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Influence of heat treatment on microstructure and mechanical properties of as-cast Mg–8Li–3Al–2Zn–xY alloy with duplex structure

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ABSTRACT

In this study, the microstructure evolution and mechanical properties of as-cast Mg–8Li–3Al–2Zn–0.5Y alloy during solid solution treatment from 300 °C to 450 °C were firstly investigated, and then the effect of Y content (from 0.5 wt% to 1.5 wt%) on the age softening of solid solution treated Mg–8Li–3Al–2Zn alloy was also analyzed. The results show that the as-cast Mg–8Li–3Al–2Zn–0.5Y alloy mainly consists of α-Mg, β-Li, Al_2Y and AlLi phases. With the increase of solid solution temperature from 300 °C to 450 °C for as-cast Mg–8Li–3Al–2Zn–0.5Y alloy, the AlLi phase is decomposed and the atoms of Al and Li dissolve into the matrix gradually. The hardness, yield strength and ultimate tensile strength of the tested alloy are increased dramatically; however, the ductility is relatively decreased. Meanwhile, the room temperature aging treated Mg–8Li–3Al–2Zn–0.5Y has age hardening during initial time, and the addition of Y is helpful to the thermal stability of Mg–8Li–3Al–2Zn alloy. In addition, the fracture behavior and strengthening mechanism of the studied alloys were also investigated systematically.

1. Introduction

In recent years, Mg–Li alloys have drawn increasing attentions because of their impressive advantages, such as high specific strength and stiffness, good magnetic shielding and damping capacity [1]. The density of Mg–Li alloys is lower than that of normal Mg alloys by 15–25%, and lower than that of Al alloys by about 50% [2,3]. Therefore, Mg–Li alloys are ideal materials in the fields of aerospace, military industry and 3C (Computer, Communication and Consumer Electronics) industry, etc. [4,5]. And according to the Mg–Li phase diagram, when Li content is between 5.7 wt% and 10.3 wt%, the BCC structured β-Li phase of the Li solid solution coexists with the HCP structured α-Mg phase of the Mg solid solution. The alloys with this structure have excellent integrated tensile properties [6,7]. However, wide application of Mg–Li alloys is restricted by their low strength. The addition of alloying elements and heat treatment are the major methods to improve the mechanical properties of Mg–Li alloys [8,9].

Al and Zn are common alloying elements in Mg–Li alloys. The Mg–Li–Al and Mg–Li–Zn alloys have been conducted by a lot of researches [6,7,10–16]. With the increase of Al and Zn contents, the mechanical properties of alloys were improved. Moreover, it has been proved that Y element is effective in improving the strength of Mg–Li–Al–Zn alloy with grain refinement strengthening and second phase strengthening [10,17,18]. In addition, as some recent researches [19–21], solid solution treatment is an effective way to optimize the microstructure and the hardness of Mg–Li alloys. However, the influence of solid solution treatment on tensile properties of Mg–Li alloys has been few reported so far.

In this study, as-cast Mg–8Li–3Al–2Zn–0.5Y alloy was selected as the research subject because of its good tensile properties [10]. The effects of solid solution treatment on the microstructure and mechanical properties of the Mg–8Li–3Al–2Zn–0.5Y alloy were investigated. And then, the influence of Y content on the age softening of the Mg–8Li–3Al–2Zn alloy was also analyzed.

2. Experimental procedure

Four alloys with nominal compositions of Mg–8Li–3Al–2Zn–xY (x=0, 0.5, 1 and 1.5 wt%, Mg–8Li–3Al–2Zn was named as LAZ832) were prepared by melting commercial pure (CP) magnesium (99.9 wt%), lithium (99.9 wt%), aluminum (99.9 wt%), Zinc (99.9 wt%) and Mg–20 wt% Y master alloy in a vacuum induction melting furnace under the protection of argon gas. After melting, the melt was poured into a steel mold to form as-cast specimens.

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Table 1.
Chemical composition of the studied alloys.

Alloy	Contents (wt%)				
	Li	Al	Zn	Y	Mg
LAZ832	8.02	2.94	1.76	–	Bal.
LAZ832–0.5Y	7.70	2.98	1.99	0.40	Bal.
LAZ832–1Y	8.01	3.09	2.09	0.85	Bal.
LAZ832–1.5Y	7.95	2.87	2.01	1.24	Bal.

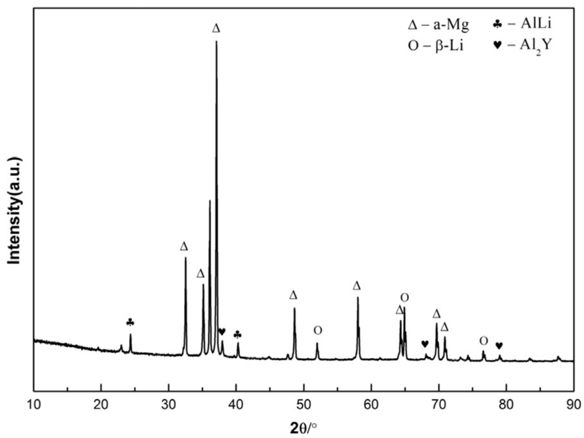

Fig. 1. XRD pattern of the as-cast LAZ832–0.5Y alloy.

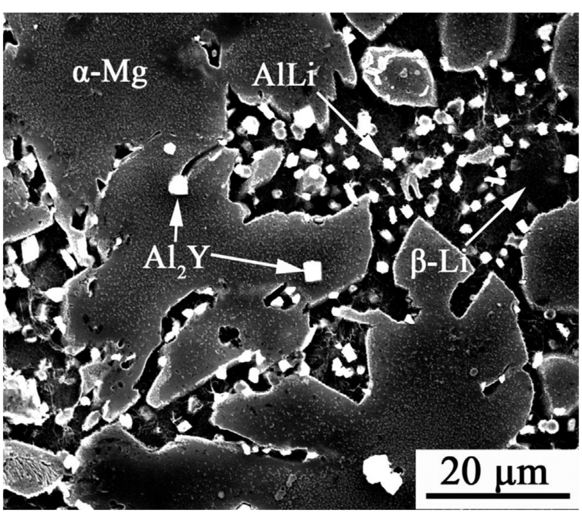

Fig. 2. SEM image of the as-cast LAZ832–0.5Y alloy.

As-cast LAZ832–0.5Y specimens were solid solution treated for 2 h under the argon atmosphere. The solid solution temperatures were 300 °C, 350 °C, 400 °C and 450 °C, respectively. Then the solid solution treated LAZ832–0.5Y specimens were cut into rectangular samples with gauge size of 15 mm × 3 mm × 2 mm for tensile test. Meanwhile, the solid solution treated (350 °C × 2 h) LAZ832–0.5Y specimens were aged at room temperature (RT) and 75 °C, respectively. In addition, in order to identify the effect of Y content on the age softening of the LAZ832–*x*Y ($x=0$, 0.5, 1 and 1.5 wt%), the solid solution treated (350 °C × 2 h) LAZ832–*x*Y ($x=0$, 0.5, 1 and 1.5 wt%) were aged at RT and 75 °C, respectively.

Chemical composition of the studied alloys was determined by inductively coupled plasma-atomic emission spectrometry (ICP-AES) which was listed in Table 1, and the errors are no more than 0.5%. After being polished and etched with 4% (volume fraction) nital, the microstructure was observed by optical microscope (OM, ZEISS) and scanning electron microscopy (SEM, JEOL-6460). Phase analysis was characterized by X-ray Diffraction (XRD, Rigaku) with a resource of CuK_α radiation. The Vickers hardness (HV) was taken using 49 N load and holding time of 15 s Tensile properties of the studied alloys were performed on a tensile tester (Zwick/Roell) at the initial strain rate of $1.67 \times 10^{-3}\ s^{-1}$. The fracture surface was analyzed by SEM.

3. Results and discussion

3.1. Microstructure of the as-cast LAZ832–0.5Y alloy

Fig. 1 shows the XRD result of the as-cast LAZ832–0.5Y alloy. It illustrates that the as-cast LAZ832–0.5Y alloy mainly consists of α-Mg, β-Li, Al_2Y and AlLi phases. Fig. 2 reveals SEM image of the as-cast LAZ832–0.5Y alloy. According to the previous study [10], the gray phase is α-Mg and the black phase is β-Li. Moreover, it has been confirmed that the large particles which are located in α-Mg phase and along the grain boundaries are Al_2Y phase, and the little particles which found mainly in the β-Li phase and grain boundaries are AlLi phase. Fig. 3 illustrates that, in optical images, the white regions are α-Mg phase and the gray regions are β-Li phase. The distribution of Al_2Y and AlLi phase is the same as shown in Fig. 2.

3.2. Microstructure of the solid solution treated LAZ832–0.5Y alloys

The microstructures of LAZ832–0.5Y alloy after solid solution treatment are shown in Fig. 4. The AlLi phase extends from β-Li phase and grain boundaries to the whole β-Li phase dispersedly after solid solution treatment at 300 °C for 2 h. After 350 °C for 2 h, most of AlLi phase is solutionized into the matrix. The remaining

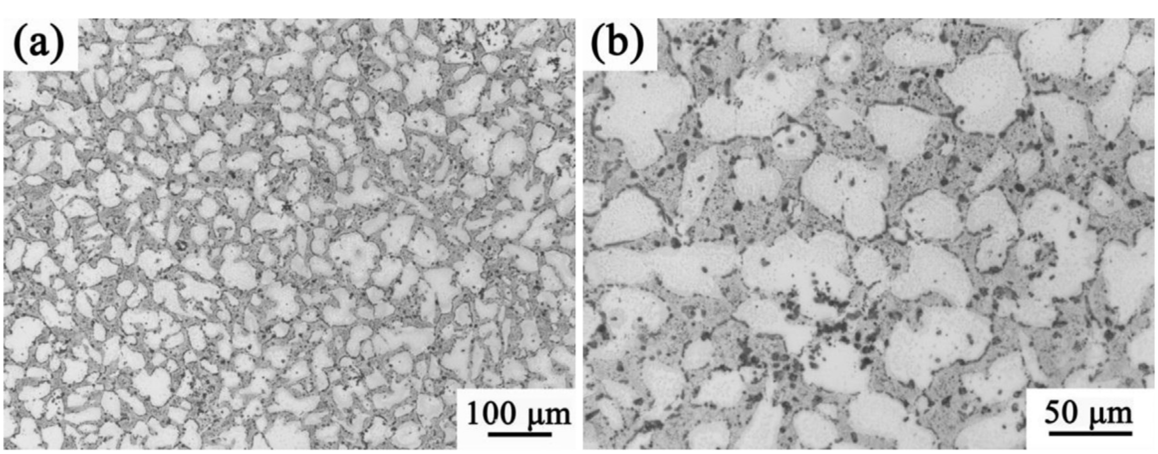

Fig. 3. Optical microstructure of the as-cast LAZ832–0.5Y alloy.