Materials and Design 36 (2012) 451–458

Contents lists available at SciVerse ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Effect of copper addition on wear and corrosion behaviours of Mg_2Si particle reinforced composites

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ARTICLE INFO

Article history:
Received 11 October 2011
Accepted 22 November 2011
Available online 29 November 2011

Keywords:
A. Nonferrous metals and alloys
E. Wear
E. Corrosion

ABSTRACT

The purpose of this study is to investigate the effect adding Cu has on the wear and corrosion properties of "in situ" Mg_2Si particle reinforced Al–12Si–20Mg matrix composites, produced with help of the nucleation and growth of the reinforcement from the source matrix, in order to overcome the disadvantages of composites produced by externally reinforcing ceramic particles. Composites known as Al–12Si–20Mg–XCu were produced by adding Cu, at the rate of 1%, 2%, and 4%, to the Al–12Si–20Mg alloy in order to achieve this purpose. The microstructural characterisation, hardness, wear and corrosion properties of composites, produced using the casting method, were analysed. Dry environment wear experiments for investigated alloys were conducted using a pin-on-disc type wear device under different loads and at different sliding distances. The change in weight loss of the solution containing 30 g/l NaCl + 10 ml/l HCl, and the tafel extrapolation method were used to analyse corrosion behaviour. Results of microstructural characterisation concluded that as the amount of Cu added to the Al–12Si–20Mg alloy increased, the size and volume of the Mg_2Si particle, formed within the matrix, decreased, and $CuAl_2$ intermetallics formed within the matrix. Results of wear experiments concluded that adding Cu developed wear resistance under small loads; however, reduced wear resistance under high loads. According to results of corrosion experiment, corrosion resistance increased with the addition of Cu.

1. Introduction

Finding out the tribological behaviour, and investigating the production of Al–Si–Mg alloys have gradually gained great significance ever since Al–Si–Mg alloys have started being used in tribological applications, such as internal combustion engine, pistons, liners, clutches, pulleys, and shafts [1]. Controlling their microstructure via suitable casting procedures, applying heat treatment, or adding minor alloying elements allow to improve mechanical, corrosive and wear characteristics of these alloys. Adding alloying elements is the easiest and the most efficient method to improve the mechanical properties of alloys [2,3].

For many commercial Al alloys, the desirable mechanical properties are developed by adding alloys and applying heat treatment to heterogeneous microstructures. It is possible that adding alloying elements has effect on the wear properties of Al–Si–Mg, since it strengthens them through solid solution and hardening precipitation [4]. Ce, Cu, Cr, Fe, Mn, Ti, Zn, and Zr are some of the alloying elements that are added to these alloys. The added alloying elements either dissolve or form compounds within the microstructure [5].

It is a well-known fact that the size of the reinforcement, the volume ratio, and the nature of the matrix–reinforcement interface control the characteristics of the metal matrix composites. Optimum mechanic characteristics are obtained when ceramic particles, relatively thin and thermally stable, are uniformly distributed within the metal matrix [6]. Efforts made to meet such requirements result in developing new composites. These new composites are in situ metal matrix composites produced by the reinforcement formation within the metallic matrix as a result of chemical reactions that develop between the element and compounds and/or elements during the process of composite production. As a result, new "in situ" particle reinforced composites have recently started being produced with the help of the nucleation and growth of the reinforcement from the source matrix, in order to overcome the disadvantages of composite production performed by externally reinforcing ceramic [7,8].

There are numerous studies in literature [9–14] that refer to the production of in situ composites containing Mg_2Si particles as reinforcement. However, the number of studies that investigate the wear and corrosion behaviours of in situ composites is limited. Hence, this study investigates the production, microstructural characterisation, hardness, wear, and corrosion characteristics of in situ Mg_2Si particle reinforced Al–12Si–20Mg alloy matrix composites, containing different rates of Cu, produced using modified conventional casting method.

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doi:10.1016/j.matdes.2011.11.052

Table 1
The chemical composition of the Al–12Si–20Mg alloy.

Alloys	Si (%)	Mg (%)	Fe (%)	Cu (%)	Mn (%)	Zn (%)	Ti (%)	Al (%)
Al–12Si–20Mg	12.2	19.1	2.1	0.3	0.3	0.1	0.05	65.9

2. Experimental details

The investigated alloys in the study were produced in an atmosphere controlled 1200 °C capacity electric resistance furnace. Prior to producing the final alloy containing a high rate of Mg, a master alloy was produced by adding 1%, 2% and 4% Cu to a 12% Si weighted commercial Al ingot alloy. The alloy elements added were pure 20% Mg, 0.05% Strontium, 0.2% red phosphorus, and 0.3% NaCl + $30MgCl_2$ + 10KCl salt mixtures were added to the fusion created by melting the readymade master alloy at 800 °C that was pre-heated at 300 °C in order to produce the final alloy. Strontium, red phosphorus, and salt mixture were used to modify the microstructure of the final alloy. All of the above mentioned additions were charged over 15% by weight to compensate for the loss of oxidation. The surface of the melt was coated with a preservative substance and Ar gas. The degassing process was carried out using a liquid alloy with a 0.4% C_6Cl_6 by weight. The melt was poured into a 300 °C metallic mould in order to produce bar shaped ingots, with a diameter of 20 mm and a length of 250 mm. Table 1 illustrates the chemical composition, determined using the optical emission method, of the Al–12Si–20Mg alloy.

In accordance with the standard metallographic procedure, including a grinding process up to 1200 mesh and a following polishing process with a diamond solution conducted on the specimens, microstructural analysis on the prepared specimens was conducted using light optical microscopy (LOM) and a scanning electron microscope (SEM). XRD analyses were carried out by Philips PW1710 model X-ray diffractometer using Cu Kα radiation. Diffraction patterns were obtained over range of Bragg angle from 10° to 90°. The microstructure images were taken using a Leica DM ILM light optical microscope with a Leica DFC290 camera system, and a Jeol 6060 SEM. Energy Dispersive Spectroscopy (EDS) analyses were carried out on the light and grey coloured spots in the microstructural images, captured during investigations carried out using the SEM Jeol 6060.

The mechanical properties of the alloys, at room temperature, were determined using hardness tests, which were carried out in a Shimadzu HMV2 microstructure test device where a 1000 g immersion load was applied using a Vickers indenter. The mean of 10 successful measurements was taken to establish the hardness values.

The dry environment wear tests of the investigated alloys were carried out using a pin-on-disc type wear device. A 10 mm-diameter and 20 mm-long test specimen and a stainless steel disc with a hardness of 59 HRC was used as the counter face in the wear tests carried out on the specimens. The specimens were tested under 3 N, 5 N, and 20 N, at a sliding rate of 0.5 m/s, and a sliding distance of 2000 and 4000 m. The weights of the samples were measured before and after the experiment using electronic scales with 0.1 mg accuracy, after which the results of the experiment were evaluated according to the loss in weight. The surface of the specimens were analysed using LOM

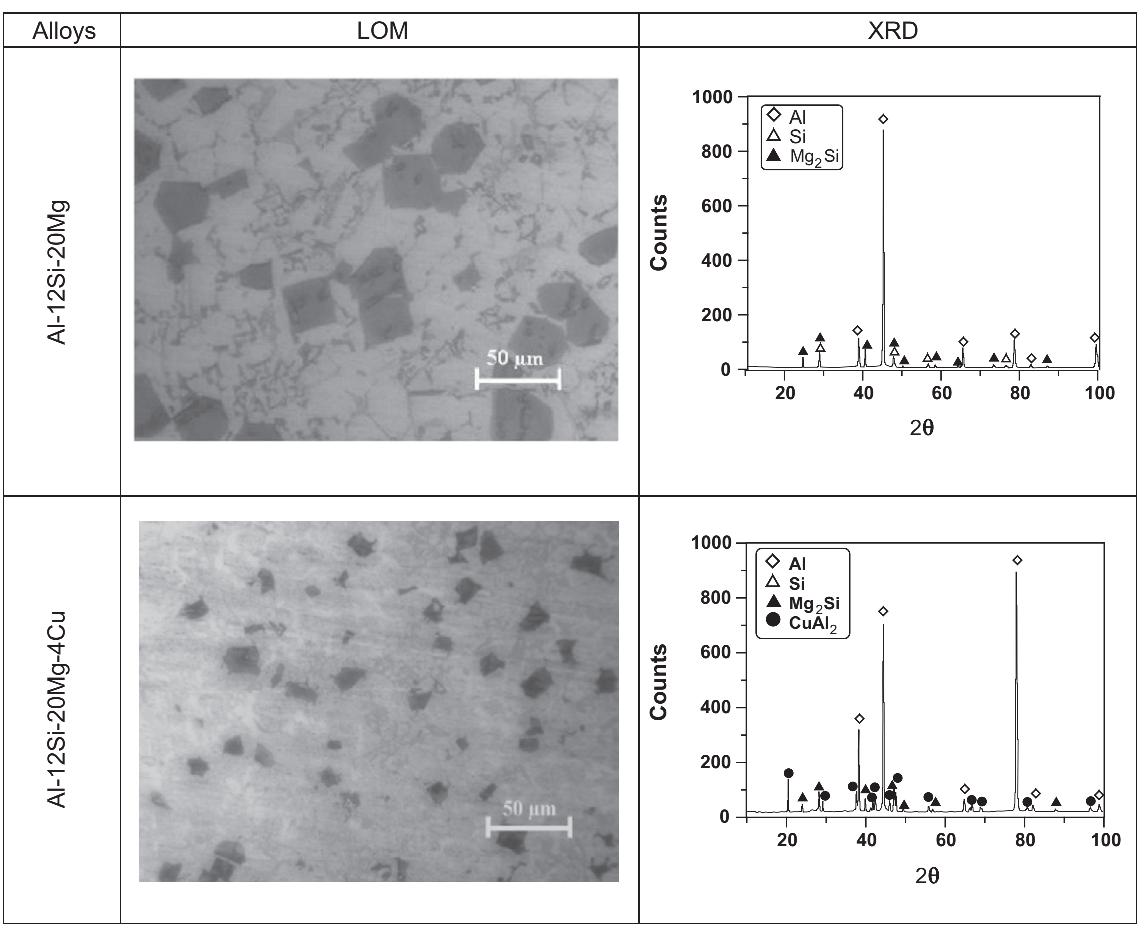

Fig. 1. LOM micrographs and XRD patterns of the Al–12Si–20Mg and Al–12Si–20Mg–4Cu alloys.