INFLUENCE OF THE COOLING RATE IN AL-40%CU ALLOY MICROSTRUCTURE

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Abstract. *The aim of the present work was to verify the influence of the cooling rate in microstructure of the Al-40wt%Cu alloy. This alloy was melted and cooled in the aluminum chill and in two ceramic moulds of different dimensions. Observed that high cooling rate influenced in the sample microstructure. Therefore, samples that solidified in the chill aluminum presented high cooling rate and consequently a larger microstructure refined. The crystal growth velocity usually increases with high cooling rate, provoked changes morphology in microstructure.*

Keywords*: Al40%-Cu Alloys; Rapid Solidification; Microstructure.*

1. INTRODUCTION

The practical objective of the grain refining is the mechanics resistance increase and the league plasticity during the solidification. In many leagues, these improvements in the properties are essential for its industrial application (aluminum base leagues), whereas in others leagues the practical advantages of a grain refining are only secondary (Kondic, 1970). In previous works (Jones, 1982) the rapid solidification of metals and metallic leagues can be through the application of high rate of cooling (10^2 - 10^6 K/s) or for imposition of super-cooling high levels of through the minimizes or eliminates of nucleation agents. The rapid solidification can take formation of structures with characteristics property itself and great technological interest such as fine thickness, homogeneous structure without segregation, supersaturated solid solutions, metastable phases and amorphous structures (N. Wang; B. Wei, 2001). The techniques of rapid cooling, for example, cooling in crucible and melt-spinning nowadays are applied in industrial scale to produce leagues with refined structures and until metastable. The aluminum has great industrial importance for presenting low density (ρ = 2,8 g/cm³), and still possessing great electric and thermal conductivity, beyond raised latent heat of fusing. When crystallizing the aluminum process the cubical system of centered face e, does not possess allotropic modifications.

The aluminum alloys process great mechanics resistance, resistance to the corrosion and the chemical substance attack, electric conductivity, ductility, among others benefits. The main process of aluminum treatment is the lamination, whose bedding is the reduction or modification of metallic part thickness of a through its compression in laminating called special equipment. Another habitual process for the aluminum conformation is the drawing, through which metal, in semisolid state, passes through a leaked mold, of similar form and same dimension of the part that if it desires to get. The copper frequently is used as a league element, to provide to the mechanical properties of bigger hardness and resistance demanded in service, producing precipitation hardening increasing the mechanics resistance to the steel level. The Al-Cu leagues takes bigger resistance to the aluminum alloys, reaching with easiness values above of 400 Mpa for the endurance limit in bodies test. Due to bad casting, hardly or only with great effort these values are gotten in real parts. Although the solution to act as neither grain refiner, its actions nor always is efficient for the fine grains attainment. One form to improve the mechanical properties in the aluminum alloys and to produce a grain refine in the league microstructure the through the cooling variation rate. Meanwhile, this work had as objective to verify the influence of the cooling rate in the microstructure of Al40% Cu league (percentage in weight), using for this different crucibles of casting.

2. EXPERIMENTAL

The used league has the following composition: Al40%Cu (value in weight). Two ceramic crucibles had been used, with different dimensions: one with height 23 mm for diameter 18 mm and wall thickness the crucible of 1,5 mm and the other with 40 mm of height for 19 mm of diameter and thickness of the wall of the crucible of 3,5 mm, and one crucible of aluminum, to verify the influence of the speed cooling in the studied league microstructure. The followed procedures had been the following: first the amounts of each metal in its percentage in weight had been separate, in a total amount of 30 g of the casting league. If it has one better agreement of the process (Figure 2), shows to all the technique sequence PSPP (Plasma Skull Push-Pull) using the machine Discovery All, shown in the Figure 1.

Initially the elements are piled up on a copper crucible, of form that the elements with bigger point of fusing are placed in the inferior part of the crucible, as shown in Figure 2 (a). A rotate tungsten electrode originate a plasma torch, that is only obtained when it is made use in an argon atmosphere, that is responsible for the elements fusing in agreement showed in Figure 2 (b). It is necessary that the materials, that will be casting, are to a distance of 3,5 up to

5,0 mm of the tungsten electrode, contrary case the plasma torch is not set in motion. The plasma torch provoking the elements fusion forming a LMF button, as showed in Figure 2 (c). The casting league was leaked one aluminum crucible and in two ceramic crucibles with different dimensions, leading the attainment of a cylindrical tablet, as it can be observed in Figure 2 (d). Before if injecting the LMF button for the tablet formation, the league is casting 5 times to guarantee better homogeneit.

Figure 1. Fusion Plasma Machine: Discovery All of the EDG Equipment and controls.

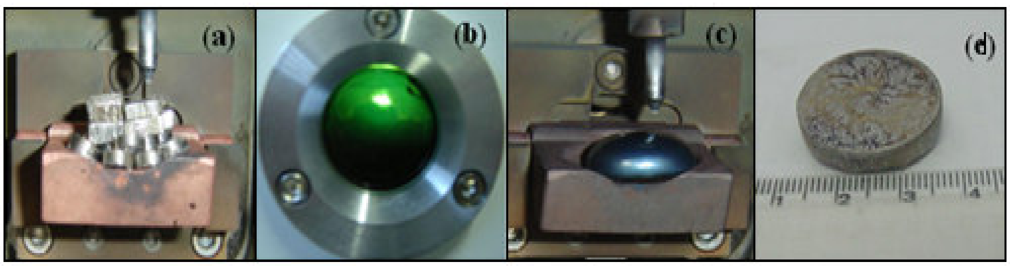

Figure 2. Fusion Plasma Process for the method Skull Push-Pull (PSPP). (a) Piling up of the materials in the copper crucible. (b) Plasma torch. (c) Button of LMF after fusion. (d) Tablet gotten for the injection of the casting button in metallic mold.

A important factor is observed during the process, the time of each fusion. The most indicated for this process it is that after the first fusion, the time following fusion is reduced, to prevent the overheating the equipment casting, as well as preventing that the LMF button is imprisoned to the copper cradle of the equipment. The samples had been prepared by conventional metallography, being made the inlaying of each sample and after that they had passed for successive stages of burnishing (sandpapers with size of grains varying between 88 μm and 18 μm) and burnishing, carried through with alumina, whose grains size of the same ones varied between 1 μm and 0,2 μm. With the satisfactorily polishing surfaces, the samples had been attacked by a solution of Fluosilic Acid 3% per 10 seconds, being later washed with alcohol and dried with hot air. After that the samples had been analyzed in an optic microscope and photographed with specific increases of 200x for each sample. This work was developed in the Laboratories of Casting and Metallography of the Department of Mechanic Engineering in the Sciences and Technology Center of the Campina Grande Federal University.

3. RESULTS AND DISCUSSION

The composition of the Al40% Cu is shown in the diagram in Al Cu phase of Figure 3.

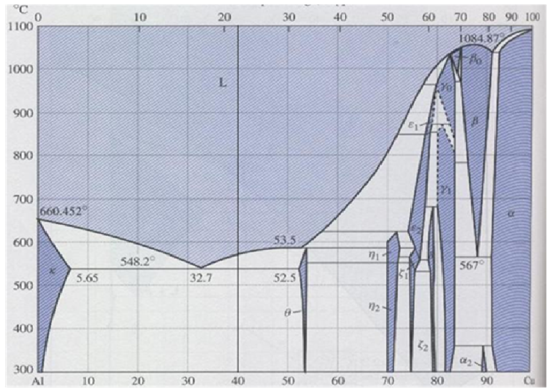

Figure 3. Diagram of Al-Cu showing the composition of the used league Al40%Cu.

According to phase diagram, the solidification of the hypereutectic league Al40%Cu happens in the following form: at the beginning of the in the solidification the first phase that appears has covered-θ dendrite form for after that appearing the eutectic phase formed by aluminum-κ and has covered-θ. Analyzing the microstructure of the sample cooled in the ceramic crucible with thickness of the wall of 3,5 mm (Figure 4), it was verified that dendrites primary had presented an average size of the order of 75 µm and lamellas of eutectic a 10 µm average thickness. Now analyzing the microstructure of the sample cooled in the ceramic crucible with thickness of the wall of 1,5 mm (Figure 5), it was verified that dendrites primary had presented an average size of the order of 60 µm and lamellas of eutectic a average thickness 5 µm.

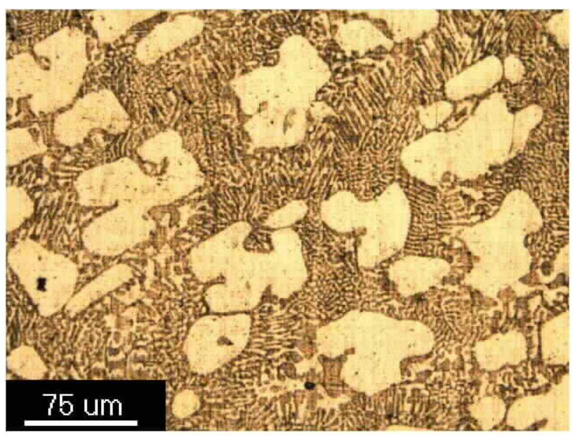

Figure 4. Microstructure of the sample cooled in ceramic crucible with 3,5 mm of thickness.

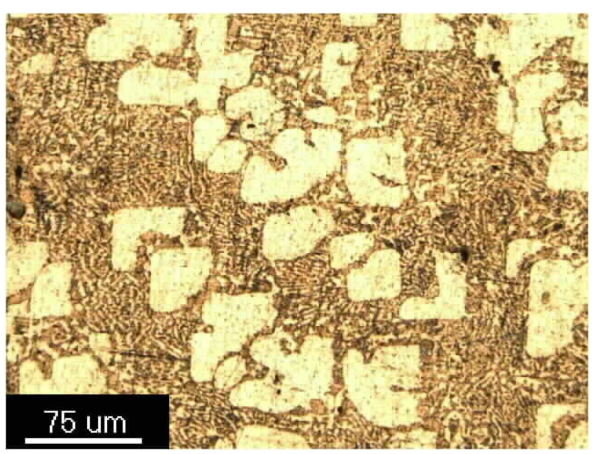

Figure 5 - Microstructure of the sample cooled in ceramic crucible with 1,5 mm of thickness.

Observing the sample that was made solid in crucible of aluminum (Figure 5), is verified that it presented a so great minor of dendrites primary in the order of 35 μm and a sufficiently fine eutectic. How much bigger the heat extraction rate, faster is the growth speed due to the high degree of super-cooling that is submitted the league. As consequence of the high degree of super-cooling, the solidification process is fast e a refined microstructure is gotten.

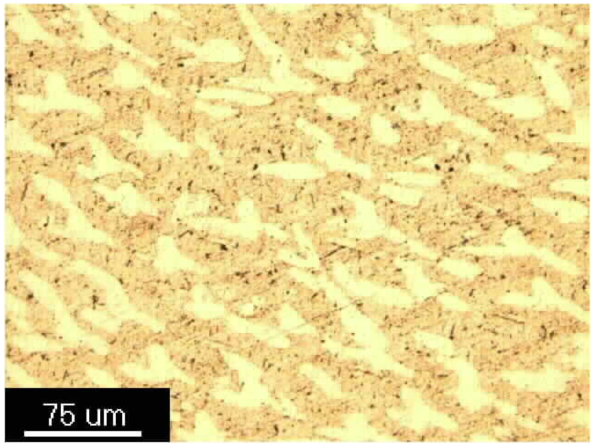

Figure 6 - Microstructure of the sample cooled in crucible aluminum.

The motor force for the super-cooled solidification of a casting one is the difference of the Gibbs Energies between the solid and the liquid. However, the microstructure of the league made solid dumb with the increase of the super-cooling. When the rate cooling is small, the solidification happens in balance conditions, making that as much the nucleation how much the growth of crystals occurs slowly. But when the rate cooling is high, the growth nucleation and the speed of crystals also is high, provoking a microstructure refining in the leagues (Wang and Wei, 2001). Results of literature (Wei and Herlach, 1994, Wei, et al., 1997, Castro et al., 2001) had shown that with the increase of the rate cooling, more faster is the phases growth in the initial period of solidification training and, consequently, the result are a microstructure with refined morphology. These works have reported dendrite refinement in super-cooled samples and attribute the dendrite spalling to be the most likely mechanism to explain this phenomenon. This means that, the fast speed of growth of dendrites in the initial period of solidification training takes the formation of a morphologically not-steady structure, provoked for a motor force caused by liquid in the solid interfacial energy. This assumption can be faced as true by the fact that the morphology of samples highly super-cooled always presents a dendrite refinement, therefore samples with high super-cooling is resulted of fast growth, that in turn is resulted of the fast extraction of sample heat.

4. CONCLUSION

From the gotten results, it can concludes that how much bigger the cooling rate, faster is the speed of growth of the phases presents in the league, producing a refined microstructure well better, as it was the case of the sample that was made solid in aluminum crucible. The explanation for this inhabits in the fact of that when increases the cooling rate produces one high super-cooling, that in turn speeds up the growth of crystals not giving time to have exaggerated growth of these crystals, producing the microstructure refining in the leagues.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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7. RESPONSIBILITY NOTICE

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