al. Dendritic arm spacing affecting mechanical properties and wear behavior of Al-Sn and Al-Si alloys directionally solidified under unsteady-state conditions. Metallurgical and Materials Transactions A: Physical Metallurgy and Materials Science, v. 41, n. 4, p. 972–984, 2010.

JOSÉ MARCELINO, D. F. et al. Influência das variáveis térmicas sobre os espaçamentos dendríticos terciários durante a solidificação direcional horizontal da liga Al-6%Cu. Revista Materia, v. 20, n. 1, p. 47–63, 2015.

MALEKI, A.; NIROUMAND, B.; SHAFYEI, A. Effects of squeeze casting parameters on density, macrostructure and hardness of LM13 alloy. Materials Science and Engineering A, v. 428, n. 1–2, p. 135–140, 2006.

OU, A. I. Modeling of Microstructural Squeeze Casting of an Alloy. v. 37, n. 1 997, 1997.

Associação Brasileira do Alumínio (ABAL). Disponível em <www.abal.org.br>. Acesso em: 10 de março 2019

SOUISSI, S. BEN AMAR, M. BRADAI, C. Experimental Investigation on Microstructure and Mechanical Properties of Direct Squeeze Cast Al-13%Si Alloy. Strength of Materials, v. 44, No. 3, 2012.

6. RESPONSIBILITY NOTICE

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