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Short Communication

The microstructure, hardness and tensile properties of Al–15%Mg_2Si in situ composite with yttrium addition

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ABSTRACT

Current study investigates the effect of different concentrations of yttrium (0.1–1.0 wt.%) on the microstructure, hardness and tensile properties of Al–15%Mg_2Si cast composite. The microstructural study of the composite revealed the presence of both primary and secondary Mg_2Si phases in all specimens and also Y-containing intermetallics at higher concentrations of the respected element. It was also found that Y addition does not change the size and morphology of primary Mg_2Si particles considerably, but the pseudo-eutectic Mg_2Si was changed from a flake-like morphology to fine fibrous or rod-like. The results obtained from mechanical testing demonstrated that the addition of Y increases both hardness and ultimate tensile strength (UTS) values. Further investigations on tensile test revealed optimum Y level (0.5 wt.%) for improving both UTS and elongation values. Fracture surfaces via scanning electron microscopy (SEM) revealed that all specimens with large facets of primary Mg_2Si particles succumb to brittle fracture. The large and brittle Mg_2Si phases may act as crack initiators, while fine rod-like morphology of eutectic Mg_2Si in Al–Mg_2Si–0.5Y can be a barrier to the propagation of cracks and thus enhance the elongation values. At higher Y contents, an intermetallic phase (Al_2Y) introduced on eutectic cell boundaries, appears to be the favored path for crack propagation.

1. Introduction

Conventional processing of metal matrix composites (i.e. ex-situ composites) has some drawbacks that have to be overcome, such as interfacial reactions between reinforcements and matrices. This has led to the development of in situ metal matrix composites (MMCs). In situ synthesizing of MMCs involves the production of reinforcement within the matrix during composite fabrication. The following presents the highlighted advantages they possess as compared to discontinuously reinforced MMCs produced by ex situ techniques: the in situ formed reinforcements are thermodynamically stable in the matrix, leading to less degradation in high temperature services; the reinforcement–matrix interfaces are clean, contributing to an improvement of the wettability; fabrication cost is lowered; the in situ formed reinforcing particles are finer in size and their distribution is more uniform, resulting in better mechanical properties of the MMCs [1].

Al metal matrix composites are one of the best candidates for utilizing structural and functional applications such as aerospace, automotive and defense. Al–Mg_2Si composites have high potential as structural materials because an intermetallic compound of Mg_2Si exhibits a high melting temperature (1085 °C), low density (1.99×10^3 kg m^{-3}), high hardness (4.5×10^9 Nm^{-2}), a low thermal expansion coefficient (7.5×10^{-6} K^{-1}) and a reasonably high elastic modulus (120 GP) [2]. However, the mechanical properties of the Al/Mg_2Si composites are not satisfactory due to the coarse primary Mg_2Si particles [3]. The coarse and rough morphology of Mg_2Si intermetallics in normal Al–Mg_2Si cast composites have been found the main reason for low ductility observed in these materials. Therefore, coarse Mg_2Si particles need to be refined and modified to obtain adequate mechanical strength and ductility. Thus investigations have been carried out to modify the primary and eutectic Mg_2Si structure to improve the properties of these composites such as rapid solidification [4–6], chemical modification [7–18] and heat treatment [19]. Some efforts have been focused on the modification of the structure with the addition of different materials such as mischmetal [3,16], salt mixtures (NaCl, NaF and KCl) [9], K_2TiF_6 [10], extra silicon content [11], Sr [7], Ce [8], Li [13] and P [12]. Similar investigations have been focused on the modification effect of rare earth metals [14,15] and La, Y, Nd containing materials on the eutectic and primary Si crystals in Al–Si alloys [17]. Yttrium was also added into Mg–Mg_2Si composites as a refiner and the size of primary and eutectic Mg_2Si particles was reduced [18]. Recently, Ni was added to the composite and the results showed a great change in the morphology of pseudo-eutectic Mg_2Si phase from flakes to fibers in eutectic structure [20].

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