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Evolution of microstructure and tensile properties of extruded Mg-4Zn-1Y alloy

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Abstract: In order to investigate the effect of extrusion on Mg-4Zn-1Y alloy, microstructure and mechanical properties were analyzed by optical microscopy (OM), scanning electron microscopy (SEM), transmission electron microscopy (TEM), X-ray diffraction (XRD), energy dispersive spectrum (EDS) and tensile testing. The results indicated that the microstructure was obviously refined by extrusion and dynamic recrystallization. The second phases were dynamic precipitated and distributed more dispersively through extrusion. W-Phases ($Mg_3Zn_3Y_2$) were twisted and broken, while I-Phases (Mg_3Zn_6Y) were spheroidized by deformation. Twin bands were formed to achieve the large deformation and hinder the slip of dislocations effectively to improve tensile properties. The tensile strength and elongation of extruded Mg-4Zn-1Y alloy were 254.94 MPa and 17.9% respectively which were improved greatly compared with those of as-cast alloy. The strengthening mechanisms of the extruded alloy were mainly fine-grain strengthening and distortion strengthening.

Keywords: Mg-4Zn-1Y alloy; extrusion deformation; microstructure; mechanical properties; rare earths

Because of the large numbers of excellent properties such as low density, high specific strength, high heat conductivity, good damping capacity and machinability, magnesium (Mg) alloy is widely used in the areas of aircrafts, 3C products, national defense, automobiles, etc.[1–4]. However, the low absolute strength and ductility are major obstacles to its wider structurl applications. Therefore it is very necessary to improve the tensile properties.

At present, Mg alloys can be strengthened effectively through being alloyed with RE elements. Especially Y element is used mostly for its biggest solid solubility in α-Mg (12.5 wt.% at most). Therefore Mg-Zn-Y alloys attract widespread attention[5–7]. I-Phases (Mg_3Zn_6Y) which is one kind of quasicrystal phases can be formed in Mg-Zn-Y alloy under the condition of ordinary solidification. Mg-Zn-Y alloy can be quasicrystal-strengthened by I-Phase which is icosahedral quasicrystal structure with high hardness, high strength and low surface energy[8,9]. But the tensile properties of as-cast alloy are not ideal because the microstructure is coarse and contains inevitable shrinkage cavities and cracks. Researches show that the tensile properties can be increased through plastic deformation which can refine the microstructure and vanish defects[10–12]. The dissevered effect between I-Phases and matrix decreases as I-Phases are spheroidized through hot extrusion; besides, the microstructure is refined and elongation is increased by dynamic recrystallization which is promoted by some I-Phases.

The microstructure and mechanical properties of extruded Mg-4Zn-1Y (wt.%) alloy were studied in this paper. The effect of extrusion on the evolution of microstructure, tensile properties, and the strengthening mechanisms were preliminarily expounded.

1 Experimental

The Mg-4Zn-1Y alloy used in this experiment was smelted with pure Mg [ω(Mg)=99.9%], pure Zn [ω(Zn)=99.9%] and Mg-Y master alloy [ω(Y)=25%]. The whole melting process was protected by continuous SF_6+N_2. The cast ingot which was Φ130×100 mm was homogenized on the condition of 400 ºC×10 h to make constituent better distributed and avoid composition segregation.

The extrusion ratio (ratio of cross sectional areas of casted and extruded samples) was 42.25, extrusion temperature was 450 ºC, extrusion velocity was 1.5 mm/s and extruded bar was Φ20 mm. The schematic diagram of extrusion is shown in Fig. 1 and the real as-cast ingot and the extruded bar are shown in Fig. 2.

The specimens were sanded, polished and corroded by picric acid. The microstructure was observed by a Hitachi S-3400N scanning electronic microscope (SEM) and a JEM-2100 transmission electron microscope (TEM). The phases were analyzed by X-ray diffraction (XRD) and energy dispersive spectrum (EDS). The tensile properties were tested by a WDW-100 electronic

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universal testing machine.

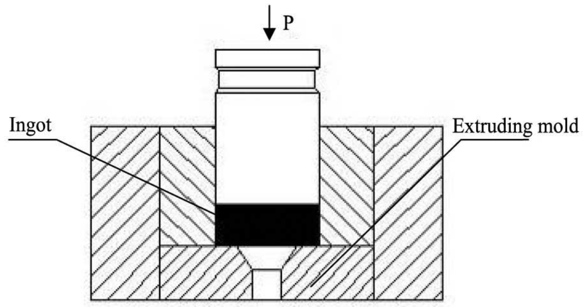

Fig. 1 Schematic diagram of extrusion

2 Results and discussion

2.1 Influence of extrusion on microstructure

The microstructure of as-cast Mg-4Zn-1Y alloy is shown in Fig. 3. The average size of grains is 50–60 μm, and shrinkage cavities and porosities are distributed randomly in microstructure (Fig. 3(a)). A large number of second phases which are spherical, short rod-like, strip and net are distributed in cast microstructure (Fig. 3(b)). TEM pictures are shown in Fig. 4. There are some small second phases whose average size is about 30 nm distributing in the microstructure. Besides, there are some dislocations and dislocations tangle.

The microstructure of cross section of extruded Mg-4Zn-1Y alloy is shown in Fig. 5. It is evident that the microstructure is refined greatly through extrusion compared with as-cast alloy. The extruded alloy is composed of non-dynamic recrystallization crystals which are bulky and a very large number of fine dynamic recrystallization

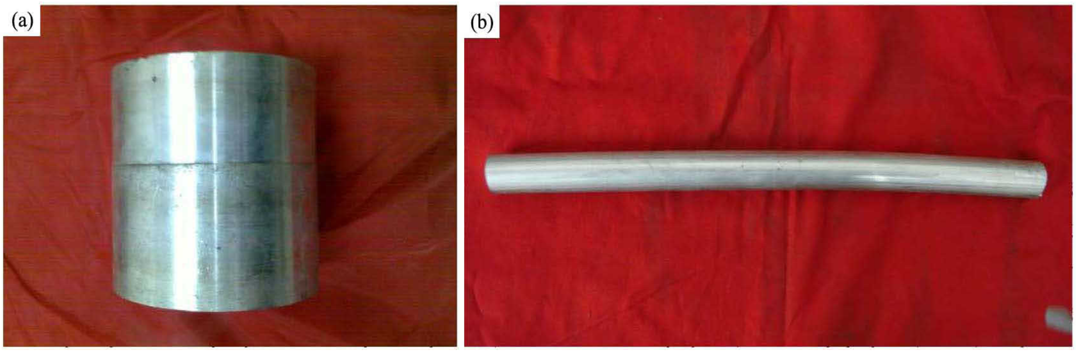

Fig. 2 Ingot (a) and the extruded bar (b)

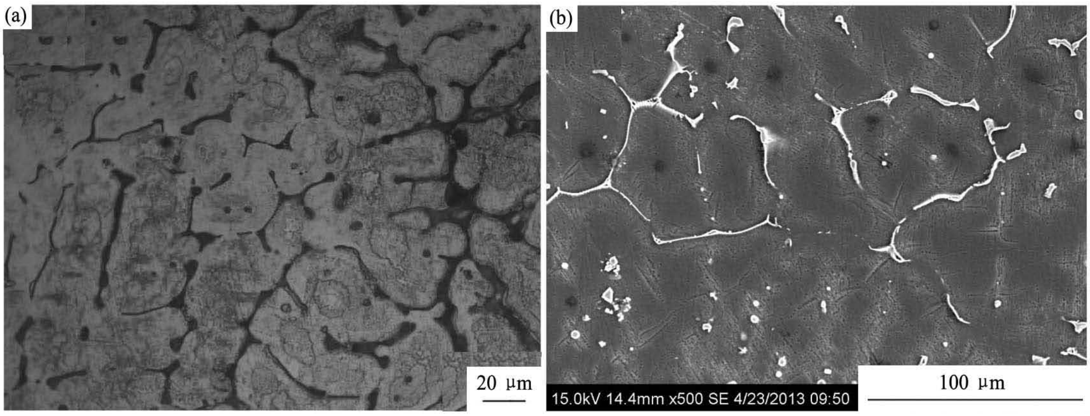

Fig. 3 Microstructure of as-cast Mg-4Zn-1Y alloy
(a) OM; (b) SEM

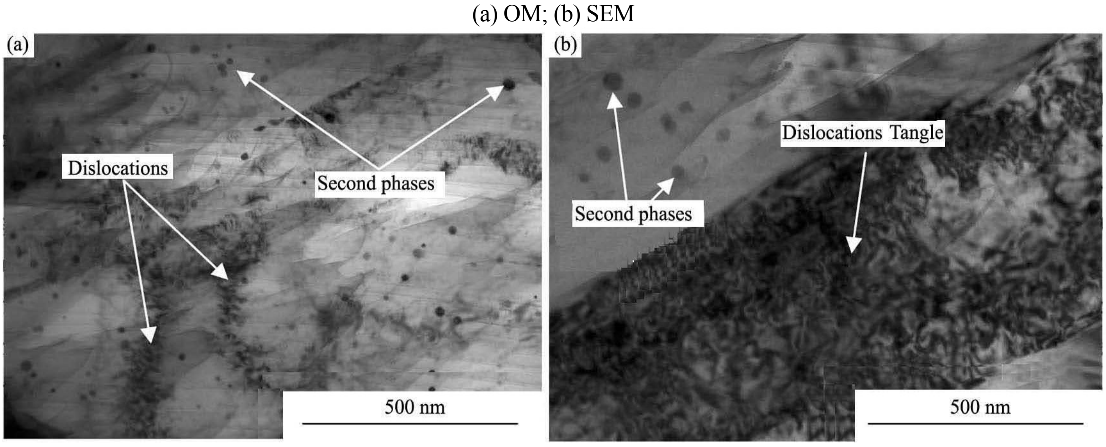

Fig. 4 TEM micrographs of as-cast Mg-4Zn-1Y alloy
(a) Distributed second phases and dislocations; (b) Typical dislocations tangle