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Mechanical properties of 1.5 wt.% TiB_2-added hypoeutectic Al-Mg-Si alloys processed by equal channel angular pressing

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Abstract

In order to improve the mechanical properties and to optimize grain refinement of Al-Mg-Si alloy, ECAP processing with an addition of hard particle TiB_2 is applied in this work. Mechanical property and microstructural evolution of Al-0.3Mg-7Si+1.5 wt.% TiB_2 specimen were investigated by using hardness-testing, optical micrograph observation and electron-backscattering diffraction (EBSD). ECAP processing was done through B_A route for 4 passes at room temperature. Hardness test results show that the ECAP process doubled the hardness of the specimen compared to annealed specimen, and from EBSD/OIM analysis, the ECAP processing refined grains from an average grain size of 35μm to 0.79 μm and led to producing grains having high misorientation angle (≥15°).

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Keywords: Al-Mg-Si, ECAP, EBSD, grain refinement.

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1. Introduction

Al-Si system alloys have been widely used in many engineering applications such as in aerospace and automobile industries due to excellent castability, good mechanical properties and corrosion resistance[1]. The addition of magnesium to the alloys improves heat treatment capability by formation of secondary phase (Mg_2Si precipitate) in the structure. This precipitate increases mechanical properties of the alloys[2,3]. The mechanical properties of Al-Si alloys can further be improved by addition of ceramics such as Al_2O_3, TiC and TiB_2. Titanium diboride (TiB_2) has emerged as an outstanding reinforcement of soft metal like aluminium and its alloys because TiB_2 exhibits outstanding features such as high melting point (2790°C), high hardness (960 HV), high modulus of elasticity ($530x10^3$ GPa) and good thermal stability[4]. And among ceramic materials, TiB_2 has an additional advantage, that is resistant to pull-out damage. The addition of hard particles to Al-Si alloys can increase its mechanical properties but at the same time it will lower its ductility. So to encounter this problem, microstructure modification can be done. It is well known that grain size is one of principal tools for controlling mechanical properties of polycrystalline metallic materials. Severe plastic deformation (SPD) techniques represent a group of metal forming processes for obtaining significant grain refinement[5]. Equal channel angular pressing (ECAP) is one of severe plastic deformation (SPD) processes for producing submicron to nanocrystalline bulk materials[6]. Microstructure evolution during ECAP is also determined by chemistry of the alloys and presence of second phase precipitates or particles in the microstructure before ECAP process[7]. An optimum ultra-fine grain microstructure with the finest grains and the highest fraction of high angle grain boundaries (HAGBs) is attained when ECAP processing is performed at the lowest possible temperature. The aim of the present work, therefore, was to study the microstructural evolution and hardness of Al-Mg-Si specimen subjected to ECAP in combination with TiB_2 addition. Specific attention was given to clarify the effect of fine TiB_2 particles on promoting grain refinement.

2. Experimental details

Casting process was done by melting the mixtures of pure aluminium, pure silicon, pure magnesium, aluminium alloys ingot of A357 type and master alloy Al-5Ti-1B. The melting temperature of casting process was at 680°C, and the molten metal was poured into metal mould pre-heated at 250°C. The shape of the as-cast specimens is rod with 13 mm in diameter and 70 mm in length. The chemical composition of the as-cast specimen is shown in Table 1 by X-ray fluorescence characterization.

Table 1. Chemical composition of as-cast specimen (wt.%)

Specimens	Si	Mg	Mn	Cu	Fe	Zn	Ti	Al
Al-0.3Mg-7Si	7.01	0.29	-	0.07	0.24	0.02	-	92.26
Al-0.3Mg-7Si + 1.5 wt.%TiB_2	7.64	0.29	0.01	0.02	0.18	0.01	1.98	89.79

The element of boron (B) could not be detected by X-ray fluorescence characterization due to low atomic number, so to prove the existence of boron as a TiB_2 constituent, X-ray diffraction characterization was used, as shown in Fig. 1.

To prevent occurring cracks of the as-cast specimens if processed through ECAP, the as-cast specimens were annealed prior to ECAP processing. The annealing was carried out at temperature 540°C for 8 hours, then followed by furnace cooling.