Solidification Characteristics of the Modified AA308-Type Alloys Determined by Thermal Analysis and EDS

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Abstract

The AA 308-type alloy is one of the most widely used aluminum diecasting alloys, and it is applied in many components in the automotive industry. The aim of this work is to investigate the solidification characteristics related to the precipitated phases that are formed in the modified AA 308-type alloys with high magnesium content. The solidification process of the alloy with the presence high quantity of magnesium under investigation has been followed by thermal analysis, EOS (Emission Optic Spectroscopy), and subsequently by metallographic examination of the solid samples using SEM and EDS.

The considered alloy was solidified in a ceramic crucible of 35 mm diameter placed inside a resistive furnace. A thermocouples set was connected to a computer system in order to obtain the solidification characteristic curves. In our experimental system the solidification process starts when a metallic bar made of aluminum reaches the melt at the same time when the furnace is turned off. The average of cooling rate obtained was 3,7 °C/s and the typical cooling curve showed characteristics peaks that correspond to the distinct precipitates formed during the solidification of the experimental alloy.

KEYWORDS: Aluminum casting alloy, thermal analysis, microstructure, and microanalysis.

1- Introduction

Aluminum is a light metal, and it is often specified in engineering applications for its feature. The as casting AA 308-type alloys are frequently used for the fabrication of innumerable components by the automotive industry because they present good mechanical characteristics and appreciable castability. The concentration range of the following elements composes the typical AA 380.1 alloy (1): Si 7.5-9.5%, Fe 1.0%, Cu 3.0-4.0% and Mg 0.1%. It is well known that the microstructure properties of AA380 type-alloys can be altered by magnesium addiction (2).

Since thermal analysis and EDS are very powerful techniques to obtain information about the evolution of microstructure developed during the solidification process related to the rate cooling (1,3), we made use of both techniques accomplished by the metallographic techniques in order to understand the behavior of the microstructure during the solidification course of the modified AA 308-type alloys with high magnesium content, as for example types and distribution of precipitates developed in the metallic matrix.

2 - Materials and Methods

The samples utilized in all experiments were obtained from casting ingots which were pouring in a permanent molding using an approximately superheating of 60 °C. The magnesium was added in the elementary form in the basic alloy which was obtained from the Al-Si and Al-Cu master alloys and also from commercial Al.

The chemical composition of the experimental alloy used in our experiments was determined by Optical Emission Spectroscopy (OES) and Graphite Atomic Absorption Spectroscopy (GAAS) techniques. Table 1 shows the chemical composition of the experimental alloy as well as the composition of the commercial AA308.1 type alloy.

For the thermal analyses the experimental alloy was melted in a ceramic crucible of 35mm diameter using a resistive furnace. The melt was maintained at 20 ° C above the melting temperature during one hour to achieve complete stabilization. Three k-type thermocouples, 10 mm equally placed from each other and horizontally distributed, were located in the center of the melt and were connected to a computer system in order to obtain the solidification curves. The solidification process occurs when a metallic bar made of aluminum reaches the melt when the furnace is turned off. The average of cooling rate obtained with the aluminum bar was 3.7 °C/s. The temperature/time relation in the center of the ingot, acquired by the central thermocouple, gives us a simple cooling curve that shows the start and end of the solidification process that can be seen in Figure 1. Information about this may be obtained if the first derivative of the cooling curve is calculated as shown in Figure 2.

For microstructure analyses, the cylindrical samples were cut horizontally in the thermocouple point. The surface was ground on, successively finer emery papers and polished in a suspension of Al_2O_3 with grain size of 1μm. The polished samples were etched by 0.5% HF- solution in distillate water and examined in a Scanning Electron Microscope (SEM) in combination with an Energy Dispersive X-ray Spectrometer (EDS) for quantitative chemical analysis in order to identify the different kinds of precipitates present in the actual material. The SEM analyses were performed by using both Secondary Electrons (SE) and Electrons Back Scattering – BSE modes.

3 - Results and Discussion

The experimental alloy modified by the adding high magnesium content exhibited a large solidification zone, ranging from 625°C to 490°C as can be seen in Figure 1. As nucleation and growth proceed into the casting, more heat is generated in the surface than in the center, once our experimental system arrangement extracts the heat through the metallic bar located in the center of the melt, where the thermocouples set was placed. The peak related to this fact is more evident due to the high cooling rate used during the experiments and it does not go back to its original steady state value as can be observed by the accentuated difference in temperature between peak 1 and peak 2 in Figure 1. The consequence of this in the microstructure appears through development of typical aluminum dendrites in the background as shown in Figure 3.

According to the EDS results, the peak indicated as number 1, in Figure 1, corresponds to the development of aluminum dendritic network; the peak 2 corresponds to precipitation of Al_{15}-phases, such as $Al_{15}(Fe, Mn)_3Si_2$ in the still pre-eutetic interdendritic liquid; peak 3 is related to eutectic main reaction involving nucleation of Si crystals; peak 4 corresponds to precipitation containing Al_5, such as Al_5FeSi, peak 5 refers to precipitation of Mg_2Si; peak 6 is related to precipitation of Al_2Cu and peak 7 refers to complex phases, as $Al_5Mg_8Cu_2Si_6$.

Figure 4 shows an image of the experimental alloy microstructure obtained by SEM in the BSE mode. Figure 5 shows a more detailed image of Figure 4, at each location the composition identification was made by EDS, where white needles correspond to Al_5FeSi, black script phase to Mg_2Si, in addiction to Si, Al_5FeSi and $Al_{15}Mn_3Si_2$ particles. The numbers marked in figure 5 correspond to the same peak numbers showed in figure 2, respectively.

The presence of both, the peak number 5 in the cooling curve and the black script phase, which is specifically located in the Al-Si eutectic region (see microstructure representative in figure 3) reveals the high magnesium content existing in our sample.

4 - Conclusions

Considering the utilized cooling rate during the solidification process and also in view of the high magnesium amount additionated to the AA308-type alloys we concluded that this element segregates preferentially to the interdrendritic region in precipitated phases as Mg_2Si and in the complexes phases as $Al_5Mg_8Cu_2Si_6$.

5 - Acknowledgments

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6 - References

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Alloy	Si (% in weight)	Fe (% in weight)	Cu (% in weight)	Mg (% in weight)
AA 380.1(1)	7.5-9.5	1.0	3.0-4.0	0.1
Basic Alloy [i]	9.59	1.04	3.54	0.004
Experimental Alloy [ii]	9.32	-	3.4	2.33

i- Optical Emission Spectroscopy.
ii- GAAS-Graphite Atomic Absorption Spectroscopy.

Table1- *Chemical compositions of the experimental alloy and the commercial AA308.1 type alloy.*

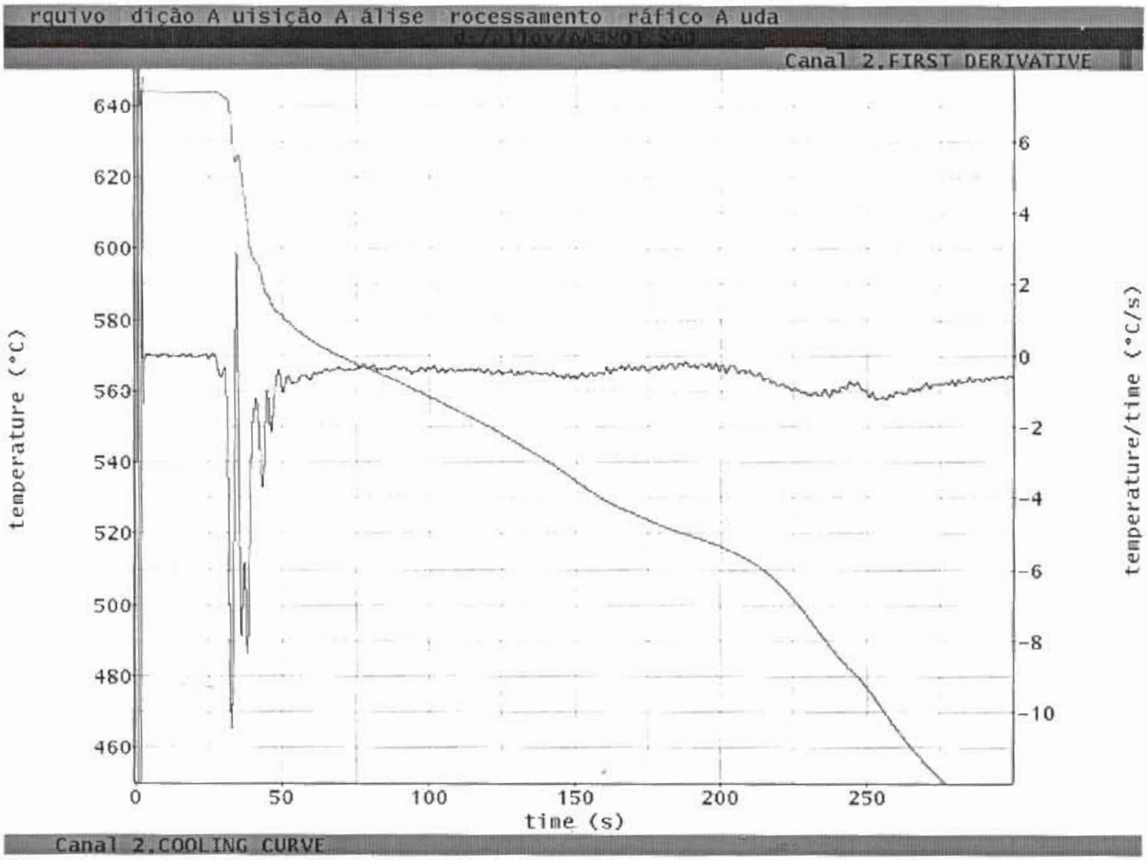

Figure 1- *Typical cooling curve for the experimental alloy and its first derivative, showing the starting and the ending of solidification proceeding (ranging tron 625ºC to 490Cº.*

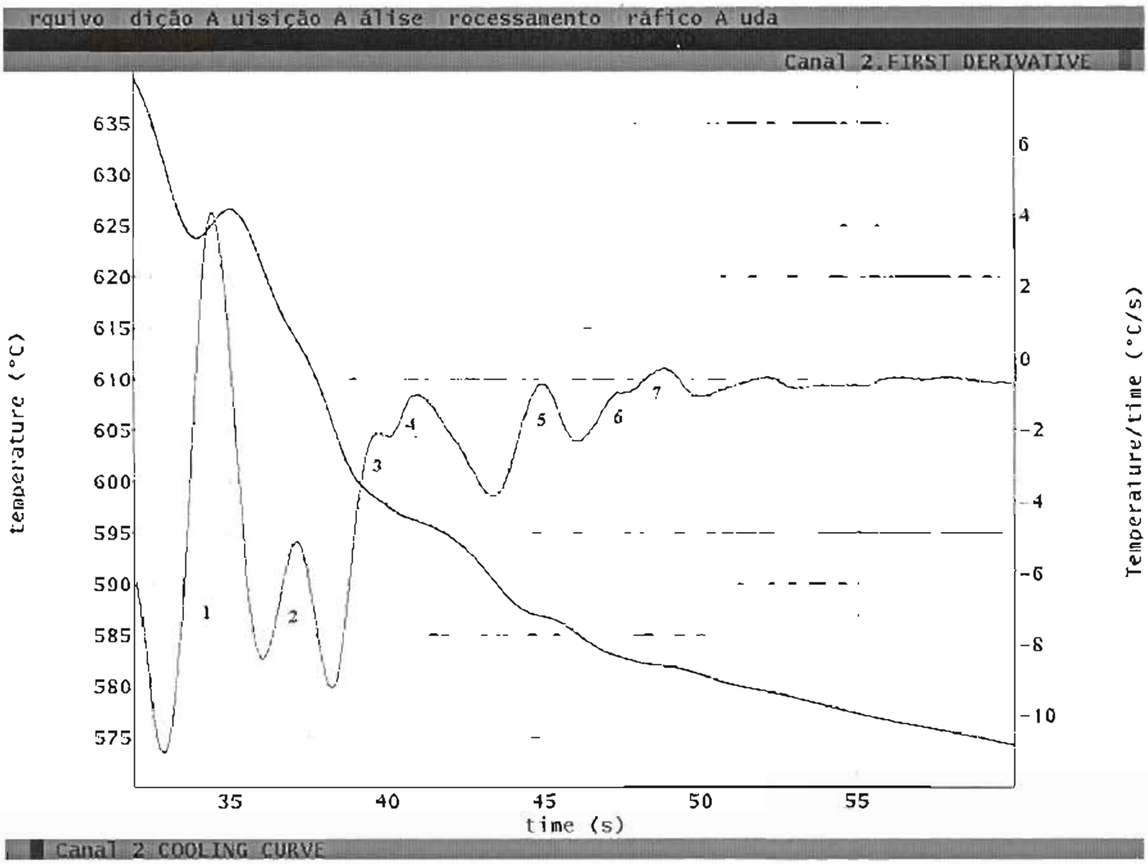

Figure 2- A detailed experimental alloy cooling curve and its first derivative. This curve was taken from the thermocouple that was 30 mm distanced from the aluminum bar.

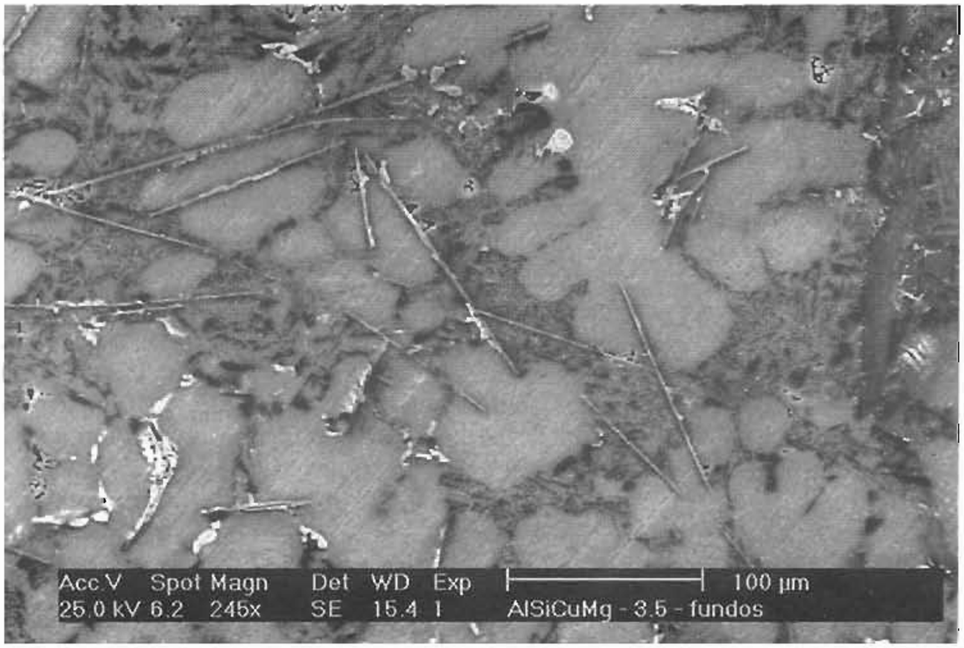

Figure 3- Microstructure image showing the development of typical aluminum dendrites in the background.

Figure 4- *Microstructure image of the experimental alloy obtained by SEM in the BSE mode giving evidence to the differences in the composition of the phases*

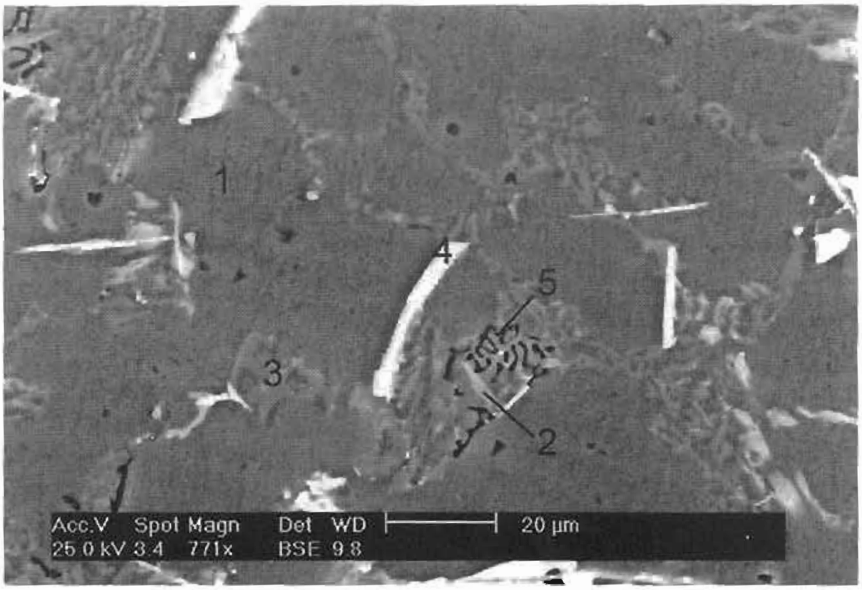

Figure 5- *A more detailed image of Figure 4, each numbered location, the composition identification was made by EDS. The numbers specified in the microstructure also correspond to the numbers of the curve in Figure 1.*