Postgraduate Studies

Die Cast A356/Stainless Steel Composite

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Introduction

Aluminium-stainless steel composites have gained popularity due to low cost of fabrication, sustainability issues of the stainless steel and potential for high-wear applications. The unique properties of fibre reinforced composite materials are to a great extent dependent on the unique nature on the matrix-fibre interface which can be defined as regions of significantly changed chemical composition constituting the bond between matrix and reinforcement for transfer of loads. Interfaces constitute important microstructural features of composites requiring appropriate fabrication techniques and optimum fabrication parameters. Major fabrication methods used for aluminium metal matrix composites are stir casting, squeeze casting, compocasting, liquid infiltration, spray deposition, direct melt oxidation process and powder metallurgy.

Microstructural changes in the matrix alloy, induced by the fabrication parameters, have an impact on the interfacial bonding between matrix and reinforcement. Interfacial bonding of aluminium -stainless steel is ductile and desirable in metal matrix composites. Although a strong interface bonding is preferable for improved mechanical properties, a poor interfacial bonding has a better damping capacity at the expense of strength as compared to strong interfacial bonds. This research presents the study of A356/stainless steel composite interface, formed via die casting.

Experimental Procedure

The matrix alloy used were primarily cast ingot of A356 (Al-7%Si-0.3%Mg) alloy and stainless steel wires of 500 µm diameter, as the reinforcement. Stainless steel wires (SSw) were aligned at a uniform distance and fixed on a stainless steel mould of 30 mm height and 90 mm diameter. The matrix alloy was melted in a muffle furnace with a clay crucible. The matrix alloy was heated up to 850°C within 2 hours before being poured into the preheated stainless steel mould.

The interface morphology was studied with a scanning electron microscope (SEM) and the elements present in the microstructural features were determined with energy dispersive X-ray spectroscopy (EDS).

Results and Discussion

Figure 1a shows the micrograph of a nearly complete interfacial bond at a single stainless steel wire. The stainless steel wire surrounds the minority eutectic Si needle-shaped particles at the interface and the majority globular structure far from interface. The morphology, closer to the interface can be seen as being of eutectic Si needle-shaped particle in Figure 1b. However, far from the interface, this morphology has evolved to the fine interdendritic eutectic Si particles (denoted as D) and globular structures (denoted as G). A minima of typical porosities and oxide inclusion contents can be observed throughout the A356 matrix alloy.

Figure 1a SEM micrograph of single stainless steel wire.

Figure 1b Magnified SEM micrograph of morphological evolution around single stainless steel wire.

Figure 2a shows a micrograph of incomplete interfacial bonds at double stainless steel wire sites. Less eutectic Si needle-shaped particles can be observed at the interface and a few voids (denoted by V) can be observed around the interface of double stainless steel wires. This condition may be due to incomplete solidification at the interface owing to the constrained interwire region and lack of vibration. At higher magnifications, near the double stainless steel wires, Figure 2b, the coarse acicular eutectic Si needle-shaped particles were found to be dispersed among the fully developed primary aluminium dendrites.

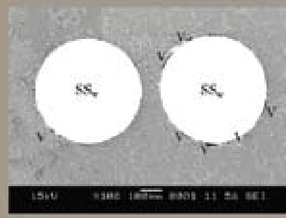


Figure 2a SEM micrograph of double stainless steel wire.

Figure 2b Magnified SEM micrograph of coarse acicular eutectic Si needle-shaped particle near to the double stainless steel wires.

Figure 3 illustrates the EDS spectrum for a eutectic Si needle-shaped particle which shows that only Si exists and there is no formation of any intermetallic compounds. Interfacial debonding, associated with large voids, is shown in Figure 4 due to intimate contact between stainless steel wires thus no matrix alloy contact between the wires.

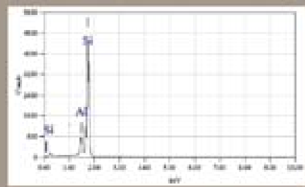
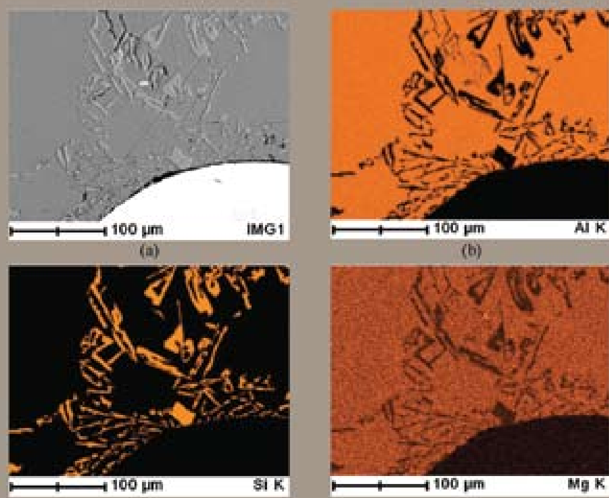


Figure 3 EDS spectrum of eutectic Si needle-shaped particle.

Figure 4 Debonding associated with large void around double stainless steel wires.

Figure 5(a) shows a SEM micrograph of a region close to the stainless steel wire. EDS mapping confirmed the elemental presence of Al, Si and Mg close to the stainless steel wire, as shown in Figures 5(b), 5(c) and 5 (d) respectively.



(a) (b) (c) (d)

Generally, heavy concentration of needle-like structures at single stainless steel wire sites were observed as in Figure 1a compared to that of double stainless steel wires of Figure 2a. However, globular structures are seen in larger sizes far from single stainless steel wire sites compared to that of double stainless steel wires. These features may be due to a faster solidification rate around the single stainless steel wires compared to double stainless steel wires.

Conclusion

Nearly complete interfacial bonding at the A356/stainless steel wire interfaces, due to a complete and stable solidification process is characterized by the morphological evolution around the stainless steel wires. Incomplete interfacial bonding at A356/stainless steel wire interfaces caused by incomplete and a non-stable solidification process due to constrained interwire regions and a lack of vibration. Intimate contact between the stainless steel wires caused interfacial debonding at the A356/stainless steel wire interfaces and prevented matrix alloy contact between the wires. Heavy concentration of eutectic Si needle-like particles occur at single stainless steel wire sites compared to that of double stainless steel wires. Globular structures can be seen in larger sizes around single stainless steel wire sites compared to double stainless steel wire sites. These features may be due to faster solidification rate around the single stainless steel wires compared to double stainless steel wires.

Acknowledgement

The author is grateful to UniMAP for the financial support under Short Term Grant (9003-00021).