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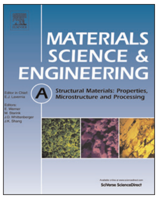

Microstructures and properties of Al–Mg–SI alloy overhead conductor by horizontal continuous casting and continuous extrusion forming process

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ABSTRACT

Al–Mg–Si alloy overhead conductor was prepared by horizontal continuous casting and subsequent continuous extrusion forming. The mechanical properties, electrical conductivity and microstructural evolution of the processed conductor were characterized. It was indicated that improved combined mechanical and electrical conductivity properties were obtained for the processed alloy wires when compared with previously reported results. The enhanced properties were associated with the continuous in-line solution treatment and the refined and homogeneous (sub)grains during horizontal continuous casting and subsequence continuous extrusion forming, as well as a high density of dislocations and finer Mg_2Si precipitates formed after drawn and followed by aging at 155 °C for 3 h.

1. Introduction

Al–Mg–Si alloys are widely used in transmission lines owing to its light weight, good corrosion properties, excellent strength and high conductivity [1–3]. Several typical methods have been developed for production of Al–Mg–Si alloys conductor, which were: (a) conventional extrusion-drawing method: including semi-continuous casting, homogenization, extrusion, solution treatment, drawing and artificial aging; (b) continuous casting and rolling (CCR) without in-line solution treatment: including continuous casting and rolling, solution treatment, drawing and artificial aging; (c) continuous casting and rolling with in-line solution treatment: including continuous casting and hot rolling, drawing and artificial aging. Among these processes, in-line solution treatment is the key technology, which can be helpful for subsequence drawing and artificial aging.

Horizontal continuous casting (HCC) has been widely employed in casting of nonferrous metal wires such as aluminum, magnesium, zinc, copper and their alloys due to its characteristic superiorities which includes low investment cost, low energy consumption, high efficiency and high surface quality [4–7]. Continuous extrusion forming process, i.e. Conform process, was widely used in the efficient continuous production of Al alloys and other metals. This process owns the advantages of saving energy, high extrusion ratio and production efficiency, superiors in length and homogeneity of the production and so on [8]. Variety forms of products including tubes, solids, complex profiles and coaxial products can be produced by the Conform process [9,10]. Zhang et al. [11] investigated the microstructure and properties of Al–0.63Fe–0.24Cu alloy conductor prepared by horizontal continuous casting and subsequent continuous extrusion forming and found that the processed alloy had good comprehensive mechanical properties and electrical conductivity. Mitka et al. [12] investigated the 6063 aluminum alloy processed by the Conform process and reported superior mechanical properties, regular structure and high surface quality after continuous extrusion forming. However, few studies on the Al–Mg–Si alloys conductor processed by HCC and Conform process have been reported.

In this work, Al–Mg–Si alloy overhead conductors were prepared by horizontal continuous casting and subsequent continuous extrusion forming, and the microstructural evolution and properties are characterized. The objective is to explore the possibility of achievement for Al–Mg–Si alloy overhead conductor with continuous in-line solution treatment, and improve its properties based on horizontal continuous casting and subsequence continuous extrusion forming.

2. Experimental procedures

The processing routes diagram is shown in Fig. 1. The

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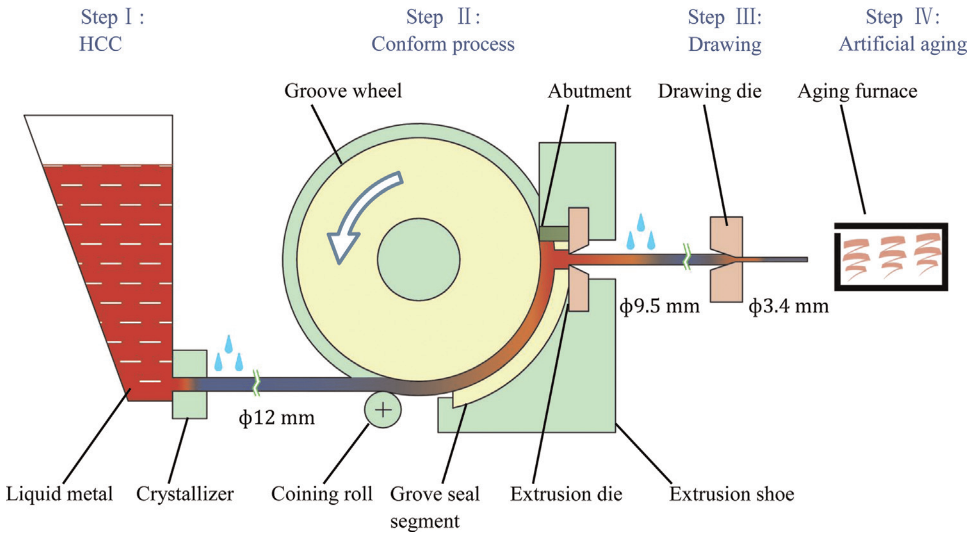

Fig. 1. Processing routes diagram of HCC, Conform, drawing and artificial aging.

experiments were performed on the Al–Mg–Si alloy rod stocks with diameter of 12 mm, which were prepared by the HCC. The chemical compositions of the experimental alloy were 0.65Mg, 0.58Si, 0.17Fe, 0.002Cu, 0.002Mn, 0.03B and balance Al (wt%). Then the as-cast rods were cleaned and extruded to coiled material with diameter of 9.5 mm on the LJ300 continuous extrusion forming machine. The wheel revolving speed was 22 rpm and the die exit temperature was about 430 °C. After extrusion, the extruded materials were water-cooled at about 2 m away from the die exit. Then the extruded coiled material was drawn into wires with diameter of 3.4 mm at room temperature and followed by artificially aging at 155 °C, 165 °C and 175 °C, respectively, the aging time ranged from 1 to12 h.

Vickers microhardness measurements were performed by using 100 gf load for 15 s on the surface of the aged samples for at least 5 readings. Tensile strength was tested on a computer-controlled INSTRON 3382 universal testing machine at a constant strain rate of $1\times10^{-3}\ \mathrm{s}^{-1}$, and the microcosmic fracture features of the tensile specimens was also examined on the QUANTA200 SEM. Electrical conductivity was measured and adjusted by employing a four-probe method at room temperature. The microstructures were characterized by optical microscopy (OM) and JEM-3010 transmission electron microscopy (TEM). The X-ray diffraction (XRD) spectra was recorded by a Siemens D5000 diffractometer system with monochromated CuKα radiation operating at 40 kV and 300 mA. The step size and scanning speed were set to 0.04°/min and 5.00°/min, respectively.

3. Results and discussion

3.1. Microhardness and electrical properties variation during artificial aging

The Vickers hardness variation of the processed Al–Mg–Si alloy wires under various aging time are shown in Fig. 2. It was indicated that the aging behavior was influenced by the aging time and aging temperature. Obvious age hardening was observed during artificial aging. As the aging time increases, the hardness firstly increased very fast and reached a peak, and then it gradually declined, rebounded and reached a second peak. It is obvious that the second peak is lower than the first one. The higher temperature accelerates the hardness reach to the peak, but result in a lower value of hardness. In general, optimized artificially aging temperature was determined to be 155 °C which gained higher hardness values and better stability.

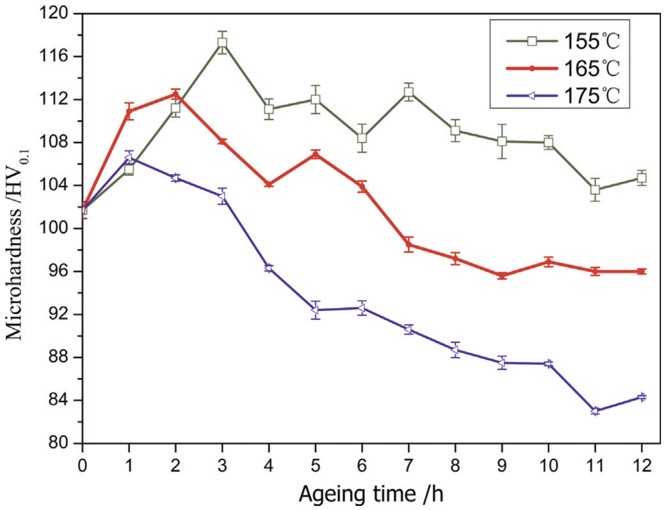

Fig. 2. Microhardness curves of the Al–Mg–Si alloy wire during artificial aging.

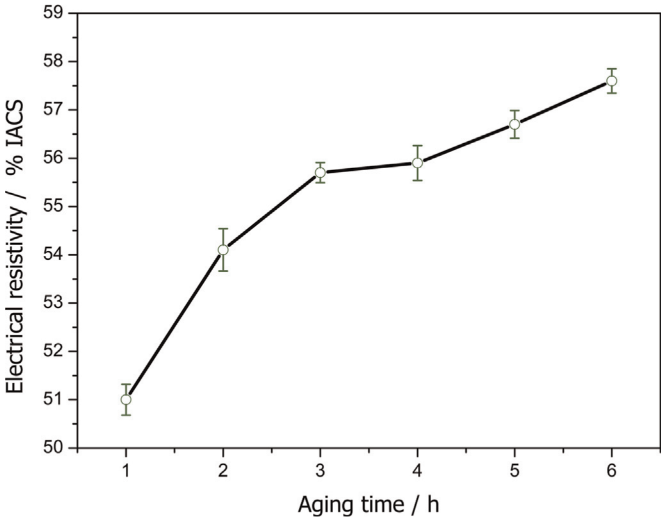

Fig. 3. Electrical conductivity of the Al–Mg–Si alloy wire during artificial aging.

Fig. 3 shows the electrical conductivity curves during artificially