G Model
JMST-1134; No. of Pages 13
ARTICLE IN PRESS
Journal of Materials Science & Technology xxx (2017) xxx–xxx
Contents lists available at ScienceDirect
Journal of Materials Science & Technology
journal homepage: www.jmst.org

Partial melting behavior and thixoforming properties of extruded magnesium alloy AZ91 with and without addition of SiC particles with a volume fraction of 15%

Yu-Shi Yi [a], Yi Meng [a,b,*], Dan-Qing Li [a], Sumio Sugiyama [c], Jun Yanagimoto [c]

[a] College of Materials Science and Engineering, Chongqing University, Chongqing, 400044, China
[b] National Engineering Research Center for Magnesium Alloys, Chongqing, 400044, China
[c] Institute of Industrial Science, The University of Tokyo, Tokyo, 153-8505, Japan

ARTICLE INFO

Article history:
Received 8 October 2017
Received in revised form
10 November 2017
Accepted 16 November 2017
Available online xxx

Keywords:
Semisolid forming
Metal matrix composites
Magnesium alloy
Microstructural evolution

ABSTRACT

A series of reheating-isothermal holding experiments and compression tests were conducted on pristine magnesium alloy AZ91 extruded by equal channel angular extrusion (ECAE) and SiC particles (a volume fraction of 15%) reinforced AZ91 composite (AZ91-SiC_p) by regular extrusion. Dissolution of eutectic compounds and partial melting of the α-Mg matrix occurred during the reheating of these materials. Spherical semisolid slurries of these materials were obtained when the reheating temperature and isothermal holding time were 550 °C and 20 s, respectively. The presence of SiC_p in AZ91-SiC_p not only caused lower liquid fractions of semisolid slurries but also resulted in higher values of flow stress during semisolid compression tests. Both AZ91 alloy and AZ91-SiC_p composite exhibited better thixoforming properties at high temperatures. Segregation of SiC_p did not occur during thixoforming of AZ91-SiC_p composite after an isothermal holding at semisolid temperatures for 20 s.

1. Introduction

Because of the substantial advantages including high specific strength-to-weight ratios, low density, good recyclability, and abundant resources, magnesium (Mg) alloys have been applied widely in aerospace, automotive, and biomedical industries [1]. However, the applications of conventional Mg alloys in structural parts operating in high-temperature environments have been inhibited by their poor high-temperature mechanical properties [2]. To improve the high-temperature mechanical properties of Mg alloys, various methods such as precipitation strengthening, grain refinement, solid solutions, have been proposed [3]. In addition to these methods, Mg-matrix composites fabricated by the addition of reinforcement phases have recently attracted attention [4]. To fabricate Mg matrix composites, various reinforcement phases, such as alumina fibers, carbon fibers, graphite fibers, alumina particles, graphite particles, and SiC_p, have been employed [5]. SiC_p-reinforced Mg matrix composites are more popular in industrial applications, because Mg matrix composites with more homogenous distribution of reinforcement phases and more stable mechanical properties could be obtained by simple processing on common equipment with low raw material cost [6].

Although the high-temperature mechanical properties of Mg alloys are effectively improved by SiC_p reinforcement phases, the plasticity of SiC_p-reinforced Mg-matrix composites is not sufficiently high for conventional forging methods. To realize the near net shape manufacturing of Mg-SiC_p composite products, several special forming methods, including spray deposition [7], powder metallurgy [8], stir casting [9], and high-pressure die-casting [10], have been employed. However, spray deposition requires the use of expensive equipment. Powder metallurgy and casting cannot be used for manufacturing products with good mechanical properties. Compared to these methods, semisolid forming (SSF), proposed by Flemings [11], is one of the more attractive methods for manufacturing Mg-SiC_p composite products. Good formability and less forming defects are ensured by the excellent fluidity and adjustable viscosity of semisolid-state materials. The manufacturing of non-ferrous alloy matrix-SiC_p composite product by SSF was investigated in the past decade. Chen et al.

* Corresponding author at: College of Materials Science and Engineering, Chongqing University, Chongqing, 400044, China.
E-mail addresses: mengyi@cqu.edu.cn, mengyi1113@gmail.com (Y. Meng).

https://doi.org/10.1016/j.jmst.2017.11.044
1005-0302/© 2017 Published by Elsevier Ltd on behalf of The editorial office of Journal of Materials Science & Technology.

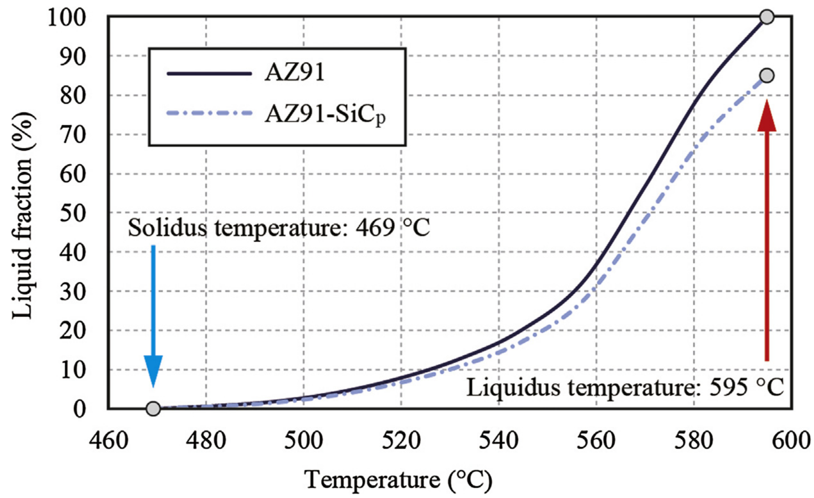

Fig. 1. Liquid fractions of AZ91 and AZ91-SiC_p at different temperatures.

have made significant progresses in thixoextrusion processes of Mg matrix composites [12,13]. They combined stir casting with plastic deformation to fabricate Mg matrix composites reinforced by micron-sized SiC particles [12,13]. After thixo-extrusion, final components are with good surface quality and no evidence of internal defects [12,13]. Jiang et al. studied the rheoforming of SiC_p-reinforced 7075 aluminum matrix composites [14]. Zhang et al. studied the SSF of SiCp-reinforced 2014 aluminum matrix composite [15]. However, the investigations of SSF of Mg-SiC_p composite have been limited due to the reaction of Mg alloys with oxygen at elevated temperatures. Basic experiments should be conducted to obtain and accumulate fundamental knowledge in order to successfully manufacture Mg-SiC_p composite products by SSF. The preparation of semisolid slurries containing spherical solid particles surrounded by liquid matrix is key for a successful SSF [16]. The strain-induced melt activation (SIMA) method and recrystallization and partial melting (RAP) method can be implemented using quite standard equipment to obtain spherical semisolid slurries at the temperatures below their liquidus temperatures [17,18]. SIMA and RAP are the most suitable methods for the preparation of spherical semisolid slurries of materials liable to react with oxygen at elevated temperatures, such as ferrous and Mg alloys [19,20]. Fabrication of starting materials by plastic deformation, such as extrusion and rolling, could be considered as the strain-induced step of SIMA. The melt activation step of SIMA could be conducted by reheating these starting materials [21].

To investigate the effects of SiC_p on partial melting behavior and thixo-forming properties of strain-induced Mg alloy AZ91, extruded AZ91-SiC_p composite and ECAE-processed AZ91 alloy were used in this study. Since these materials were fabricated by extrusion, their reheating-isothermal holding process could be considered an SIMA treatment. Microstructural evolutions of these materials during reheating and isothermal holding with various parameters were studied based on the experimental results. Then, semisolid compression tests were conducted. The relationship between the thixoforming properties and morphologies of these materials was also investigated and discussed.

2. Experimental procedures

AZ91-SiC_p composite was made from SiC_p with an average diameter of 10 μm and Mg alloy AZ91 rolling bars with the chemical composition listed in Table 1. The volume fractions of SiC_p and AZ91 matrix were 15% and 85%, respectively. Based on the data measured by differential scanning calorimetry (DSC), the solidus and liquidus temperatures of AZ91 were identified as 469 and 595 °C, respectively. The liquid fractions of AZ91 at different temperatures were

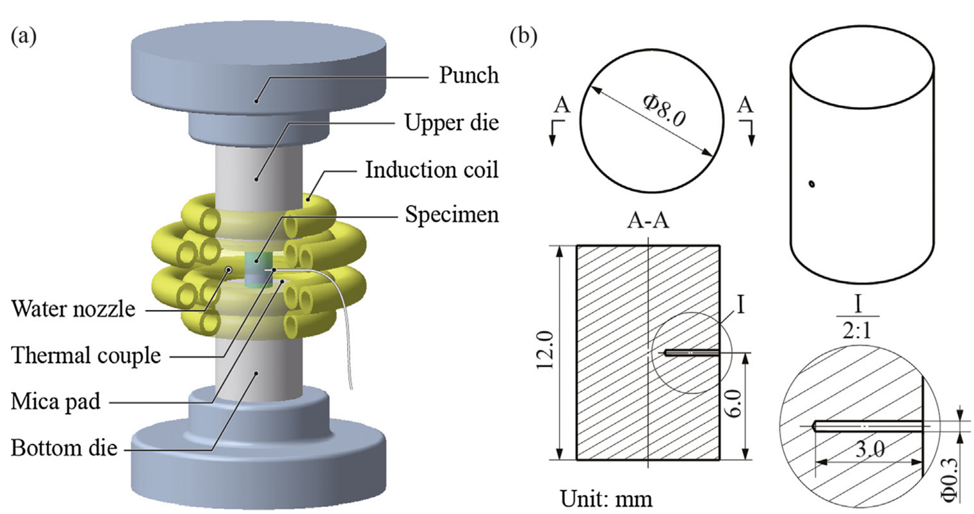

Fig. 2. Illustration of experimental setup (a) and specimen dimensions (b).