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Study of Porosity in Heat Treated Aluminum 319 Alloys.

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In recent years, metal foams have gained the attention of materials science research due to the unique combination of alloys and porous structures properties. Aluminum and its alloys are one of the most commonly used materials in engineering as a result of their characteristic properties such as low density, good ductility, and high corrosion resistance, these properties make aluminum alloys an excellent candidate as a base metal in foams manufacturing. [1]

During the XIX century a wide variety of different metal foams manufacturing processes were developed, with different methods for generating pores in molten or solid metal. Among these methods the use of over solution heat treatments allows to obtain pores without needing the use of gases, chemical compounds or preforms to generate them. A conventional solution treatment has the objective of solubilize the secondary phases or change their morphology in order to enhance aluminum alloys' mechanical properties and is usually accompanied by an ageing treatment. However when solubilization temperature is exceeded, overheat not only causes solubilization of secondary phases but also melts them down forming micropores in aluminum alloys. [2] This condition has been exploited to fabricate foams from solid aluminum volumes [3] or in combination with other foams' manufacturing processes such as infiltration over space holder particles. [4]

In the present research work, over solution heat treatment applied to aluminum 319 alloy is studied, this alloy constitutes an excellent option for aluminum foams manufacturing due to properties like corrosion resistance, good weldability, acceptable mechanical properties and good castability. Besides this, 319 alloys have low cost and good recyclability making them a highly available material.

In our case of study over solution treatment was applied using a temperature of 570°C slightly below the solidus line in the Al-Si phase diagram for a Silicon content of 5%, two different dwell time conditions were used (3 and 6 h) in combination with two cooling methods (air at room temperature and water), obtaining a total of 4 combinations as shown in Table 1. The samples were submitted to optical microscopy analysis following the standard sample preparation using sandpaper with 120-2000 grits for abrasive grinding and powdered alumina for polishing process. Optical microscopy analysis was conducted using an Olympus GX41F microscope and an Infinity 1-3C camera for image capture.

Pore generation in all samples was successful. For dwell time of 3 hours, sample cooled in air at room temperature showed a bigger pore size in comparison with water cooled one. However, when dwell time is increased to 6 hours, sample cooled in water showed a bigger average pore size with an increasing of approximately 200%, on the other hand average pore size for air cooled sample almost remained constant. This behavior can be explained because of the microstructural changes on the alloy, as shown in Fig. 1.A, air cooled sample pores are mainly generated from melting of secondary phases with a fragmented and slightly rounded microstructure that is also distributed in a wider area in comparison with water cooled sample (Fig. 1.B) that shows a microstructure mainly composed by needle type secondary phases, since secondary phases in air cooled sample cover a bigger area generated generated pores have bigger size. However, when dwell time is increased to 6 hours, the air-cooled sample showed in Fig. 1.C presented pores generated by melting of a microstructure composed by homogeneously distributed needle type secondary phases characteristic of the intermetallic compound β-Al_5FeSi with similar pore size to the sample with dwell time of 3 hours. On the other hand, pores from water cooled sample with dwell time of 6 hours are mainly generated from the melting of Chinese script type secondary phases characteristic of the intermetallic compound α-$Al_{15}(Fe,Mn)_3Si_2$, in this case pore formation follows the elongated shape of this secondary phase resulting in bigger por size with equally elongated shapes as shown in Fig. 1.D. The behavior of the samples with dwell time of 6 hours is due to the cooling rate, higher cooling rates favor the formation of α-$Al_{15}(Fe,Mn)_3Si_2$, while slow cooling rates favor the formation of β-Al_5FeSi as reported by Farina et al. [5]

It was concluded that over solution heat treatments successfully allow to obtain porosity in 319 aluminum alloys, however higher temperatures can be employed in order to maximize pore size. Dwell time showed a big influence in secondary phases' transformation since α-$Al_{15}(Fe,Mn)_3Si_2$ and β-Al_5FeSi are only present with duel time of 6 hours. It is worth to mention that this research work it's not concluded yet, research team plans to use another analysis techniques such as Scanning Electron Microscope for a better identification of the secondary phases melt during oversolution treatment.

Table 1. Pore size results obtained from oversolution heat treatments.

Sample No.	Dwell time (h)	Cooling Method	Average pore size (μm)
S-4	6	Water	732.97
S-3	6	Air	537.82
S-2	3	Water	363.61
S-1	3	Air	532.15

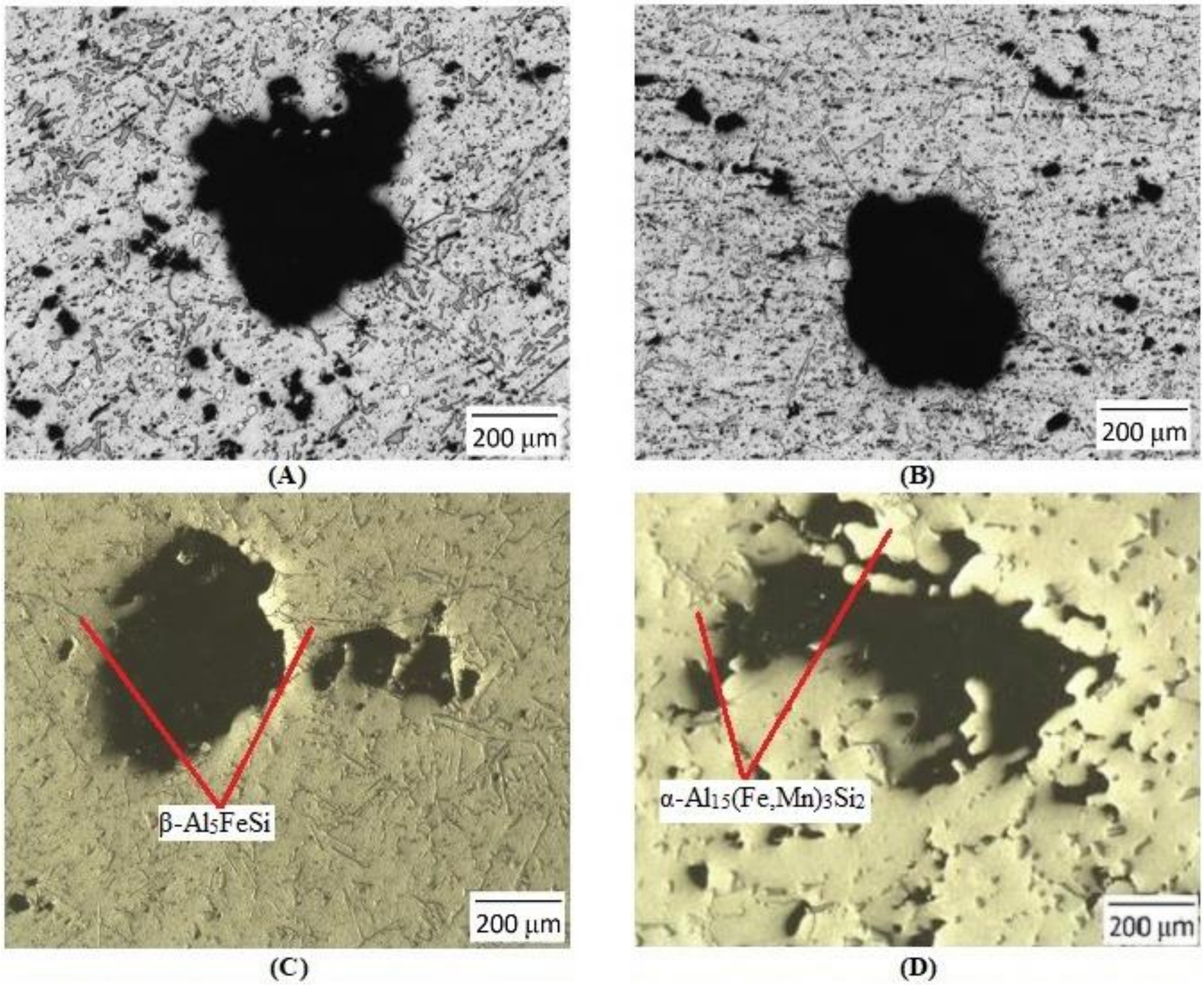

Figure 1. Pore micrographs obtained for different samples. A) S-1, dwell time 3 hours, air cooled. B) S-2, dwell time 3 hours, water cooled. C) S-3, dwell time 6 hours, air cooled. D) S-4, dwell time 6 hours, water cooled.

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