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Short Communication

Effects of thermal treatment on precipitate shape and mechanical properties of Mg–8Gd–4Y–Nd–Zr alloy

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ABSTRACT

Precipitation reactions in a Mg–8Gd–4Y–Nd–Zr alloy have been investigated using TEM, HREM, hardness measurements and tensile testing. Globular β′ precipitates, which were different from the typical plate-shaped β′ precipitates usually observed in Mg–Gd-based alloys, were detected in the 160 °C/192 h-aged sample. Instead of dissolution and then precipitating as plate-shaped β′ precipitates, the formed globular β′ precipitates grew up when further aged at 215 °C, which resulted in the decrease in strength comparing with that of the 215 °C single-stage aged samples. Two-stage ageing treatments on the alloy demonstrated that ageing 192 h at 150 °C plus 16 h at 215 °C made the ultimate strength and the yield strength improved 17 MPa and 13 MPa, respectively.

1. Introduction

Magnesium–rare earth alloys, particularly those based on the Mg–Y–Nd and Mg–Gd–Y systems, have great potential in aerospace and racing automotive industries due to their attractive properties [1]. Both of the two alloy systems are precipitation-hardenable, and precipitation strengthening is the main strengthening mechanism [2]. Thus, the precipitation reactions in these alloys have attracted considerable attention [3–8]. The precipitation sequence has been determined to be Mg (SSSS) → β″ → β′ → β_1 → β [3,4,6,9–11]. The β″ phase usually formed at the initial stage of ageing [4,6–8,10–13]. It is fully coherent with the matrix and the composition was identified as Mg_3RE [12,13]. The β′ phase, which is usually detected in the peak-aged samples, was considered to be the main strengthening phase [2]. The β_1 phase was observed to nucleate at the interface of the β′ precipitates with the matrix [3,9,14], and it will transform in situ to the equilibrium β phase [3,14]. Moreover, the precipitate morphology, as another key factor for strengthening, has also been proved to play an important role in mechanical properties of magnesium alloy [15]. However, the morphology of the most effective strengthening phase β′ in the Mg–Gd-based alloys has rarely been discussed. In order to optimize the properties of the alloy, it is necessary to correlate the precipitate morphology to heat treatment. In this paper, for the first time, we investigated the effects of ageing treatment on precipitate morphology and mechanical properties of Mg–8Gd–4Y–Nd–Zr alloy.

2. Experimental procedures

An alloy ingot with a nominal composition of Mg–8.0Gd–4.0Y–1.0Nd–1.0Zr (wt.%) was prepared from high purity Mg (>99.93%), Mg–31.25Gd (wt.%), Mg–25.48Y (wt.%), Mg–30.15Nd (wt.%) and Mg–30.23Zr (wt.%) master alloys by melting in a mild steel crucible at 760 °C under argon atmosphere. The actual chemical composition of the ingot was determined to be Mg–7.71Gd–3.45Y–1.02Nd–0.51Zr (wt.%). The ingot was quenched into cold water after solution heat treatment at 520 °C for 12 h, and then it was cut into 15 mm × 15 mm × 2 mm pieces by electric-sparking wire-cutting machine. The as-quenched samples started to age at different temperatures within 24 h. Hardness tests were performed on a HV-10B type Vickers microindenter, with a load of 30 N. The reported values in this paper were the average of nine indentations. The samples for tensile testing were machined into 5 mm gauge in diameter and 25 mm gauge length [16]. Tensile testing was carried out on a MTS universal materials testing machine at a crosshead speed of 1 mm/min. Samples for transmission electron microscopy tests were ion milled using the Precision Ion Polishing System (GATAN 691). Microstructure observations were performed in JEM-3010 and Tecnai G2 20 transmission electron microscopes.

3. Results and discussion

3.1. Age hardening behaviour

Fig. 1 shows the hardness curves of the samples aged at the temperatures ranging from 120 °C to 215 °C. The temperatures can be divided into three ranges according to the hardness increasing trend: (I) 120 °C–150 °C, (II) 160 °C–200 °C, (III) 215 °C. The critical

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