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A comparative analysis of constitutive behaviors of Mg–Mn alloys with different heat-treatment parameters

Jing Zhang [a,b,*], Chao Fang [a], Fuqing Yuan [a], Chuanpu Liu [a,b]

[a] *College of Materials Science and Engineering, Chongqing University, Chongqing 400044, China*
[b] *National Engineering Research Center for Magnesium Alloys, Chongqing 400044, China*

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ABSTRACT

Mg–1.8Mn (wt.%) alloy was solution-treated by three regimes to obtain different initial microstructures. Isothermal hot compression tests were conducted in the temperature range of 250–450 °C and strain rate 0.01–1 s^{-1} for each of the initial states. Constitutive constants for each initial state were obtained and compared. The results showed that homogenization of initial microstructure can significantly decrease the deformation resistance during hot working. It was also revealed that the dispersion of second-phase particles 1–1.5 μm in size with appropriate volume fraction (1–2%) and inter-particle spacing in initial microstructure can impart superior hot work deformation ability to the materials. Excessive amounts of particles resulted in an increase of the flow stresses and working-hardening degree. A large volume fraction of nano-sized particles also imposed difficulty in plastic deformation but with less harmful effects than the larger-sized particles. The influencing mechanism of the particle distribution on the constitutive behavior is discussed.

1. Introduction

As the lightest structural metallic materials, magnesium alloys have attracted considerable research interests in their application in various structural components of aircrafts, automobiles and hand tools. However, the application of wrought magnesium alloys is still very limited. One of the technical problems is their low plastic deformation ability due to its intrinsic hexagonal closed-packed (HCP) crystal structure. For a wider application of magnesium alloys, great efforts have been made into the development of new high-performance alloys and the optimization of processing conditions [1–6]. Hot extrusion or rolling is the common process for bulk metal working of magnesium alloys. The starting material for such a forming process is generally a cast billet. This is why the hot-working characteristics of billet are crucial to forming process; which are in turn dictated by its microstructure, in addition to the hot deformation regimes. The control of the initial microstructure by heat treatment has proven to be one of the most important methods to improve the hot-working ability of magnesium alloys and the mechanical properties of the wrought alloys [7,8]. Microstructural constituents normally include matrix and second-phase particles. The effects of second-phase particles on the hot workability of Mg–Al–Zn (AZ) series alloys, such as AZ31 [9], AZ80 [10], AZ91 [11], have received the most investigation, and it has been widely accepted that homogenization treatment can improve the hot workability due to the dissolution of the intermetallic particles, namely γ-$Mg_{17}Al_{12}$ phase, present in the as-cast material. Contrarily, a recent report [12] on a Mg-RE series alloy, Mg–9Gd–3Y–0.5Zr, showed that homogenization increased the flow stress and the strain-hardening rate during hot compression deformation, resulting in an inferior hot workability than as-cast alloy. Stanford et al. [13] also reported that different particle distributions played crucial roles on the marked difference of the deformation behavior among several wrought Mg alloys. Traditionally, the homogenization degree of a billet is assessed by the volume fraction of undissolved intermetallic particles and/or the arm spacing of dendritic structures. In industry production, where economy is always one of the most important factors to consider, appropriate homogenization processing parameters are normally taken where no obvious decrease in the primary particle volume fraction with time is achieved or where the dendrite arm spacing increases to two times the original value. However, existing reports strongly suggest that from the perspective of deformability, the above-mentioned criterion is far from sufficient to determine a proper pretreatment for Mg alloys, although the mechanism remains unclear.

In this study, we examine the effects of solution treatment on the hot workability of Mg–Mn alloy. Mg–Mn alloy is one of the most widely used wrought magnesium alloys, having sound welding properties and corrosion-resistance. It can be produced in the form of sheets, forgings, extruded profiles, rods, and tubes. Mg–Mn binary alloy exhibits the simple peritectic reaction

* Corresponding author at: College of Materials Science and Engineering, Chongqing University, Chongqing 400044, China. Tel.: +86 23 65111167; fax: +86 23 65102821.
E-mail address: jingzhang@cqu.edu.cn (J. Zhang).

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