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The influence of Li on the tensile properties of extruded in situ Al–15%Mg_2Si composite

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ABSTRACT

This work was carried out to investigate the effect of different Li concentrations (0.15, 0.3, 0.5 and 0.7) as a modifying agent on the microstructure and tensile properties of an in situ Al–15%Mg_2Si composite. Cast, modified and homogenized small ingots were extruded at 480 °C at extrusion ratio of 18:1 and ram speed of 1 mm/s. Various techniques including metallography, tensile testing and scanning electron microscopy (SEM) were used to characterize the mechanical behavior, microstructural observations and fracture mechanisms of this composite. The results showed that 0.5%Li addition and homogenizing treatment were highly effective in modifying Mg_2Si particles. The results also exhibited that the addition of Li up to 0.5 wt.% increases both ultimate tensile strength (UTS) and tensile elongation values. However, the tensile results slightly decrease with the addition of more Li (>0.5 wt.%). The highest UTS and elongation values were found to be 280 MPa and 16% for homogenized and extruded Al–15%Mg_2Si–0.5%Li composite, respectively. Fracture surface examinations revealed a transition from brittle fracture mode in as-cast composite to ductile fracture in homogenized and extruded specimens. This can be attributed to the changes in size and morphology of Mg_2Si intermetallic and porosity content.

1. Introduction

For some applications composite materials are considered to be more suitable than conventional materials as they have desirable mechanical, thermal and wear properties. Recently, particulate reinforced composites (PMMCs) have attracted considerable attention due to their relatively low costs and inherent isotropic properties [1–3]. Further, an in situ process of fabricating aluminum MMCs possess some merit, such as even distribution of reinforcement, well matrix/reinforcement interface, thermodynamically stable systems and much lower production costs compared to their ex situ process counterparts. The simple technical process and optimized interface of the in situ MMCs have attracted considerable attention recently [4–6].

The intermetallic compound Mg_2Si exhibits a high melting temperature (1085 °C), low density (1.99×10^3 kg/m^3), high hardness (4500 MN m^{-2}), a low coefficient of thermal expansion (7.5×10^{-6} K^{-1}) and a reasonably high elastic modulus (120 GPa) [7]. In normal as-cast Al–Mg_2Si composites, the primary Mg_2Si phases are usually coarse which lead to the reduced mechanical properties. Therefore, Mg_2Si crystals must be modified to ensure adequate mechanical strength and ductility of the composite [8].

Recently, it was reported that modification of Al–Mg_2Si microstructure has been developed through common gravity casting by additions of rare earth [8,9], potassium fluotitanate [10], Al–Sr master alloys [11], sodium salt [12] or melt superheating treatment [13]. However, some inherent defects are introduced in these PMMCs. For example, potassium fluotitanate [10] addition decreases the size of Mg_2Si particles, while it has no influence on its morphology. Furthermore, although sodium salt can change the size and morphology of Mg_2Si phases, the required amount of the modifier should be too high (10%) [12].

However, the improper control of some process parameters of this technique can lead to some defects in cast composites such as porosity and non-uniform distribution of the particles. Therefore, thermomechanical procedures such as extrusion, rolling or forging seem to be effective ways for decreasing the porosity and obtaining a more uniform particle distribution in such composites [14–19]. Metal forming processes can change the structural features, which influence the properties of these materials [20]. The properties of the MMCs are mainly sensitive to the type of reinforcement and the fabrication processing techniques [21]. For example, in extrusion process the tensile elongation and UTS values of the composite increase, as extrusion ratio increases [22].

While there have been a number of studies to tailor the properties of aluminum using different types and amounts of reinforcement, no attempt has been made to study the effects of hot

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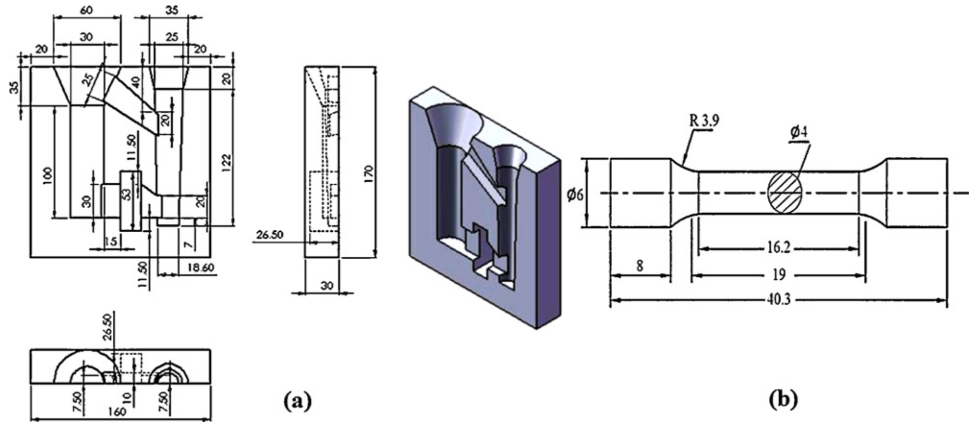

Fig. 1. (a) The schematic of cast iron mould and (b) sketch map of tensile samples.

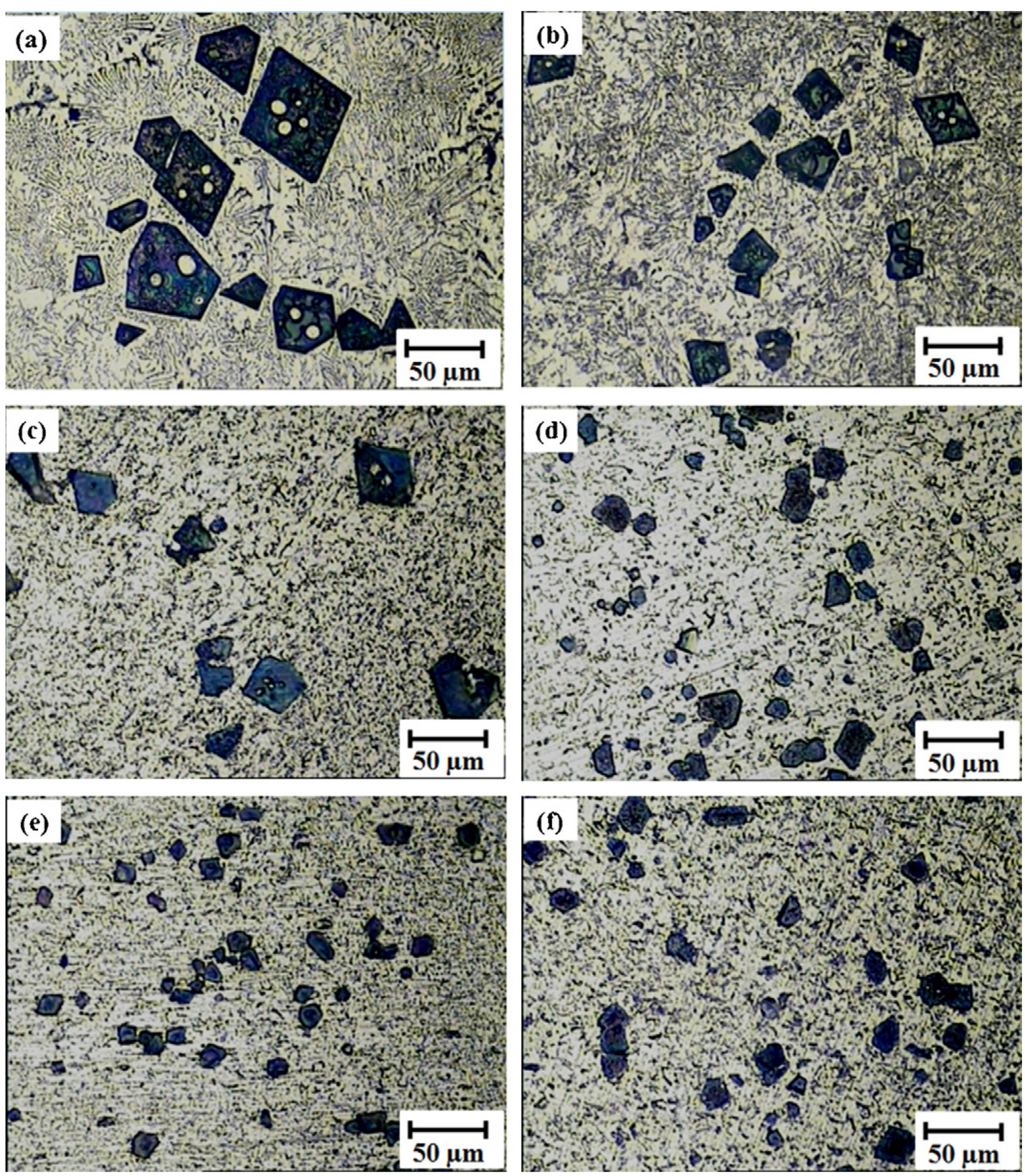

Fig. 2. Typical microstructures of: (a) as-cast Al–15%Mg_2Si, (b) EX-0%Li, (c) EX-0.15%Li, (d) EX-0.3%Li, (e) EX-0.5%Li and (f) EX-0.7%Li.