STUDY OF THE INFLUENCE OF THE SIC REINFORCEMENT IN THE MODIFICATION EFFECT OF SR IN THE A359/SIC METAL MATRIX COMPOSITE

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Keywords: Metal Matrix Composites MMC, Al-Si alloy, grain refiners.

Abstract

In this work the influence of the SiC ceramic reinforcement in the Sr modifier efficacy has been evaluated for different reinforcement percentages in a A359/SiC composite material. Manufacturing process was gravity casting and the reinforcement percentages were 10 and 20 wt. % of SiC particles. Microstructures were analysed in reinforced samples containing both modifiers and grain refiners (Al-5Ti-1B) and in reinforced samples without those aditives. Solidification curves have been analysed and the observations have been correlated with the formation of main phases observed in the microstructural analysis carried out by SEM-EDX and optical microscopy. It has been observed that the presence of strontium has slightly increased the reinforcement agglomeration observed in the grain boundary region. Moreover, samples reinforced with 20 wt. % SiC present similar eutectic microstructure with or without strontium addittion.

1. Introduction

Aluminium-silicon alloys with near eutectic compositions are widely used due to their good castability properties that the silicon provides [1]. At present, these alloys are usually cast with some other additive elements that improve differents aspects such as the final microstructure. That is the case of the strontium element that is included in the chemical composition to avoid the needle-shape (coarse plate-like morphology) microstructure of the eutectic phase, transformating the eutectic in a a fine fibrous structure [2].

When A359 alloy is reinforced with SiC particles by stir casting the resulting composite material obtained presents better stiffness and good wear resistance with small increase in production costs. In some cases, metal matrix composites (MMC) are selected as best choice for a specific component. When MMC material is processed for the manufacturing of components it is used to implement the same conditions as their matrix alloys. In this case it means that strontium element is added to the melting. Strontium is one of the most popular additives used in the aluminium foundry industry due to its microstructure modification ability. This additive is the responsible of the transformation of the eutectic Si from coarse plate-like morphology to a fine fibrous structure. Other modifications in the structure provided by the addition of Sr are the decrease of interface stress of phases as well as the control of the growth of non desirable phases [3].

2. Experimental procedure

2.1. Material

A359 aluminium alloy belongs to the 3xx.x series comprising the alloys with silicon, copper and/or magnesium as main alloying elements (ENAC-AlSi9Mg). These alloys present good casting properties, high mechanical properties as well as the possibility of get thermally treated. Two commercial reinforced alloys, Duralcan´s F3S.10S and F3S.20S, have been used in this work. The former presents a SiC particle reinforcement content of 10 wt. % and the latter has 20 wt. % SiC reinforcement. Silicon modifier has been introduced to half of the samples by the addition of a master alloy Al-Sr 3.5%. The amount of master alloy was adjusted to obtain a final composition of 0.04% Sr. Grain refiner AlTi5B1 was also added up to a level of 0.6 wt. % in the same samples. Six different samples have been prepared: aluminium alloy without neither reinforcements nor additives, with 10% reinforcement without any additives, 20% reinforcement without additives and the same three samples with additives (Al-Sr3.5% and AlTi5B1). Table 1 shows the composition of the aluminium matrix.

Si	Fe	Cu	Mn	Mg	Zn	Al
9.0-10.0	0.2 max.	0.2 max.	0.1 max.	0.25-0.6	0.1 max.	rest

Table 1. Chemical composition of A359 alloy, wt. %.

2.2. Samples processing

All the alloys were melt in the same conditions in an induction furnace with silicon carbide crucibles. Samples were obtained by gravity casting with a mould at room temperature. The casting temperature was 730ºC. The casting step of the six alloys has been controlled so that there were no differences in the casting parameters and procedure. Two castings of each material were made to check that reliable data were obtained.

2.3. Microstructural characterisation

Once samples were produced, they were polished and etched for microstructural characterisation, (etching NaOH in water 10 wt.%). Observations were made in an Olympus BH optical microscope and the chemistry of intermetallic phases was analysed with a SEM-JSM 7000f EDX-Pentafet (Oxford) equipment.

3. Results and discussion

3xx.x alloys are broadly used due to their good balance of properties and cost. The main alloying elements of these alloys are Si and Mg. Although the presence of silicon is good for casting properties, a too large amount of coarse eutectic phases may lead to a decrease in ductility. On the other hand the presence of magnesium involves the formation of the Mg_2Si intermetallic phase , improving mechanical properties by precipitation hardening mechanism. Iron element reacts with Al, Si and Mg to form insoluble intermetallic compounds, in detriment of the tensile strength and ductility. The amount of magnesium available for the age hardening mechanism decreases with precipitation of iron intermetallics.These are the main phases that get formed during solidification of A359 after casting: primary crystals of α-aluminium with interdendritics regions of eutectic silicon needles, as well as silicon cuboids. Iron and element may appear in the intermetallic phases β-Al_5FeSi and π-$Al_8Mg_3FeSi_6$. These crystals are needle-shaped and cause a deterioration in the mechanical properties of the alloy, in particular the ductility and toughness, [4]. When modifiers are added to a non reinforced alloy the eutectic silicon loses its needle-shape and becomes more spherical around α-Al dendrites. Iron intermetallics (ß-Al_5FeSi and π-$Al_8Mg_3FeSi_6$) usually appear far from these modified regions.

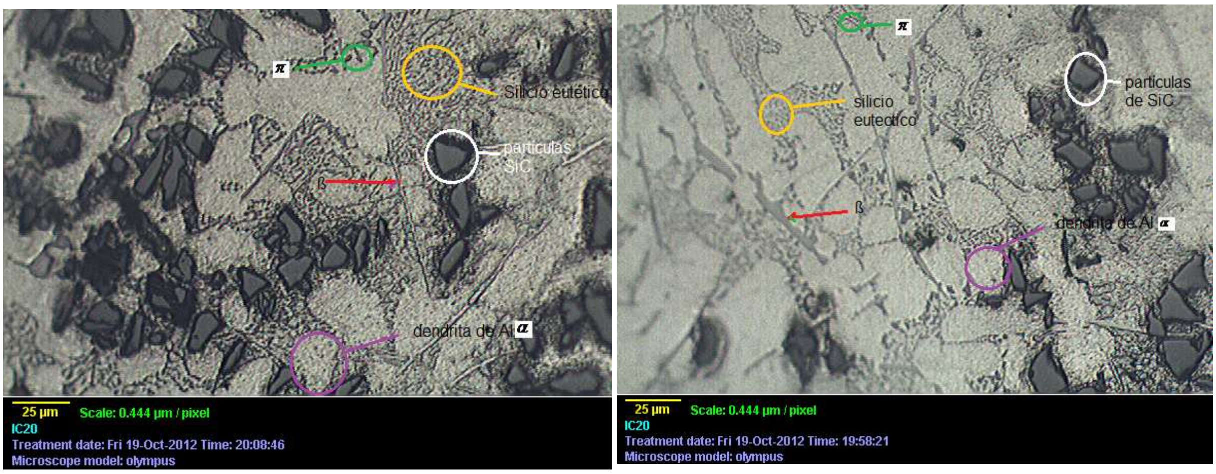

Figure 1. a) A359-10% SiC non modified structure, 200X . b) A359-10% SiC modified structure, 200X. Both microstructures present $Al_8Mg_3FeSi_6$ intermetallic (smaller green circle), ß- Al_5FeSi phase (red arrow), SiC particles (white circle), spheroisided eutectic silicon (yellow circle) and α-aluminium (purple circle).

Comparing the microstructures observed for samples with 10 wt. % SiC reinforcement, it can be seen that the shape of the eutectic silicon is similar in both cases, with and without strontium addition, Figure 1. Moreover, in the case of modified samples, the formation of aggregates seems to be higher than in the case of non modified samples. This behaviour could be related with the mechanism of interface activation that promotes the strontium addition.

Figure 2. a) A359-20 wt. % SiC non modified structure, 200X . b) A359-20 wt. % SiC modified structure, 200X. Both microstructures present SiC particles (white circle), spheroidised eutectic silicon (yellow circle) and α-aluminium (purple circle) (at this reinforcement percentage iron intermetallics are not easily visible with optical microscope).

This is possibly related to the different mechanism of phase precipitation due to the presence of strontium and the possible influence on the solidification front pushing phenomenon in comparison with the non modified samples. This behaviour has been more clearly observed in the 20% reinforced samples, Figure 2. Moreover, it has been seen that the eutectic silicon shape of the 20% reinforced samples was quite similar in both cases, (with and without modifier and grain refiner). This result agrees with previous studies of similar alloys, [5] pointing out a behaviour of the reinforcement as microstructure modifier agent as well as grain refiner at the studied processing conditions.

4. Conclusions

Microsture observed in the non reinforced samples correspond to those explained in the literature where the strontium element acts as expected modifying the silicon eutectic. However, when SiC particles are added it has been seen that the addition of Sr is not necessary to change the eutectic needle-shape structure. In both cases (with and without additives) the silicon eutectic structure appears spheroidised. This result agrees with the observations of Nagarajan et al. [5], explaining the role of the SiC reinforcement particles as heterogeneous nucleation sites of eutectic Si. It has been observed that microstructures of samples without Sr addition present better dispersion of SiC particules than samples with additives. This behaviour is more evident in samples with 20 wt. % SiC reinforcement. The mechanism of this behaviour is not clear, but it could be related with the hindering that entails the particles presence in the solidification of the alpha-aluminium phase. It seems that the amount of alpha-aluminium primary dendrite regions increase with Sr addition in presence of SiC particles. This leads to a decrease of the grain boundary regions and consecuently an increase of the particle aggregation formation.

5. Acknowledgements

The research was funded within the framework of scientific financial resources of the University of the Basque Country UPV/EHU. Ref. number: EHU11-28.

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