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Mechanical properties and damping capacity of magnesium matrix composites

Zhang Xiuqing *, Liao Lihua, Ma Naiheng, Wang Haowei

State Key Lab of Metal Matrix Composites, School of Materials Science and Engineering, Shanghai Jiao Tong University, No. 1954, Huashan Road, Shanghai City, Shanghai 200030, China

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Abstract

Magnesium matrix composites reinforced by TiC particulates was prepared using in situ synthesis method. The mechanical properties and damping capacity of the composites was examined. The experimental results revealed that the TiC particulates play an important role on mechanical properties and damping capacity of the composites. In our study, compared to AZ91 magnesium alloy, damping capacity and tensile strength of the composites improve. The mechanical characterization is explained with the strengthening mechanisms as grain size and Orowan bowing. The damping characterization is explained with dislocation motion, twinning, grain boundary slip and interface slip.

Keywords: A. Metal–matrix composites (MMCs); B. Mechanical properties; Physical properties

1. Introduction

The beginning of 1990s has marked the renaissance of magnesium as a structural material, the demand mainly coming from automotive industry owing to environmental concerns, increasing safety and comfort levels. Magnesium alloy can conform to the trend owing to its high specific strength and specific stiffness, good machining ability, high damping capacity and fine size stabilization [1,2]. However, magnesium alloys reach their limit at about 200 °C, above which magnesium matrix composites (Mg-MMCs) have to be developed. Particulate reinforced Mg-MMCs might actually achieve the above expectation. Zhang et al. [3] researched the mechanical properties and damping capacity of magnesium alloy composites. Their results confirmed that the elastic modulus increased largely, but the elongation decreased with the increase of the volume fraction of the reinforcements. Seshan et al. [4] synthesized two magnesium alloys reinforced with silicon carbide particulates. The results discovered that an increase in particulate reinforcement content was observed to decrease ultimate tensile strength and ductility of the composite. Among those studies, the MMCs were ex situ synthesized. Compared to ex situ synthesis technique, in situ synthesis method is a new technique to prepare metal matrix composites owing to many advantages, e.g., fine reinforcements, clean interface between matrix and reinforcement and good mechanical characterization [5,6]. The size of in situ reinforcements is smaller than that of the ex situ reinforcements, which may result some interesting effect of reinforcements on materials properties and damping capacity.

Remelting and dilution (RD) technique is one of in situ synthesis methods. RD technique consists of two steps, firstly, master alloy that contains reinforcements is prepared; secondly, master alloy is diluted into metal melt to

* Corresponding author. Tel.: +86 21 62932569; fax: +86 21 62932004. *E-mail address:* wendya_zh@hotmail.com (X. Zhang).

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synthesize metal matrix composites. In the present study, Mg-MMCs reinforced by TiC particulates were synthesized using RD technique. And the mechanical properties and damping capacity of Mg-MMCs were researched.

2. Experimental procedure

In our study, pure magnesium was used as the base materials, and aluminum, titanium and graphite powder (purity are up 99.5% and size are less than 75 μm) were used as the base materials of master alloy. The powder mixture consisting of 50 wt.%Al, 36.4 wt.%Ti and 13.6 wt.%C was mixed by a ball mill. After had been mixed, the mixed powder was pressed into columned block (Φ30 mm × 50 mm) under 15 MPa pressure. The mixing and pressing process was achieved under argon atmosphere protection. Then, the blocks reacted under high temperature under argon atmosphere protection to prepare master alloy.

After pure magnesium has been molten, it was superheated to 750 °C under $SF_6 + CO_2$ gas atmosphere protection in a iron crucible. Master alloy was put into the magnesium melt according to 8 wt.%TiC in the composites. The magnesium melt was stirred by two blade steel stirrer with the speed of 200 rpm to facilitate the incorporation and uniform distribution of TiC particulates in the metallic melt. Finally, magnesium melt was poured into an iron sample mould to synthesize 8 wt.%TiC/AZ91.

Philips S-52 SEM and Olympus PME3 metallography microscope were applied on samples to determine the grain size of materials and the size and distribution of TiC particulates. Mechanical properties were examined on Zwick T1-FRO20 electric materials tester. Damping characterization of 8 wt.%TiC/AZ91 composites and AZ91 magnesium alloy was tested on Mark IV dynamic mechanical thermal analyzer with three-point bending mode. The size of the machined samples is 40 mm × 5 mm × 1.5 mm.

3. Results and discussion

3.1. The composition of materials

EDX analysis of 8 wt.%TiC/AZ91 composites was conducted on polish samples. The results of EDX analysis revealed that titanium is 6.43 wt.%, graphite is 1.58 wt.%, and aluminum is 8.36 wt.% in 8 wt.%TiC/AZ91 composites (as shown Fig. 1). It can be calculated that there is about 8.01 wt.%TiC particulates in the composites for element titanium is being by mean of TiC mainly. It is about 3.37 vol.%TiC particulates in the composites by mathematic calculation, which is consilient with numerical estimate about Fig. 3. There is 8.36 wt.% element aluminum in the composites, which is consilient with that of AZ91 magnesium alloy (as shown in Table 1).

3.2. Mechanical characterization

Mechanical characterization of 8 wt.%TiC/AZ91 and AZ91 magnesium alloy was listed in Table 2. Compared to AZ91 alloy, material strength of 8 wt.%TiC/AZ91 improves. Contrarily, plasticity of 8 wt.%TiC/AZ91 decreases.

The yield strength and ultimate tensile strength (UTS) of materials can be estimated by considering the strengthening mechanisms by grain size and Orowan bowing [7]. Addition of TiC particulates results to grain refinement due to more nucleation form the melt. Therefore the grain size of composites is smaller than that of AZ91 alloy (as shown in Fig. 2). According to image analysis on Olympus PME3 metallography microscope, the grain size of composites has been calculated out (as shown in Table 2). For grain strengthening, it is considered as the Hall–Petch equation [8]:

$$\sigma = \sigma_0 + KD^{-1/2} \quad (1)$$

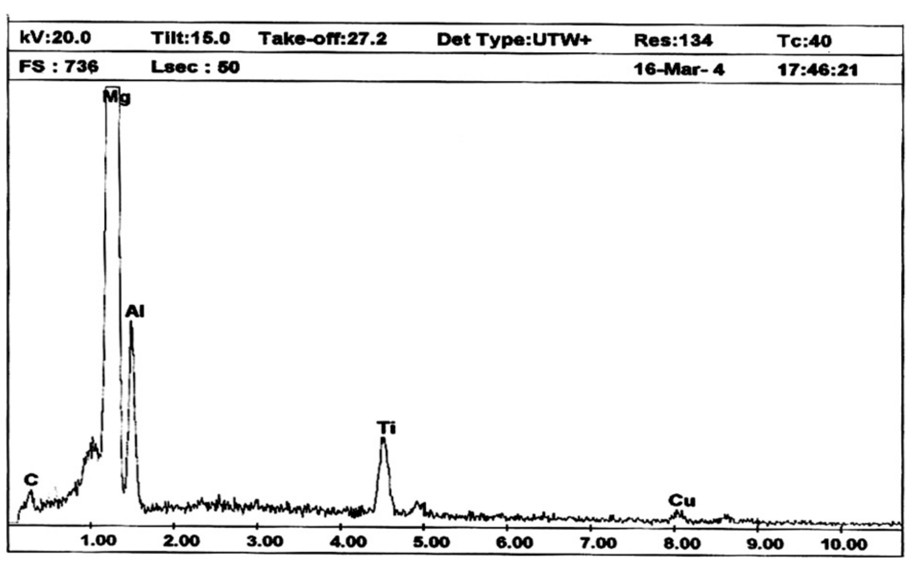

Fig. 1. EDX analysis of the 8 wt.%TiC/AZ91 composites.