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Corrosion resistance of directionally solidified Al–6Cu–1Si and Al–8Cu–3Si alloys castings

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ABSTRACT

The aim of this article is to compare the electrochemical corrosion resistance of two as-cast Al–6 wt.% Cu–1 wt.% Si and Al–8 wt.% Cu–3 wt.% Si alloys considering both the solutes macrosegregation profiles and the scale of the microstructure dendritic arrays. A water-cooled unidirectional solidification system was used to obtain the as-cast samples. Electrochemical impedance spectroscopy (EIS) and potentiodynamic anodic polarization techniques were used to analyze the corrosion resistance in a 0.5 M NaCl solution at 25 °C. It was found that the Al–8Cu–3Si alloy has better electrochemical corrosion resistance than the Al–6Cu–1Si alloy for any position along the casting length. At the castings regions where the Cu inverse profile prevailed (up to about 10 mm from the castings surface) the corrosion current density decreased up to 2.5 times with the decrease in the secondary dendrite arm spacing.

1. Introduction

In order to address the increasing demand for high performance high quality die castings for a number of applications in the industry, a variety of aluminum based engineering casting alloys have been developed.

Al–Cu–Si alloys are widely applied in both automotive and aerospace industries, mainly as light constructional materials [1–4]. These alloys have also been applied as thin-film interconnects in microelectronic devices [5]. In their composition, copper is added largely to increase the mechanical strength [2,6]. Due to the intermetallic Al_2Cu phase acting in the alloy microstructure as a cathode with respect to the Al-rich phase, the susceptibility to pitting corrosion is increased with copper additions [6–9].

A number of studies in the literature reported the effects of microstructural parameters of binary metallic alloys upon the mechanical properties and corrosion resistance, highlighting the significant role of the scale of dendritic arrays on the final properties [10–15]. Normal and inverse macrosegregation profiles can also affect the local mechanical properties of both binary and ternary alloys castings [16]. A recent study reports the effects of macrosegregation and dendrite spacings on the electrochemical corrosion behavior of a binary Al–Cu alloy [9]. However, studies dealing with the analysis of the simultaneous effects of macrosegregation and the scale of the microstructural dendritic array on the corrosion resistance of ternary Al–Cu–Si alloys cannot be found in the literature.

The aim of this article is to evaluate the local effects of Si and Cu contents and dendrite arm spacings on the electrochemical corrosion behavior of two directionally solidified ternary Al–Cu–Si alloys castings.

2. Experimental procedure

Experiments were carried out with Al–6 wt.% Cu–1 wt.% Si (Al–6Cu–1Si) and Al–8 wt.% Cu–3 wt.% Si (Al–8Cu–3Si) alloys, which were prepared by using commercially pure metals: Al (99.72 wt.%), Cu (99.92 wt.%) and Si (99.68 wt.%). The mean impurities detected were: Fe (0.25 wt.%), Pb (0.03 wt.%), Zn (0.01 wt.%) and Ni (0.01 wt.%), besides other elements found with concentrations less than 50 ppm.

In order to obtain directionally solidified castings of Al–6Cu–1Si and Al–8Cu–3Si alloy samples a water-cooled solidification set-up was used. This solidification set-up was designed in such way that the heat was extracted only through the water-cooled bottom, promoting vertical upward directional solidification. More details about the experimental procedure can be found in previous articles [9–16].

As-cast Al–Cu–Si alloys samples were selected as the working electrodes for the corrosion tests, which were positioned at the glass corrosion cell kit, leaving a circular 1 cm^2 metal surface in

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