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Effect of strain rate on microstructure and mechanical properties of a Mg-9Li-2Zn alloy sheet *

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Abstract: A two-phase Mg-9Li-2Zn alloy sheet is made by cold-rolling at room temperature, and the formability of it at room temperature is investigated in this study. Uniaxial tension tests are carried out for various strain rates between 0.5 mm/min and 250 mm/min, and the microstructural changes during the tests are observed. The sheet has high formability at comparatively low strain rates. Maximum elongation amounts to 40%. However, ductility decreases with the increase of strain rate. Even at room temperature, the stress is also sensitive to the strain rate. There are many large dimples at comparatively low strain rates, and small dimples occur at high strain rates, it shows fine sub-grains come into being.

Key words: Mg-Li alloy sheet; cold-rolling; strain rate; microstructure; mechanical properties

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1 Introduction

Magnesium-Lithium alloy is thelightest alloy at present. Its properties are as follows: high specific rigidity, impact ductility, machining, electromagnetic shielding, and shockproof etc. [1,2]. In addition it can be reclaimed, reused, and don't pollute environment, thus it is called a "green" alloy for 21st century.

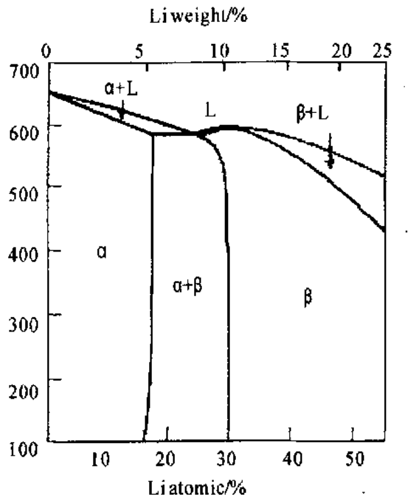

Fig. 1 The phase diagram of Mg-Li alloy

Magnesium is a hexagonal closepacked metal and has poor formability. However, it is well known that the addition of lithium to magnesium can get workable and body-centered cubic alloys[3-5]. Magnesium-lithium (Mg-Li) alloys exhibit two phase structures between 5.7% and 10.3%(mass fraction) Li contents consisting of the α (hcp) magnesium-rich and β (bcc) lithium-rich phases at room temperature (Fig. 1). The β single phase structure exists when Li being greater than 10.3% (mass fraction) Li contents. Due to their ultra-low density Mg-Li alloys are attractive, and investigations on alloy design and metallographi-

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cal as well as mechanical properties of Mg-Li alloys have been carried out for some time[1-5].

However, few studies have involved in the cold-rolling process and formability of Mg-Li sheets from a practical point of view.

The alloys whose contents are between 5.7% and 10.3%, Li are provided with preferable intensity and ductibility. And mechanical character can be improved by adding the element of Zn. In this study, author has succeeded in producing a sheet of a Mg-9%Li-2%Zn alloy with a thickness of 2 mm, and the formability of the sheet at room temperature is examined by uniaxial tension tests under various strain rates. It is found that the sheet has a considerable sensitivity to strain rate even at room temperature. The difference in the deformation mechanism depending on the strain rate is investigated by means of metallographic observations.

2 Experimental procedure

The alloy used in this study consisted of pure Mg, Li and Zn. It was melted and cast in a low carbon steel crucible under an argon atmosphere and a molten flux of 75% LiCl+25% LiF. A Mg-9%Li-2%Zn alloy was made at last. The alloy was homogenized at 523K for 24 h. Because lithium was much lost in the surface of the alloy during homogenization, every surface was milled by 2-3 mm. The alloy with the thickness of 15 mm was cold rolled to 2 mm by interannealing. The total reduction ratio was about 87%. Uniaxial tension tests were carried out. The gauge length and width of the tensile specimens were 50mm and 12.5 mm, respectively. The specimens were elongated by a constant crosshead velocity between 0.5mm/min and 250 mm/min. The microstructure of the specimens before and after the tension tests were examined. The specimens for optical microscopy were prepared by etching with a nitrate solution.

3 Results and discussion

Fig. 2 shows the microstructure of the alloy in as-casting state and the sheet. In Fig. 2 (a), the bright and dark zones correspond to the α and β phases, respectively. In Fig. 2 (b), the grains are elongated in the rolling direction. The bright and dark zones corresponding to the α and β volume fraction of each phase is about 30% α and 70% β.

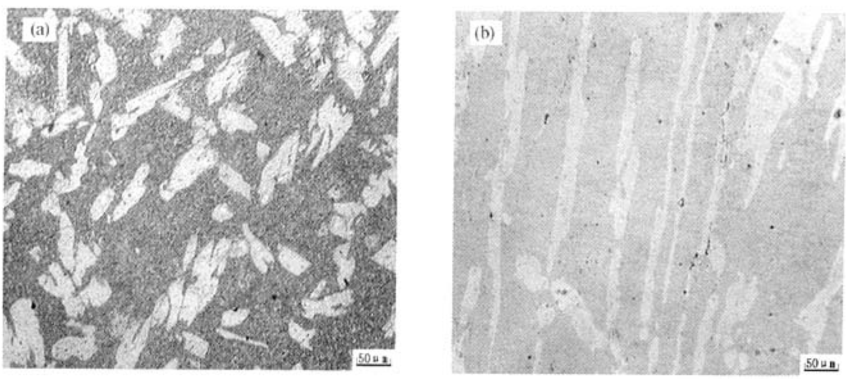

Fig. 2 Microstructure of casting alloy and the sheet before tension test
(a) Casting alloy; (b) The sheet

Fig. 3 shows the microstructures after the tension tests for various strain rates. The grains of the α becomes smaller with increase in strain rate, compared with the microstructure before the test (Fig. 2). Grains remain undivided and are elongated in the tensile direction for low strain rates. The strains in the specimens after the tension tests shown in Fig. 3(a-d) differ from each other, because the fracture strain depends on the strain rate as shown in Fig. 3.

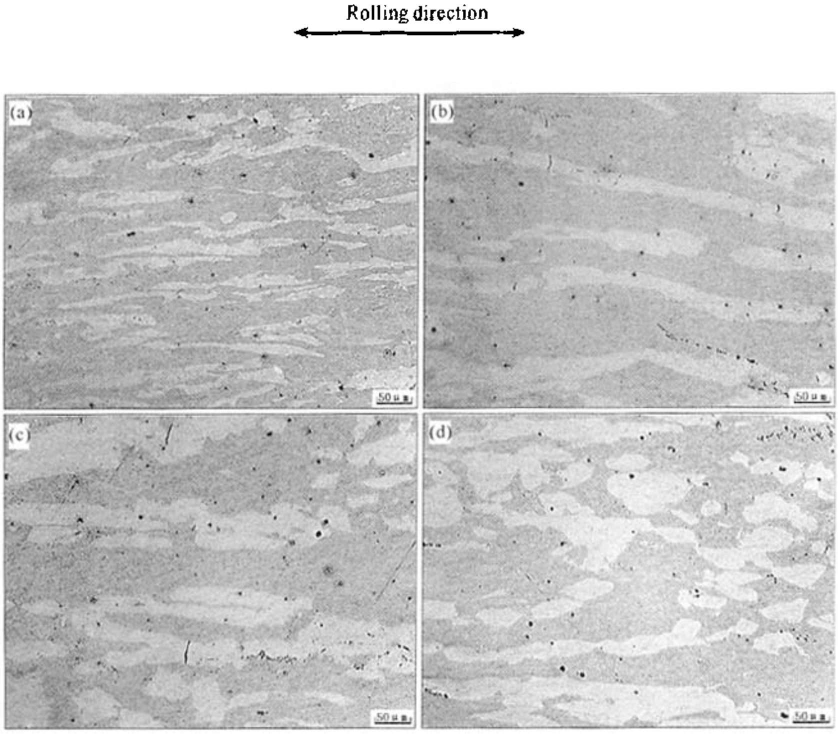

Fig. 3 Microstructure after tension for various strain rates

(a) 0.5mm/min; (b) 5 mm/min; (c) 50 mm/min; (d) 250 mm/min

Fig. 4 shows the tensile properties obtained by the niaxial tension tests in the rolling direction. The sheet has sufficiently high formability. At comparatively low strain rates, the elongation amounts to about 40%. It is notable that such large elongations are attained in specimens with the long gauge length of 50 mm with high stress in the same time. The yielding phenomenon is observed, and work-hardening is small at low strain rates. A more remarkable feature of the sheet is that not only the elongation, but also the stress depends on the strain rate even at room temperature. The stress increases notably with strain rate, while the elongation decreases. The results obtained from the tension tests in the other directions are qualitatively the same as the above[6]. Therefore, the results are described by means of figures obtained from the tests in the rolling direction only.

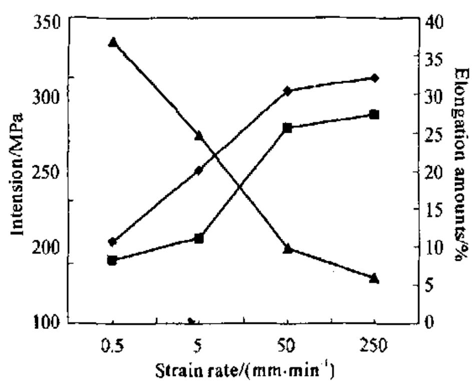

Fig. 4 Tensile properties for various strain rates

Fig. 5 shows the microstructure in the vicinity of the fracture after the tension tests for 0.5 mm/min. Towards the direction of fracture α phases show the shape "V", so it confirms "neck shrink" phenomenon occurs, while there no this phenomenon at high strain rate.

The scanning electron micrographs of the fracture surfaces of the tensile specimens are shown in Fig. 6. Ductile fracture consisting of dimples is observed for all the specimens, while the dimple size becomes smaller with increase in the strain rate. It is considered that the grain refinement at high strain rates results in smaller dimples.

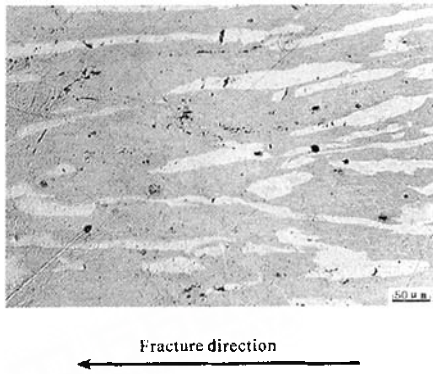

Fig. 5 Microstructure near the fracture

4 Conclusions

(1) The Mg-9% Li-2% Zn alloy is provided with perfect ductibility and it can be rolled to thin sheet at room temperature. The elongation can get to 40%.

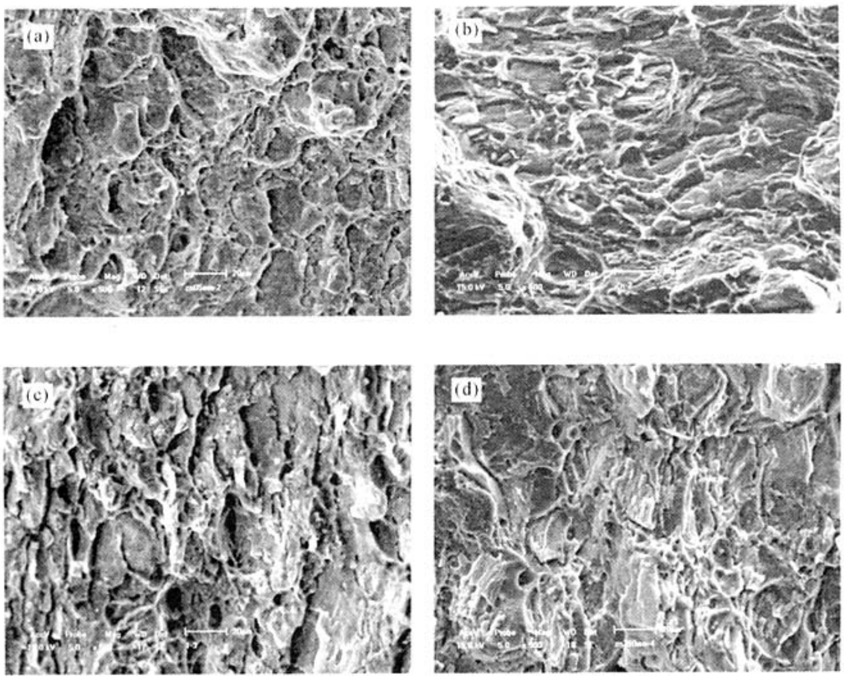

Fig. 6 Fracture after tension tests for various strain rates
(a)—0.5mm/min; (b)—5mm/min; (c)—50mm/min; (d)—250mm/min

(2) The sheet has strain rate sensitivity at room temperature. The stress increases notably with the rise of strain rate while the elongation decreases.

(3) The change in microstructure of the sheet varies depending on the strain rate. At low strain rates, the grains are elongated in the tensile direction. At high strain rates, the grains are divided into fine subgrains.

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