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The effect of solution temperature on the microstructure and tensile properties of Al–15%Mg_2Si composite

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ABSTRACT

The effect of different solution temperatures has been investigated on the microstructure and tensile properties of in situ Al–Mg_2Si composite specimens were subjected to solutionizing at different temperatures of 300 °C, 350 °C, 400 °C, 450 °C, 500 °C, 550 °C and 580 °C for holding time of 4 h followed by quenching. The microstructural studies of the polished and etched samples by scanning electron microscopy (SEM) in the solution condition indicated that the increase in the temperature changes the morphology of both the primary and secondary Mg_2Si phases. Solutionizing led to the dissolution of the Mg_2Si particles and changed their morphology. Tensile test results indicated that ultimate tensile strength (UTS) gradually decreased upon solutionizing from 300 to 550 °C while further increase in the temperature followed by a sharp decrease in UTS up to 580 °C solutionizing temperature. It was found that the elongation has become three times greater in comparison to the as-cast state. Elongation results showed an increase up to 500 °C and then reduced temperatures of 550 and 580 °C. Fractographic analysis revealed a cellular nature for the fracture surface. On the cellular fracture surface, the features of both brittle and ductile fracture were present simultaneously. As a result of solution treatment the potential sites for stress concentration and crack initiation areas were reduced due to softening of the sharp corners and break up of eutectic network respectively, while increase in the number of fine dimples rendered the nature of fracture to ductile and also increased elongation.

1. Introduction

Al-based composites, reinforced with Mg_2Si particles have been lately introduced as a new group of particulate metal matrix composites (PMMCs) that offer some attractive advantages such as low density, good wear resistance and good castability [1,2]. These composites are considered as new engineering materials and may be viable replacement for some dense alloys in automobile and airplane components. One of the most appropriate techniques to fabricate these composites is in situ process, since advantages like an even distribution of the reinforcing phase; good particle wetting and low costs of production are usually achieved [3].

It can be concluded from the equilibrium phase diagrams of the ternary Al–Mg–Si and binary Al–Mg_2Si [4,5] systems (Fig. 1) that Si can hardly dissolve into solid aluminum and tends to form precipitates with Al or other elements to strengthen the alloy. The equilibrium phase diagram (Fig. 1b) shows that Mg_2Si particles are the primary phase $(Mg_2Si)_P$ during solidification. Then α-Al and secondary Mg_2Si co-solidify from the liquid alloy in the narrow ternary phase area. According to Eq. (1), this pseudo-eutectic reaction is completed at a temperature of 583.5 °C (Fig. 1b) [4,5]:

$$L \rightarrow (Mg_2Si)_P + L_1 \rightarrow (Mg_2Si)_P + (Al + Mg_2Si)_E \quad (1)$$

where E is a Eutectic, P is a Primary, and L_1 is a Liquid in two phase region.

Unfortunately, Mg_2Si particles are prone to coarsen in the cast composite during solidification. It has been found that the coarsening of particles, resulting from the eutectic reaction, greatly deteriorates the mechanical properties, which is an important obstacle for the wide application of this type of composites [3,6–8]. Therefore, several works have been focused on the modification of the composite structure and particularly the Mg_2Si particles with the addition of various alloying elements such as P, Sr, Ce, Ti, B and Zr [5,8–11] and with the use of semi-solid processing techniques [4,9,12].

The heat treatment of Al–Mg_2Si composite can also be effective in improving its mechanical properties by homogenizing the microstructure and better distribution of the alloying elements, dissolving soluble phases containing Si and Mg formed during solidification and spheroidizing the eutectic particles [13]. In Al–Si–Mg alloys, dissolution of Mg_2Si phase can occur due to the high diffusion rate of Mg in Al and also high solution treatment temper-

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