EFFECTS OF THE REFINEMENT OF PRIMARY Si PARTICLES IN AlSi17 ON THE MICROSTRUCTURE OF THE BONDING ZONE FORMED BETWEEN AZ91 AND AlSi17 BY COMPOUND CASTING

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Abstract

The AZ91/AlSi17 bimetallic samples were formed using the compound casting method. The AZ91 magnesium alloy was top-poured onto an AlSi17 aluminum alloy insert placed in a steel mould. Two types of AlSi17 inserts, differing in microstructure, were used in this study. The insert cut from an AlSi17 alloy ingot had a microstructure with irregularly shaped and unevenly distributed, large primary Si particles. The AlSi17 alloy was cast in a cold steel mould to refine the primary Si particles. In the other insert, cut from rapidly solidified AlSi17 alloy, the fine primary Si particles were homogenously distributed in the matrix. The experiments revealed that the microstructure of the AZ91/AlSi17 bonding zone was dependent on the microstructure of the inserts used. Applying an insert with coarse primary Si crystals led to the formation of a bonding zone composed of intermetallic phases and not fully reacted Si particles. The Si particles were too large to be consumed in the reaction with Mg during compound casting and fully transformed to Mg_2Si. The use of an insert with a refined microstructure resulted in a bonding zone with fully reacted Si crystals. In this case, a eutectic ($Mg_{17}Al_{12}$ + a solid solution of Al in Mg) was observed in the bonding zone on the AZ91 side. The bonding zone close to AlSi17 alloy was composed of Mg_2Si particles uniformly distributed in the Al-Mg intermetallic phase matrix.

Keywords: Mg alloy, Al alloy, compound casting, intermetallic phases, bonding zone, microstructure

1. INTRODUCTION

In many manufacturing industries, especially the automotive and aerospace sectors, there has been an increased interest in the use of magnesium and aluminum alloys because of their low density. Some of the current research in materials science is concerned with the production of bimetals and clad alloys.

Magnesium and aluminum bimetals can be fabricated using various methods such as welding [1], brazing [2], hot rolling [3, 4], friction stir welding [5], explosive cladding [6] and compound casting [7-13].

Compound casting is a very economical process of joining two dissimilar materials. It involves casting a liquid metal onto a solid. The literature data show that compound casting can be used to produce joints between: steel and cast iron [14-16], steel and Al [17], and Al and Cu [18]. This method is also employed to join light metals, i.e. Al and Mg [7-10], two dissimilar magnesium alloys [11] and two dissimilar aluminum alloys [12, 13].

This study focused on the effects of the refinement of primary Si particles in AlSi17 alloy on the microstructure and composition of the bonding zone formed between AZ91 and AlSi17 by compound casting.

2. EXPERIMENTAL DETAILS

Two types of AlSi17 aluminum alloy inserts differing in microstructure were used in the experiments. One was obtained from an unmodified AlSi17 ingot. The other was prepared by refinement, which involved heating the material to 720 °C, keeping it at that temperature for 30 min and pouring it into a cold steel mould. The inserts were 30 mm in diameter and 5 mm in thickness. The insert surfaces were prepared by grinding with up to 800 grit SiC papers and cleaning with ethanol. Then, the aluminum insert was placed at the bottom of a metal mould to be heated to 370 °C. The AZ91 magnesium alloy was used as the cast material. The melting was performed in the argon atmosphere. 100 g of AZ91 heated to 650 °C was top-poured onto the AlSi17 insert placed in the steel mould under normal atmospheric conditions. After cooling to room temperature, the AZ91/AlSi17 bimetallic casting was removed, cross-sectioned and prepared for metallographic observations. The final polishing was performed on a STRUERS automatic polishing machine, using colloidal silica.

The metallographic observations were carried out using a Nikon ECLIPSE MA 200 optical microscope and a JEOL JSM-5400 scanning electron microscope. The chemical composition was examined with an energy dispersive x-ray spectrometer (EDS).

3. RESULTS AND DISCUSSION

Figure 1a presents the microstructure of the AlSi17 insert cut from the unrefined AlSi17 ingot. The coarse, primary Si crystals were non-uniformly distributed in the matrix. The AlSi17 alloy poured to a cold steel mould exhibited a refined structure (**Figure 1b**) with primary Si crystals finer and more uniformly distributed in the matrix.

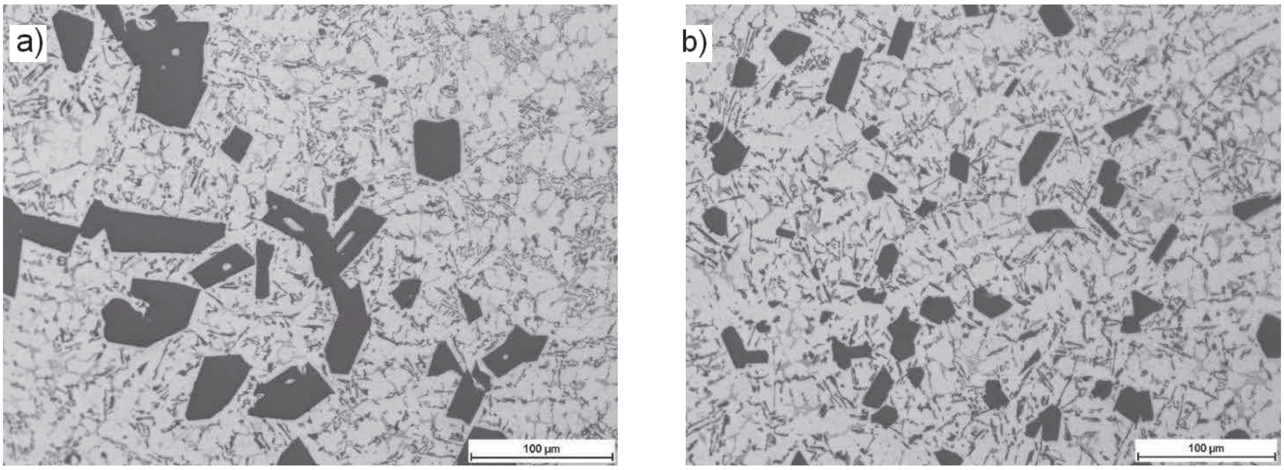

Figure 1 Microstructures of the AlSi17 inserts: (a) cut from the AlSi17 ingot, (b) cut from the rapidly solidified AlSi17 alloy

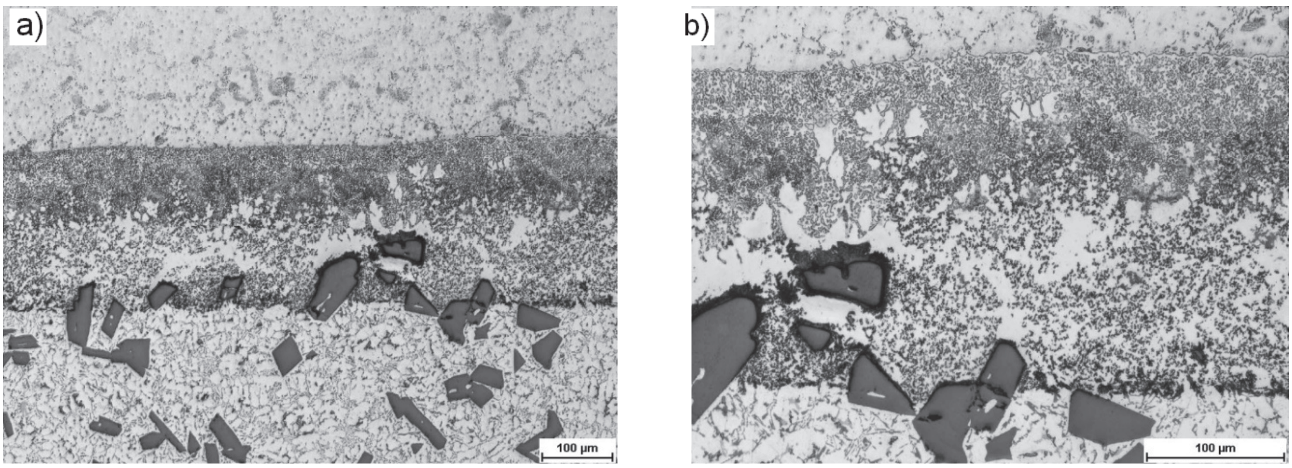

Figure 2 Microstructures of the bonding zone between the AZ91 and the unrefinedAlSi17: (a) lower magnification, (b) higher magnification

A micrograph of the bonding zone between the AZ91 and the unrefined AlSi17 is shown in **Figure 2a**. The results indicate that during the compound casting process, a continuous, defect-free bonding zone was formed at the AZ91/AlSi17 interface. **Figure 2b** shows the microstructure of the bonding zone in the AZ91/AlSi17 bimetallic sample, observed at a higher magnification. The primary Si particles are visible in the AlSi17 alloy and in the bonding zone. The Si particles present in the bonding zone are surrounded by a dark rim. The results of the EDS quantitative analysis of this bonding zone were provided in the earlier publications of the authors [7, 8].

The analysis of the bonding zone on the AZ91 side (**Figure 3**a) indicated a eutectic composed of the $Mg_{17}Al_{12}$ intermetallic phase (light phase) and a solid solution of Al in Mg (dark phase). Light $Mg_{17}Al_{12}$ dendrites were observed below the eutectic. The bonding zone close to the AlSi17 alloy (**Figure 3b**) had a different microstructure. The primary Si grains present in the bonding zone were surrounded by a dark rim of the Mg_2Si phase. The fine, dark particles of the Mg_2Si phase were also observed in the light matrix of the bonding zone. The chemical composition of the light matrix was close to the Al_3Mg_2 intermetallic phase. The casting of the AZ91 alloy onto the AlSi17 insert led to the occurrence of the diffusion processes at the interface. The primary Si crystals and the eutectic Si particles in the AlSi17 alloy reacted with Mg, which led to the decomposition of the Si grains and the formation of the Mg_2Si phase. The primary Si particles in the unrefined AlSi17 alloy were too large to be fully consumed in the reaction with Mg and transformed to the Mg_2Si phase during compound casting. Thus, large not fully reacted Si particles observed in the bonding zone were surrounded by an Mg_2Si phase rim.

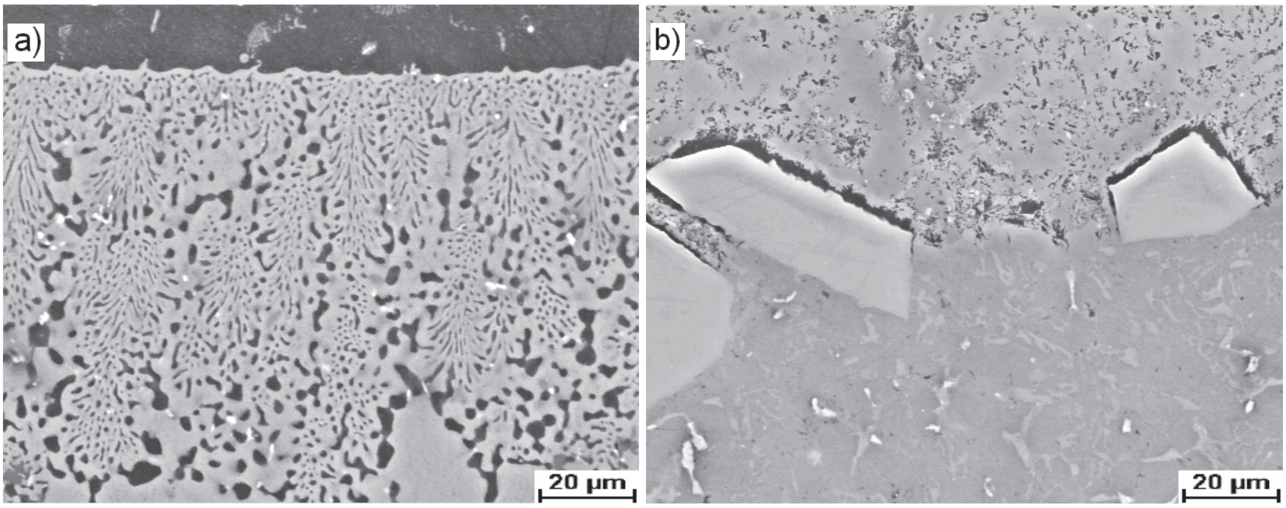

Figure 3 Details of the microstructure of the bonding zone between the AZ91 and the unrefined AlSi17 observed by SEM: (a) AZ91 side, (b) AlSi17 side

The microstructure of the bonding zone formed between the AZ91 alloy and the AlSi17 insert with a refined microstructure is shown in **Figure 4**. As can be seen, this microstructure of this bonding zone is more homogenous than that discussed above. The primary Si crystals in the thermally modified AlSi17 alloy are fine. During the compound casting process, the reaction at the AZ91/AlSi17 interface led to complete transformation of the fine primary Si particles into the Mg_2Si phase. Only locally were agglomerates of Mg_2Si particles observed.

The AZ91/AlSi17 bonding zone with a homogenous microstructure on the AlSi17 side (the fine Mg_2Si particles uniformly distributed in the Al-Mg intermetallic phase matrix) is likely to have mechanical properties better than the bonding zone with unreacted, large primary Si crystals. Further research is required to study the impact of the refinement of the primary Si particles in the AlSi17 alloy on the mechanical properties of the bonding zone formed between AZ91 and AlSi17 during the compound casting process.

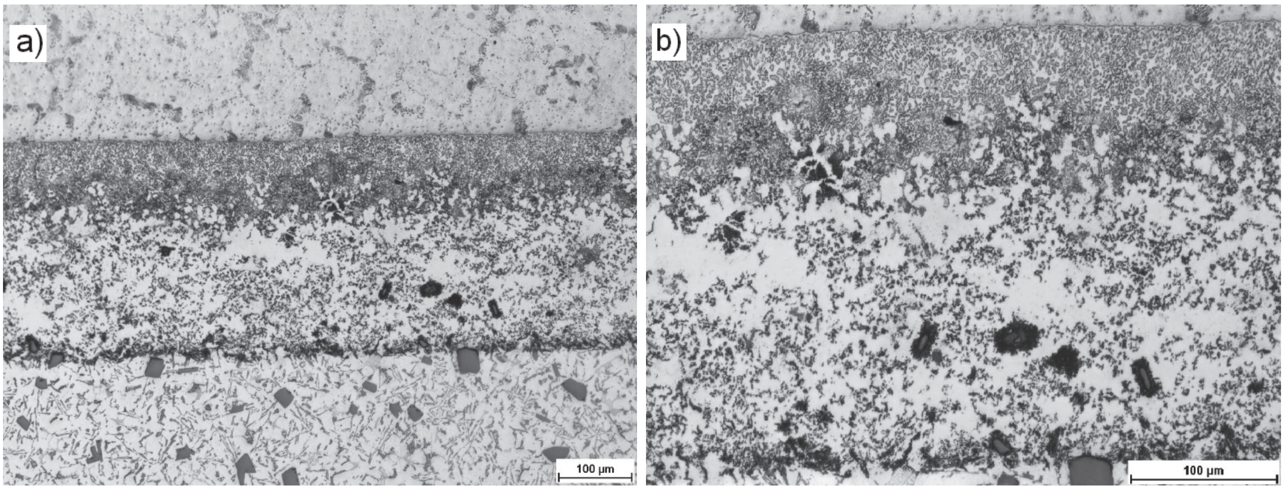

Figure 4 Microstructure of the bonding zone formed between the AZ91 and the insert cut from rapidly solidified AlSi17 alloy, (a) lower magnification, (b) higher magnification

4. CONCLUSION

The microstructure of the AlSi17 alloy used as the insert material in the compound casting process was modified by rapid solidification. The refinement of the primary Si particles in the AlSi17 alloy led to the formation of a more homogenous bonding zone at the AZ91/AlSi17 interface. The bonding zone formed between the unmodified AlSi17 alloy and the AZ91 alloy was characterized by not fully reacted, large primary Si crystals. These particles were surrounded by a rim of the Mg_2Si phase, synthesized by the reaction of Mg with the Si particles. The use of the thermally modified AlSi17 alloy as the insert material resulted in the formation of a bonding zone with uniformly distributed Mg_2Si particles and without unreacted Si particles.

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