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Effects of Al–5Ti–1B on the structure and hardness of a super high strength aluminum alloy produced by strain-induced melt activation process

M. Alipour *, M. Emamy

School of Metallurgy and Materials Engineering, University of Tehran, Tehran, Iran

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ABSTRACT

In this study the effect of Al–5Ti–1B grain refiner on the structural characteristics and hardness of Al–12Zn–3Mg–2.5Cu aluminum alloy has been investigated. The alloy was produced by modified strain-induced melt activation (SIMA) process. Reheating condition to obtain a fine globular microstructure was optimized. The specimens subjected to deformation ratio of 40% (at 300 °C) and various heat treatment times (5–40 min) and temperature (550–620 °C) regimes were characterized in this study. Microstructural study was carried out on the alloy by the use of optical and scanning electron microscopy (SEM) in both unrefined and Ti-refined conditions. The results showed that for the desired microstructures of the alloy during SIMA process, the optimum temperature and time are 575 °C and 20 min respectively. The hardness test results of the alloy also revealed that T6 heat treatment is more effective in hardness enhancement of all specimens in comparison with SIMA processing.

1. Introduction

Al–Zn–Mg–Cu alloys are used in many industrial applications because of their low density and high strength [1]. These alloys are heat treatable and show attractive properties where good combination of strength and stiffness are obtained particularly after T6 condition [2–4]. Super high strength aluminum alloys have been extensively studied after mechanical deformation for several decades [5–7], but little attention has been made on the alloy in as-cast condition and semi-solid state. As-cast structures of these alloys have a significant influence on their mechanical properties and the quality of finished products [8]. The structure of such materials can be controlled by some important factors such as: changing the composition, adding grain refining agents, minimizing inclusions and applying thermomechanical treatments [9]. The use of high concentrations of alloying elements results inhomogeneity in the microstructure and severe segregation of second phases. In casting products, the mechanical properties may vary from location to location due to the variations of grain size, the amount of eutectic phases and the amount of precipitates. Much attention has been made to reduce the segregation of the alloying elements during solidification period of high-alloyed Al alloys [5,10].

Strain-induced melt activation (SIMA) process has been used to enhance the mechanical properties of Al alloy in recent years. A conventional SIMA process produces the desired structures by deformation and following heat treatment in the mushy zone. Parameters such as heating time, temperature and the degree of cold working are critical factors in controlling the semi-solid microstructures in SIMA process [11–15]. It has been shown that the microstructure of an alloy prepared in the semi-solid state depends on its microstructure prior to partial remelting, so it is important to study the preliminary microstructure and subsequent evolution process during partial melting.

The main objective of this investigation is to study the effect of Al–5Ti–1B and modified SIMA process on the microstructure and hardness of the Al–12Zn–3Mg–2.5Cu alloy. A modified SIMA process includes homogenization and warm deformation instead of cold working in the convectional SIMA process [15]. Fig. 1 shows schematically the modified SIMA process.

2. Experimental procedure

Industrially pure Al (99.8%), Mg (99.9%), Zn (99.9) and Cu (99.9%) were used as starting materials to prepare the primary ingots of Al–12Zn–3Mg–2.5Cu aluminum alloy. An electrical resistance furnace (with a 10 kg SiC crucible) was applied for heating the parent materials and preparing the alloy ingots. Table 1 shows the chemical composition of Al–12Zn–3Mg–2.5Cu alloy. In order to prepare alloys with different Ti concentrations, the parent alloy was remelted in a small electrical resistance furnace (accompanied by temperature measuring system, ±5 °C). Different amounts of Al–5Ti–1B (0.1 wt.%, 0.2 wt.%, 0.6 wt.%, 1 wt.%, 2 wt.%, 6 wt.%, 10 wt.%) were added to the molten alloy at 750 °C. Degassing was conducted by submerging dry C_2Cl_6 tablets (0.3 wt.% of the

* Corresponding author. Tel./fax: +98 21 82096879.
E-mail address: Alipourmo@ut.ac.ir (M. Alipour).

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