Effect of Hot Rolling Reduction on the Corrosion Resistance of Mg-Li Alloys

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Keywords: Mg-Li alloy, Rolling, Reduction, Corrosion resistance.

Abstract. Mg-Li alloy samples were subjected to hot rolling with different reduction, and the corrosion resistance of the samples was investigated by potentiodynamic polarization measurements and electrochemical impedance spectroscopy measurements in 3.5% NaCl solution. The results show that the corrosion rate of the Mg-Li alloy first decreases and then increases with increasing rolling reduction.

Introduction

In recent years, Mg-Li alloy has been paid much attention, in view of its extremely low density, high ductility, excellent specific strength and rigidity. Therefore, Mg-Li alloys parts are utilized in several industrial fields, such as aerospace, weapon, automotive and electronics industries, etc. However, the corrosion of Mg-Li alloy is more serious than other Mg alloys because Li is very chemically active. The poor corrosion behavior has been a main factor preventing their further applications [1-4].

Rolling, a traditional process, has been reported to improve the corrosion resistance of some Mg alloys [5-7], but the conflicting effects have been found in some related research [7, 8]. Currently, the relation between rolling and corrosion resistance of the alloys is still not clear. Especially, there is almost no research on the corrosion resistance of Mg-Li alloy subjected to hot rolling.

In the present work, Mg-Li alloy was subjected to hot rolling with different reduction, and the corrosion behavior of the alloy samples was studied.

Experimental Procedure

The materials used were casting Mg-7wt.%Li-4wt.%Al-1wt.%Zn alloy ingots. Firstly, the ingots were made into some plates of 20 mm in thickness by spark cutting technique. Secondly, these plates were annealed at 380°C for 3h. After homogenizing annealing, the plates were heated to 300 °C, and hot-rolled from 20 mm to 18 mm, 16mm, 14mm, 12mm, 10mm, and 8mm, respectively. Finally, the hot-rolled Mg–Li alloy samples with different reduction (10%, 20%, 30%, 40%, 50%, and 60%) were cut from these sheets. After rolling, the microstructure of samples was observed by a Leica optical microscopy (OM).

The electrochemical corrosion behavior was then investigated using potentiodynamic polarization measurements and electrochemical impedance spectroscopy measurements in 3.5% NaCl solution. The electrochemical cell was a conventional three electrode cell comprising the working electrode (specimen); reference saturated calomel electrode; and a platinum counter electrode. All electrochemical measurements were made at a temperature of 25°C using a Princeton PARSTAT2273. Before electrochemical measurements, the electrodes were immersed in 3.5% NaCl solution for 20 min to achieve the stable open circuit potential. Impedance measurements were carried out at Eocp over a frequency range of 100 kHz to 0.01 Hz with sinuous potential amplitude of 10mV. Spectra analyses were performed by Zview software. The potentiodynamic
curves were recorded at a potential scan rate of 1 mV/s starting from 200 mV below the open circuit potential.

**Results and Discussion**

Figure 1 shows the microstructure of Mg-7%Li-4%Al-1%Zn alloy samples with different rolling reduction. It can be seen that the microstructure of the samples is mainly composed of $\alpha$-Mg phase and $\beta$-Li phase. The phase with the light color represents the $\alpha$ phase, while the deep color phase is the $\beta$ phase. After hot rolling, the microstructure of the alloy is elongated, and the feature is the most obvious for the sample with 60% rolling reduction, as shown in Fig. 1(c).

![Figure 1. Microstructure of Mg-Li alloy samples with different rolling reduction, (a) 20%, (b) 40%, and (c) 60%.](image)

Fig. 2 shows the polarization curves for Mg-Li alloy samples subjected to hot rolling with different reduction in 3.5% NaCl solution. When rolling reduction increases from 10% to 40%, the anodic current density of the alloy decreases gradually, as seen from the polarization curves. However, the anodic current density of the alloy increases again when rolling reduction increases to 50% and 60%. Therefore, it can be concluded from Fig. 2 that the corrosion rate first decreases and then increases with increasing rolling reduction.

![Figure 2. Polarization curves for Mg-Li alloy samples subjected to hot rolling with different reduction in 3.5% NaCl solution.](image)

Fig. 3 shows the typical Nyquist plots of impedance spectra for Mg-Li alloy samples subjected to hot rolling with different reduction in 3.5% NaCl solution. The larger diameter of the high frequency capacitance loop means the slower dissolution rate of the alloy. As shown in Fig. 3, the diameter of the capacitive arc of the sample rises gradually with rolling reduction increasing from 10% to 40%, and the diameter of the capacitive arc of the sample with 40% reduction is the largest. But the diameter of the capacitive arc of the sample with 50% and 60% reduction decreases again. The above conclusions are consistent with the results in Fig. 2. In addition, it can be seen from Fig.
that the diameter of the capacitive arc of the samples with 50% and 60% reduction is still greater than that of the sample with 20% reduction.

Recent reports show that the corrosion resistance of Mg alloys subjected to rolling maybe related to many factors, including grain refinement, particle fragmentation, texture evolution, and twin formation, etc [5-7]. The corrosion resistance change of the present Mg-7%Li-4%Al-1%Zn alloy samples with different rolling reduction should also be attributed to the combined effects of above factors.

Conclusions
Corrosion resistance of Mg-Li alloy samples subjected to hot rolling with different reduction was studied; and the results are summarized as follows.

(1) When rolling reduction increases from 10% to 40%, the anodic current density of the Mg-Li alloy samples decreases gradually according to the polarization curves, and the diameter of the capacitive arc of the samples rise gradually, seen from the impedance spectra. However, the anodic current density of the samples increases again when rolling reduction increases to 50% and 60%, and the diameter of the capacitive arc of the samples with 50% and 60% reduction decreases again.

(2) The results show that the corrosion rate first decreases and then increases with increasing rolling reduction.

Acknowledgement
The authors would like to thank Liu Feng-fang for the assistance in OM observations and stimulating discussions on the manuscript.

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