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Co-extrusion of Dual Aluminum Alloys with Special Surface Properties

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Abstract

Co-extrusion method is used for production of a dual Aluminum rod. The surface layer material for co-extrusion is prepared by rapid solidification process. The alloys Al–4.5Mg–1.0Ag (wt%) and Al–4.5Mg are selected as the surface and the bulk materials, respectively, and are co-extruded at high temperature range (450–480°C). The microstructures of rapid solidified Al in co-extruded rod consist of small grains (50μm) and some small particles (0.1–1μm). A proper annealing on the extruded rod increases the surface hardness more than 30%. Since the co-extruded material contains small T-phase particles, this increase in hardness indicates precipitation of a metastable Mg–Ag phase or a Mg–Ag–Al phase at 160°C during annealing.

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1. Introduction

As a crucial engineering material, Aluminum alloys are increasingly used in the automotive and transport

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industries, which have become the fastest growing markets for Al suppliers. The conventional process route for production of Al products, such as extruded sections, tubes or forged products is DC (direct chilled) casting, followed by homogenization, extrusion, forging and age hardening. For high-alloyed materials, this process route has its limitations because the solidification during DC casting is so slow that the material generates large macro-segregations if the alloying content is above 5–10 wt% [1, 2]. An alternative to the conventional DC casting process for such alloys is the rapid solidification process [3]. With this process, it is possible to achieve a very small-scaled crystalline structure and a homogeneous microstructure even for high alloyed materials. These factors can contribute to significant improvement with regard to material properties, with high yield strength, excellent fatigue resistant properties, reasonable ductility, high wear resistance and low thermal expansion coefficient. Such materials therefore have a great potential for automotive, aerospace and defense applications.

Various production techniques are used to produce rapid solidified (RS) material. Both melt spinning process and centrifuge melt spinning process are developed in SINTEF and NTNU [4, 5] for RS Al production. During the melt spinning process, liquid Al is poured onto a fast-rotating copper wheel, causing very rapid solidification and forming a very thin metal ribbon. Our previous investigations [4, 5] have shown that RS Al alloys with excellent fatigue resistant properties can be obtained with only small intermetallic particles. Excellent properties with high pitting corrosion resistance can also be made from Al materials even without particles. Alloying elements with a high solubility, such as magnesium, zinc, silver and to some extent manganese, copper and chromium, are highly desirable for such purpose.

To improve the production efficiency of lightweight parts through the combination of multi-materials and forming technologies, this investigation aims to examine the possibility to combine the production of RS Al-material with co-extrusion method for production of a dual Al rod with high strength and/or excellent corrosion resistant properties at the surface and a ductile alloy in the bulk. As the surface layer is expected to be thin, pure Al without the common impurities and more exotic elements like Ag, Sc etc. can be used in the RS material for making the surface layer. The commercial Al materials as the bulk alloy also should have a low content of impurities. In doing so, a process route through production of RS Al, compaction of RS Al ribbons, and co-extrusion of RS Al with base Al alloys is proposed.

The first part in this paper focuses on alloying for Al RS and base metals, rapid solidification, compacting of the RS material and successive co-extrusion. The second part is the microstructure analysis by EDS and hardness measurement of the co-extruded material, and annealing of the co-extruded rod and subsequent analysis.

2. Experimental

2.1. Alloying

The base material is Al-4.5wt%Mg produced in Hydro Aluminium at Sunndal Verk. The compositions are determined by emission spectrometer. The main result is seen in Table 1. The material is grain refined with about 66 ppm borides, and is also expected to be refined by 64 ppm TiB_2 and Ti in solid solution [1].

Table 1. Base alloy compositions (wt%)

Si	Fe	Mg	Zn	Ti	Ni	Pb	Sn	Ca	B	Zr	V	Ga	Al
0.0753	0.0705	4.5252	0.0034	0.0173	0.0031	0.0021	0.0004	0.0004	0.0030	0.0017	0.0059	0.0087	95.2837

For RS-material the same alloy is used except that 1wt% Ag is added. Silver is selected as it may interact with Magnesium and form particles for strengthening or remain in solid solution. The Al–4.5Mg is remelted in a graphite crucible and cast as rods with 40-44 mm in diameter. Then Al–4.5Mg–1.0Ag is alloyed by adding silver at 720°C and cast in a graphite crucible with an inner diameter of 40mm.

2.2. Rapid solidification, compacting and co-extrusion

The rapid solidification device used is a laboratory scale melt spinning machine at NTNU/SINTEF. The working zone is shown in Figure 1a. The casting alloys are heated in a closed crucible by induction heating until melting at

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