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Reactions in magnesium composites reinforced with SiC particles

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1. INTRODUCTION

Cast composites designed as based on a magnesium matrix and reinforced with silicon carbide particles constitute a new group of materials that feature the desired set of properties [1-7]. The use of magnesium for the matrix of composites allows a low weight of the final element to be obtained, while assuring the proper level of properties; the introduction of SiC particles, on the other hand, enables the tribological properties, Young's modulus, tensile strength and hardness of the composite to be enhanced [6-11].

It should be noted that the Mg-SiC system is characterized by (i) a very good wettability of SiC by molten Mg, (ii) a very high stability of SiC in liquid Mg. Investigations carried out so far [2, 4] have determined the possibility of obtaining adhesive bonding between components and high volumetric fractions of SiC particles with their uniform distribution within the matrix (Fig.1).



Figure 1. TEM image of magnesium –SiC particle interface, magn. 2750x

2. RESULTS

The main alloying elements for magnesium are presently aluminium, zinc and rare-earth elements. The three basic types of the groups mentioned above were analyzed in respect of the possibility of forming the desirable structure of composites.

Alloys of AZ91 type contain chiefly aluminium with zinc and manganese. Although aluminium is able to react with SiC forming very unfavourable carbide Al_4C_3 , it does not exhibit this tendency in magnesium alloys. Composites made on the basis of the matrix of

Mg-Al binary alloys were characterized by a uniform distribution of SiC particles and their adhesive bonding with the matrix. In the case of using the standard AZ91 alloy for the composite matrix (Fig. 2), serious difficulties in introducing larger volumetric fractions of particles and obtaining a uniform distribution of particles arise, and problems caused by increased gas porosity occur. Preliminary investigation carried out suggest an adverse effect of manganese present AZ91 alloys on the obtained structure of composites. It appears that for a matrix of magnesium-aluminium type, alloys without addition of manganese should be used.



Figure 2. TEM image of Mg-8%Al alloy -SiC particle interface, magn. 2750x

Alloys of zinc-magnesium type (GZ6) make another advantageous matrix for composites reinforced with SiC particles (Fig. 3). These alloys are often modified with zirconium that causes a change in the structure from dendritic to cellular and grain refining. Although thermodynamic analyses suggest a possibility of reaction of zirconium with SiC, tests performed on composites made on the matrix of the standard GZ6 alloy did not reveal these tendencies. These composites were characterized by the capability of introducing considerable fractions of SiC particles, uniform distribution of SiC particles, and low porosity.



Figure 3. TEM image of Mg-6%Zn-0.6%Zn alloy –SiC particle interface, magn. 50000x

Another group of magnesium alloys is designed with addition of rare-earth elements introduced most often in the form of mischmetal (Ce, La, Nd, Pr and other). Composites made on the basis of the GRE3 alloy-matrix featured also good wettability, a uniform distribution of SiC particles within the matrix and a low porosity. The formation of thick layers of a characteristic needle-shaped morphology at the component interface was, however, observed.

Thermodynamic calculations performed for this composite system have made it possible to determine the likelihood of reaction of SiC with rare-earth elements to form carbides and silicides. Detailed identification of compounds will require, however, the use of electron transmission microscopy. TEM micrographs illustrate the needle precipitates at the interfaces between the SiC particles and matrix alloy (Fig. 4). Selected area diffraction patterns allowed top identify the precipitated as the RE₃Si₂ phase (on the base of Ce₃Si₂). The presence of thick layers of a needle-shaped morphology at the component boundary may significantly reduce mechanical properties and decohesion mechanisms at the interface.



Figure 4. TEM image of Mg-3%RE alloy -SiC particle interface, magn. 2000x

It should be also noted that, silicon carbide particles should be surface cleaned prior to being introduced into the magnesium melt. This is because they tend to be covered with a SiO₂ film even at ambient temperatures. In the case of a magnesium matrix, superficially oxidized particles give rise to the occurrence of two unfavourable phenomena. With short times of the process of mixing the liquid composite suspension, the oxide film may remain on the particles, forming an intermediary layer at the component interface (Fig. 5a). or creating the Mg₂Si precipitates at the interface (Fig. 5b). This layers exhibit low strength and contributes to decohesion between the components when composites are deformed.



Figure 5. TEM images of Mg–SiC particle interfaces; a) SiO_2 layer at the interface, magn.20000x; b) Mg₂Si precipitates at the components interface, magn.11500x.

3. CONCLUSIONS

The influence between the matrix and a reinforcement is a very important structural factor influencing the properties of the metal matrix composites. The achievement of the desired composite structure and a bond between the components requires controlling of the phenomena and reactions taking place in these materials. As indicated above, the influence of individual alloying elements on the nature of the magnesium – silicon carbide interfaces is one of the main factors affecting the microstructure of these composites.

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