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Effects of Hot Extrusion and Heat Treatment on Mechanical Properties and Microstructures of AZ91 Magnesium Alloy

Ming Tan[1, 2, a] , Zhaoming Liu [1, b] Gaofeng Quan [2, c]

1 School of Mater. Sci. & Eng., Dalian Jiaotong University, Dalian, 116028, China
2 School of Mater. Sci. & Eng., Southwest Jiaotong University, Chengdu, 610063, China
a tanmingnc@163.com, b lzm100@163.com, c quangf@gmail.com

Abstract

The effects of heat treatment on the microstructure, tensile property and fracture behavior of as-extruded AZ91 magnesium alloy were studied with OM and SEM. The results show that the grains of as-cast AZ91 alloy are refined by hot extrusion due to dynamic recrystallization, and the mechanical properties are improved obviously. The ductility is significantly enhanced after solution treatment of the as-extruded AZ91 alloy, tensile strength is almost the same as before, and hardness is significantly reduced after solution treatment and artificial aging treatment. The tensile strength reduced and the ductility is significantly enhanced of as-extruded after annealing processes. The fracture surface of as-extruded AZ91 magnesium alloy has the mixed modes of ductile and brittle characteristics. But after T6 or annealing treatment, the dimple number increases evidently.

Key words: AZ91 magnesium alloy; as-extruded; heat treatment; tension; fracture

1. Introduction

Magnesium alloys have been considered as one of most potential advanced structural materials because of its low density (1/3 lower than aluminum), high specific strength and specific stiffness [1] . Magnesium alloys have got wide application in airplane and automobile industries [1-3] . However, some magnesium alloys have poor formability because of its hcp crystal lattice structure. Cast magnesium alloys normally have low strength and poor ductility as well as less precipitation hardening effect.

It is well known that thermomechanical processing can refine the microstructure of magnesium alloys, and has significant influence on their corrosion and mechanical properties [4, 5] . Magnesium alloys

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produced by hot-extrusion have higher strength, better ductility and better various mechanical properties [6] .

Extrusion is in tri-directional compression stress condition, which makes it available to obtain perfect form and compact structure [7] .

Magnesium alloys are more and more widely used as structural materials since l990s. At present Mg—Al series alloys are widely used. Such as AZ91 magnesium alloys.

2. Experimental

The AZ91 magnesium alloy is selected as test material, its chemical composition is listed in Table 1. The as-cast AZ91 alloy were at first homogenized at 380℃ K for 19h, and then was hot-extruded at 380℃ with an extrusion ratio (λ) of 35.

Table 1 Chemical composition of AZ91 magnesium alloys (% wt)

Item	Al	Zn	Mn	Si	Cu	Ni	Fe	Mg
Mass fraction	8.3～9.7	0.3～1.0	0.20	0.01	0.03	0.002	0.005	Bal

The first group of the extruded AZ91 alloy specimens were solution treated for 4 h at 415℃ ， then quenched and aged for 16h at 175℃, the heat treatment process was termed as T6 (Temper). The second group aged for 1 h at 200℃. The specimens of the two groups were machined into cylindrical specimens with cross-section of 6 mm in diameter and 25 mm in gauge length according to GBT232-1999 for tensile tests, which was carried out at room temperature using a WDW-E100D electro-servo testing machine with a tensile speed of 2mm/min. The tensile direction was parallel to the extrusion direction. The fracture of tensile sample was observed by SEM.

Following standard metallographic procedures, the polished surfaces of the as-cast and hot-extruded AZ91 alloys were etched using a solution of 6 g picric acid+100 mL ethanol+5 mL acetic acid+100mL water, and their microstructures were examined by optical microscope. And brindle hardness test is conducted at the same time.

3. Results and discussion

The mechanical properties of AZ91 alloy at different states are shown in Table 2. It can be seen that hot extruding processing can improve the mechanical properties of as-cast AZ91 obviously. And it is also indicated that ultimate strength of as-extruded alloy is 330 MPa, and enhanced to 342 MPa after T6 Temper, and reduced to 283 MPa after annealing treatment.

Table 2 Room temperature mechanical properties of AZ91 alloy

Processing condition	Hardness (HB)	Ultimate strength / MPa	Elongation / %
As-cast	59	172	3.4
As-extruded	74.4	330	9.6
T6 Temper	64.2	342	16.6
As-annealed	68.6	283	27

As a result of dynamic recrystallization, fine grains are obtained in AZ91 alloy after extruding, which results in the improvement of mechanical properties of extruded alloy. After T6 Temper, both elongation and ultimate strength of the alloy decrease, while the hardness increases contrarily. After annealing treatment, both hardness and ultimate strength of the alloy decrease, while the elongation increases contrarily.

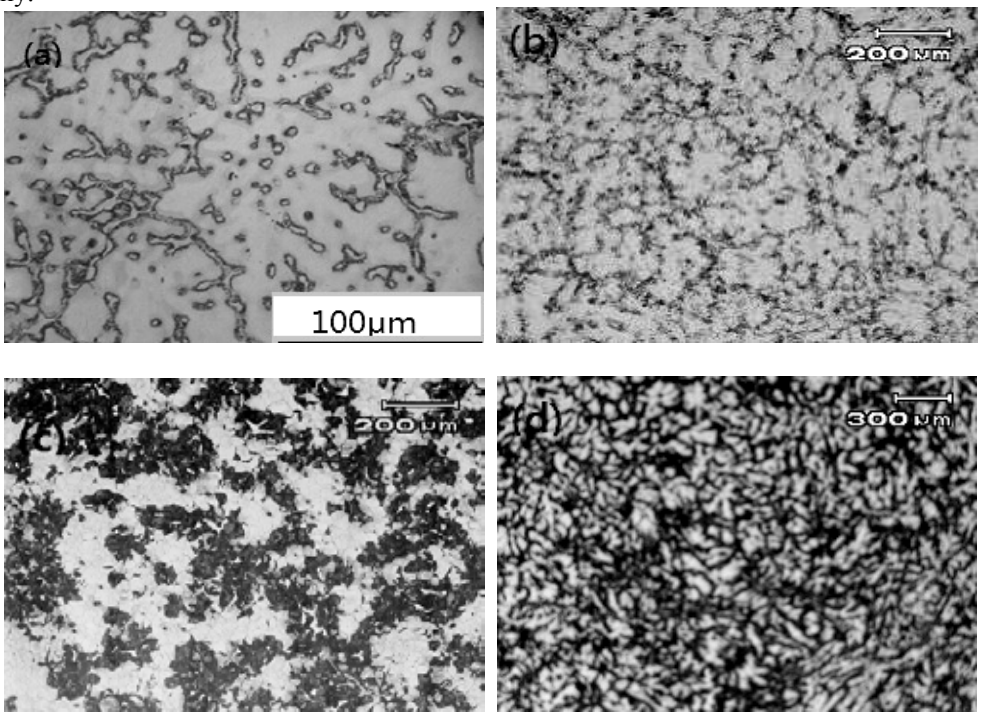

Figure 1 Microstructure of AZ91alloys ,(a) as-cast; (b) as-extruded; (c) T6 Temper (d) as-annealed

Figure 1 shows the microstructures of AZ91 alloy under different condition. The microstructures of AZ91 alloy under all conditions consist of consist of α-Mg and Mg17Al12.Most of Mg17Al12 formed networks at the grain boundaries in as-cast alloy, and they are broken and dispersed discontinuously after hot extrusion. And the grain size of AZ91 alloy is obviously refined because of the occurrence of the dynamic recrystallization during hot extrusion. And the T6 Temper of as-extruded alloy makes the grain size homogeneous and grows lightly. It can be noted that the microstructure of as-extruded alloy (Fig.1(b) does not change significantly compared with the as-extruded state alloy after annealing treatment followed by 200℃ for 1h (Fig.1(d)). Fig.2 shows tensile fracture surfaces of AZ91 alloys. The as-cast sample is brittle fracture because there are only few dimples at the fracture surface. The fracture of extruded sample is obviously ductile because there are a lot of dimples at the fracture surface, and after T6 Temper or annealing treatment, its dimple number increases evidently. This agreed well with the experiment results of elongation.

4. Conclusions

1. The results show that the grain of AZ91 alloy as-cast is refined by extruding and dynamic recrystallization, the mechanical properties increase obviously.

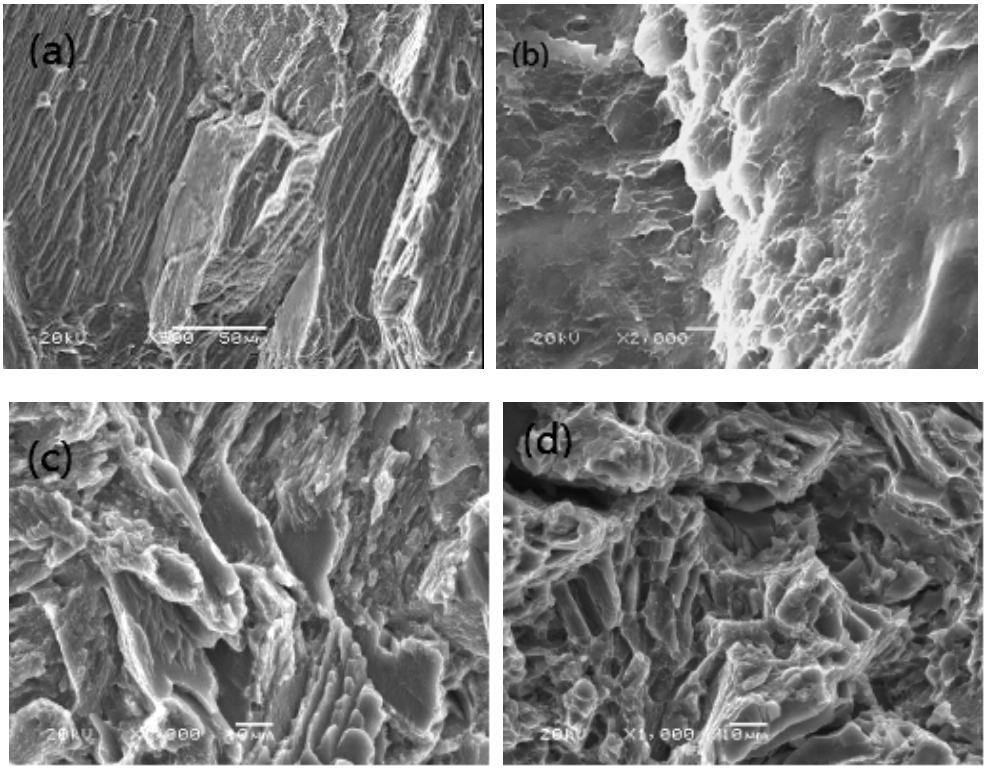

Fig.2 Fracture surfaces of tensile AZ91 alloys (a) as-cast; (b) as-extruded; (c) T6; (d) as-annealed

2. The ductility is significantly enhanced under T6 Temper of the as-extruded AZ91 alloy, tensile strength is almost the same as before and hardness is significantly reduced after solution treatment and artificial aging treatment. The tensile strength was reduced and the ductility is significantly enhanced of as-extruded AZ91 magnesium alloy after annealing processes.

3. The fracture surface of AZ91 as-extruded has the mixture of ductile and brittle characteristic. But after T6 or annealing treatment, its dimple number increases evidently.

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