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Effects of zirconium addition on as-cast microstructure and mechanical properties of Mg–3Sn–2Ca magnesium alloy

Mingbo Yang [a,b,c,*], Xiaofeng Liang [a], Zhu Yi [a], Fusheng Pan [c]

[a] Materials Science & Engineering College, Chongqing University of Technology, Chongqing 400054, China
[b] Key Laboratory of Automobile Components Manufacturing and Testing Technology of the Education Ministry, Chongqing University of Technology, Chongqing 400054, China
[c] National Engineering Research Center for Magnesium Alloys, Chongqing University, Chongqing 400030, China

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ABSTRACT

At present, the mechanical properties of the Mg–3Sn–2Ca magnesium alloy are not satisfying and further enhance needs to be considered via further alloying/microalloying additions. The effects of Zr addition on the as-cast microstructure and mechanical properties of the alloy were investigated by using optical and electron microscopies, differential scanning calorimetry (DSC) analysis, and tensile and creep tests. The results indicate that adding 0.41, 0.76 or 1.18 wt.% Zr can refine the grains of the alloy, and the primary CaMgSn phases in the Zr-containing alloys are changed from coarse needle-like net to relatively fine short block and/or particle-like shapes. As a result, the tensile and/or creep properties of the Zr-containing alloys are improved. Among the Zr-containing alloys, the alloy with the addition of 0.76 wt.% Zr exhibits the relatively optimum mechanical properties.

1. Introduction

Magnesium alloys are the lightest structural alloys commercially available and have great potential for applications in automotive, aerospace and other industries. At present, the most widely used magnesium alloys contain Al as a major alloying element. However, the application of commercially available Mg–Al-based alloys is limited by their poor creep behavior at elevated temperatures (>120 °C). Therefore, improving the elevated temperature properties has become a critical issue for possible application of magnesium alloys in hot components [1,2]. Among many possibilities, Mg–Sn–Ca based alloys are of special interest [3–5]. It has been reported that the Mg–3Sn–2Ca alloy can offer superior creep properties even compared to the creep resistant magnesium alloy AE42 [6]. According to the investigations of Huang et al. [4], the high creep properties of the Mg–3Sn–2Ca alloy are mainly ascribed to the CaMgSn and Mg_2Ca phases in the alloy, especially the CaMgSn phase with higher thermal stability. However, it is further reported that the mechanical properties of the Mg–3Sn–2Ca alloy are not satisfying due to the detrimental effect of the coarse needle-like primary CaMgSn phase in the alloy [7]. Therefore, further enhance in the mechanical properties of the Mg–3Sn–2Ca alloy needs to be considered. In the previous investigations [8,9] the authors of this paper found that Ce or Y additions to the Mg–3Sn–2Ca alloy can refine the CaMgSn phase thus leads to enhance the properties, but the application of the two additions is limited due to relatively high cost. It is well known that grain refinement which is used to improve the mechanical properties of magnesium alloys is an important practice in the magnesium industry, and it has been well demonstrated that Zr is an extremely potent grain refiner for Mg alloys [10]. Although Emley et al. [11,12] reported that Zr could not be used in Mg alloys that contain Al, Si, Sn, Ni, Fe, Co, Mn and Sb, the powerful evidence which Zr is unsuitable for the Sn-containing magnesium alloys is not provided. Oppositely, Liu et al. [13] found that adding 0.4–1.2 wt.% Zr to the Mg–5Sn alloy can effectively refine the grains of the alloy. In addition, Lee et al. [14] reported the grain refining efficiency of Zr in magnesium alloys may be further improved by the combined additions of Ca and Zr because Ca promotes the dissolution of Zr into the magnesium melt. Therefore, it is expected that Zr addition to the Mg–3Sn–2Ca alloy is possibly beneficial to the microstructural refinement and properties improvement of the alloy. Due to the above mentioned-reasons, the present work investigates the effects of Zr addition on the as-cast microstructure and mechanical properties of the Mg–3Sn–2Ca alloy.

2. Experimental procedures

The Mg–3Sn–2Ca alloys with different compositions (Table 1) were prepared from commercially pure Mg and Sn (>99.9 wt.%), and Mg-19 wt.% Ca and Mg-31 wt.% Zr master alloys made by

* Corresponding author at: Materials Science & Engineering College, Chongqing University of Technology, Chongqing 400054, China. Tel.: +86 23 68667455; fax: +86 23 68667714.
E-mail address: yangmingbo@cqut.edu.cn (M. Yang).

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