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ARTICLE

Effect of SiCp on Microstructure and Mechanical Properties of Mg-Zn-Ca-Mn Matrix Composites

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Abstract: Mg-Zn-Ca-Mn matrix composites reinforced with two volume fractions (1 and 3 vol%) of SiC particles (1 μm) were fabricated by a semisolid stirring assisted ultrasonic vibration method, and then extruded at 350 °C with the extrusion ratio of 15:1. The microstructures of the composites were examined by optical microscopy (OM), scanning electron microscope (SEM) and transmission electron microscopy (TEM). The microstructure analysis shows that the relatively uniform SiCp distribution and the refined grains are obtained in the 1 vol% SiCp/Mg-Zn-Ca-Mn and 3 vol% SiCp/Mg-Zn-Ca-Mn composites after the extrusion. The introduction of SiCp can improve yield strength and ultimate tensile strength. Both of the yield strength and ultimate tensile strength increase with the increase of SiCp content.

Key words: composite; microstructure; tensile property

Magnesium alloys are structurally and strategically important materials due to their high specific strength, good welding ability, good cast ability, high thermal conductivity and resistance to electromagnetic radiation. Therefore, magnesium and its alloys are widely studied in the aerospace, military, especially in the automotive industries[1-4]. However, the major restricting factors of magnesium and its alloys in critical industrial and commercial applications include poor mechanical properties, comparatively low friction and wear resistance [5,6]. Therefore, the improvement of the tensile strength of magnesium and its alloys is very important. Most of these drawbacks can be overcome by adding the high modulus and strength reinforcements into the magnesium matrix. Recently, the researchers interest in developing SiCp reinforced magnesium matrix composites has grown obviously. Nie et al. [7] fabricated the nano-sized SiCp/AZ91 composites by stir casting and ultrasonic dispersion, and it was found that the introduction of nano-sized SiCp resulted in the simultaneous enhancement of tensile strength and yield strength of magnesium alloys. Study of Deng et al. [8] on the tensile behaviour of the AZ91 magnesium reinforced with submicron SiCp illustrated that a little amount of SiCp (~200 nm) had a significant effect on grain refinement and mechanical properties of the AZ91 magnesium alloy. Some researches have been done on 10 μm SiCp reinforced magnesium matrix composites, and these researches revealed that the introduction of 10 μm SiCp led to a significant improvement of fracture, yield strength and ultimate strength[4]. These investigations on the SiCp reinforced magnesium matrix composites confirm that the size, content and the shape of particles have a great influence on the mechanical properties of magnesium alloys [9-11]. However, until now few results have been reported in the literatures on magnesium matrix composite reinforced by 1 μm SiC particles, especially fabricated by a semisolid stirring assisted ultrasonic vibration method[12-14].

Therefore, the primary aim of the present study is to illustrate the effects of 1 μm SiC particles on the microstructure and mechanical properties of magnesium matrix composites extruded with extrusion ratio of 15:1.

1 Experiment

In the present study, the Mg-Zn-Ca-Mn magnesium alloy ingots with chemical composition (Zn-4.514, Ca-1.167,

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Mn-0.055, Mg-balance) were used as the matrix alloys. The SiCp with an average particle size of ~1 μm was used as reinforcements. The 1 μm SiCp reinforced Mg-Zn-Ca-Mn magnesium matrix composites were fabricated by a semisolid stirring assisted ultrasonic vibration method, and the details of fabrication were given in Ref. [15].

The Mg-Zn-Ca-Mn alloy and SiCp/Mg-Zn-Ca-Mn composites ingots were extruded at 300 °C with the extrusion ratio of 15:1 at a constant ram speed of 15 mm/s, and then cooled in air.

The microstructures of the as-extruded SiCp/Mg-Zn-Ca-Mn composites and Mg-Zn-Ca-Mn alloy were observed by optical microscope (OM) and scanning electron microscope (SEM). The average grain size was obtained by Image Pro-Plus software. The tensile tests were carried out on an Instron-1186 tension machine at room temperature and the crosshead speed was 0.5 mm/min. The dimensions of tensile specimens were described in Ref. [15].

2 Results and Discussion

2.1 Microstructures

The optical micrographs of the as-extruded SiCp/Mg-Zn-Ca-Mn magnesium matrix composites with different particle contents are shown in Fig.1. Fig.1a illustrates that the average grain size of the Mg-Zn-Ca-Mn alloy is about 3.5 μm after hot extrusion. Compared with the Mg-Zn-Ca-Mn alloy, much smaller grain size can be found in the as-extruded SiCp/Mg-Zn-Ca-Mn magnesium matrix composites. When the volume fraction of SiC particle is 1vol%, the average grain size of the as-extruded SiCp/Mg-Zn-Ca-Mn composite is about 3.0 μm, but the recrystallization is not fully finished. Its grain distribution with large grains of 13 μm and small grains of about 1~3 μm is inhomogeneous. However, the average grain size of the as-extruded SiCp/Mg-Zn-Ca-Mn composite is about 2.5 μm when the volume fraction of SiC particle is 3 vol%. The dynamic recrystallization (DRX) in the composite is more complete than that in the 1 vol% SiCp/Mg-Zn-Ca-Mn composite. It can be attributed to two reasons: (1) the hot extrusion plays a significant role in refineing the microstructure of matrix; (2) the addition of SiC particles may stimulate DRX of the magnesium matrix. Moreover, we can see from Fig.1b and 1c that the size and degree of DRX near particle-rich zones are smaller than that near particle-poor zones. This is attributed to the manifold effect, and the SiCp makes an indelible contribution to this situation. Some researches showed that DRX in the SiCp/Mg-Zn-Ca-Mn composite is sensitive to the SiCp content on a local scale. And the stored energy and the larger driving force would make the contribution to the nucleation of matrix in the SiCp-rich and SiCp-clusters zones.

As shown in Fig.2, it can be observed that most of the SiC particles are distributed along the extrusion orientation in the as-extruded composites. The reason is that the flow velocity of matrix is faster than that of reinforcing phase during hot extrusion. In addition, two kinds of regions exist in the extruded SiCp/Mg-Zn-Ca-Mn composites: SiCp-rich and SiCp-poor zones, as shown in Fig.2. This is attributed to the uneven distribution of SiCp in the cast SiCp/Mg-Zn-Ca-Mn composite. The higher magnification images of the SiCp/Mg-Zn-Ca-Mn composites are shown in Fig.2b and 2d. It is illustrated that the SiCp distribution is relatively uniform, and the good wetting property between SiCp and Mg-Zn-Ca-Mn alloy is observed in the SiCp/Mg-Zn-Ca-Mn composites.

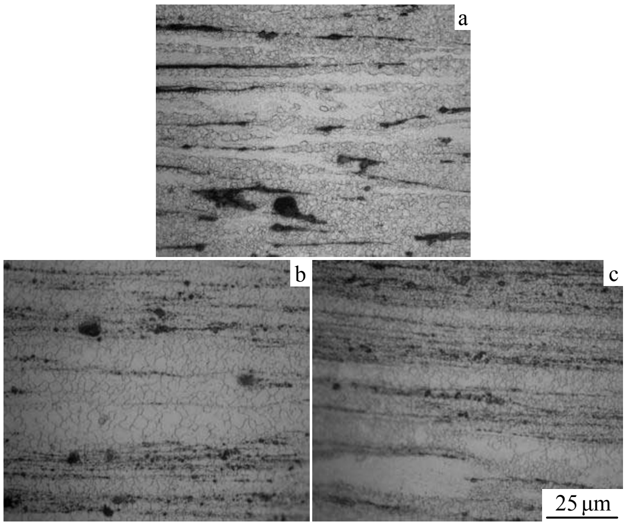

Fig.1 OM micrographs of Mg-Zn-Ca-Mn alloy (a), 1vol% SiCp/Mg-Zn-Ca-Mn composite (b), and 3vol% SiCp/Mg-Zn-Ca-Mn composite (c)

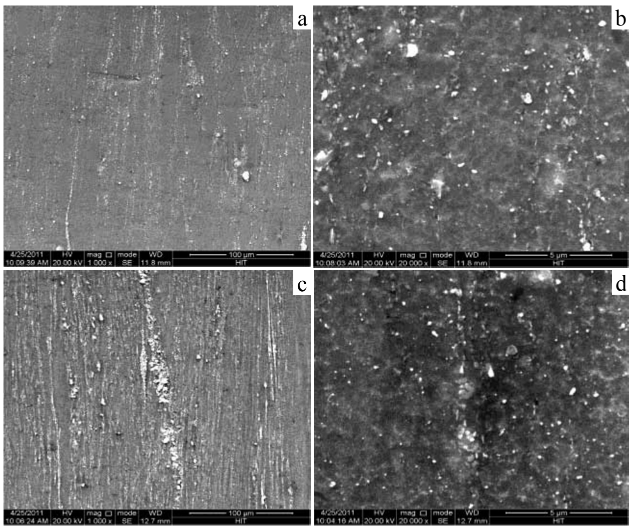

Fig.2 SEM micrographs of 1vol%SiCp/Mg-Zn-Ca-Mn composite (a, b) and 3vol% SiCp/ Mg-Zn-Ca-Mn composite (c, d)

Fig.3 shows the TEM image of the SiCp/Mg-Zn-Ca-Mn composites after hot extrusion. It illustrates that the good