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Corrosion Behavior and Mechanical Properties of Mg-Based Alloys by Rapid Solidification Technology of Twin Roll Casting

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Abstract. Mg-based alloys were prepared by rapid solidification of twin roll casting (TRC) which shows that the Mg-RE alloy expressed the quasi-amorphous phased and fine crystalline phase dual-phase material. Corrosion behavior of Mg-Based alloy in 3.5% NaCl solution after 48h immersion and mechanical properties were investigated. The result show that The Mg-RE alloy strip exhibited good corrosion resistance and higher ultimate tensile strength and elongation comparing to the AZ31 alloy strips. The elongation of Mg-RE alloy strip is also high than the AZ91 and ZK61 under powder metallurgy processing. These indicate that Mg-RE alloy produced by our method has a better ductility. This may due to the special microstructure of the Mg-RE alloy forms, i.e., quasi-amorphous phase plus fine crystalline phase dual phase state.

1. Introduction

The term lightweight has been proposed for many years and it is still a hot topic in modern society, magnesium and its alloys as lightweight material are well accepted for many applications in automobile and aerospace industries. However, the applications of Mg alloys are very limited because of the restricted plasticity of Mg (owing to the hexagonal closed-packed crystal structure which possesses few slip systems) and the poor corrosion resistance (do not form a protective oxide film) comparing with other metals [1, 2]. By adopting nanocrystalline or quasicrystalline [3] phases it provides an efficient way to improve the ductility and corrosion resistance of the Mg alloys and is important for future development of high-strength ductile material.

Twin-roll strip casting process combines casting and hot rolling into a single step, having an advantage of one-step processing of flat rolled products [4]. Besides being such a cost-effective process, twin-roll strip casting also has beneficial effects on microstructure such as reducing segregation and grain size with a consequent improvement of mechanical properties and corrosion resistance [5]. In this work, we focused on developing a new kind of Mg-based alloy with proper mechanical performance and good corrosion resistance. Considering its application, we proposed a cost-competitive method to produce the new material in sheet-form. It is considered as an efficient mass-production technique.

2. Experimental

The ingots of Mg-RE alloy were prepared by induction melting the mixture of pure Mg, Al and RE (for Mg-RE alloy) in an induction furnace under the protection of high-purity argon. Chemical compositions of the ingots were measured by X-ray Fluorescence spectrometry and the results are listed in Table 1. Twin roll casting experiments were carried out under casting conditions of casting speed 30 m/min and pouring temperature 953 K. Initial roll gap was set as 0 mm. An oil tank was set directly down to the rolls to avoid further grain growth as the as-cast strip was dipped into the oil tank as soon as it exits from the rolls.

Table 1. Composition of the Mg-RE alloy

Elements	Mg	Al	Si	Mn	Zn	La	Ce
at%	94.6	3.99	0.107	0.12	0.04358	0.464	0.66
wt%	89.2427	4.1779	0.1169	0.2550	0.1106	2.5007	3.5963

Specimens alloy with a dimension of 14mm × 14mm × 1mm were prepared for scanning electron microscope (SEM) and electron probe micro-analysis (EPMA) were prepared by the standard technique of grinding and polishing, followed by etching in a saturated solution of picric acid.In order to check out whether the mechanical properties of the as-cast Mg-RE alloy were improved by using the processing method proposed by the current study, a tensile test was also conducted. The dimension of the specimen is shown in Fig.1.

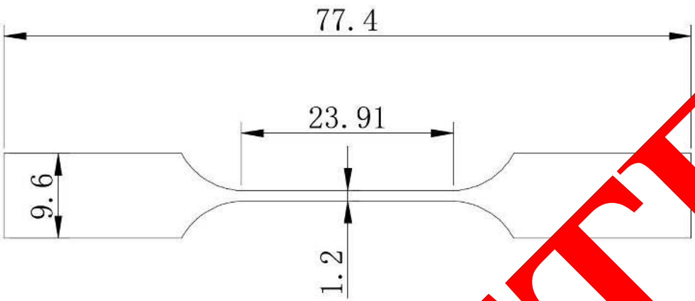

Fig.1. Specimen dimension for tension test.

3. Results and Discussion

Corrosion properties. Mg-RE alloy expressed the quasi-amorphous character which achieved the expected structure target at beginning, i.e., quasi-amorphous phased and fine crystalline phase dual-phase material. In order to evaluate the corrosion resistance of the Mg-RE alloy, corrosion tests were conducted. It was adopted as comparison. Also, we used AZ31 sheet material as one more group of comparison.

The SEM image of the AZ31 Light sheet after immersed in 3.5% NaCl solution for 48h at 50°C. As shown in Fig.2(a), some parts of the specimen were corroded seriously and dissolved into the corrosion solution. Fig.2(b) shows the corrosion status of the other regions. The loose and cracked corrosion products generated and vermicular expanded as immersion time gets longer. It shows filiform corrosion.

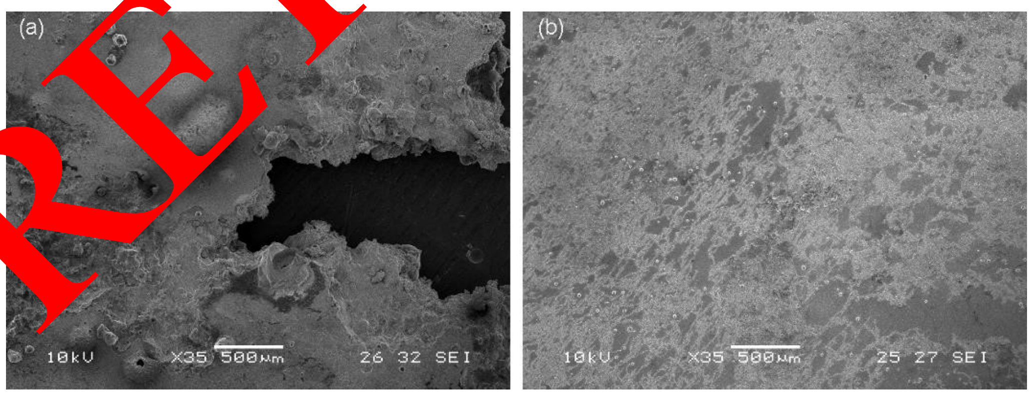

Fig.2. SEM image of the AZ31 sheet after immersed in 3.5% NaCl solution for 48h at 50°C.

As shown in Fig.3(a), it shows the results of SEM image of the corrosion products (left) and distribution map of magnesium on the corroded surface after corrosion (right). It can be found that the content of Mg decreased with the generation of corrosion products. This also reflects that the corrosion layer contains less amount of Mg. Optical microscopy image in the cross-section of the corroded specimen was shown in Fig.3(b). It shows that the corrosion layer has a thickness of 10~20 μm.

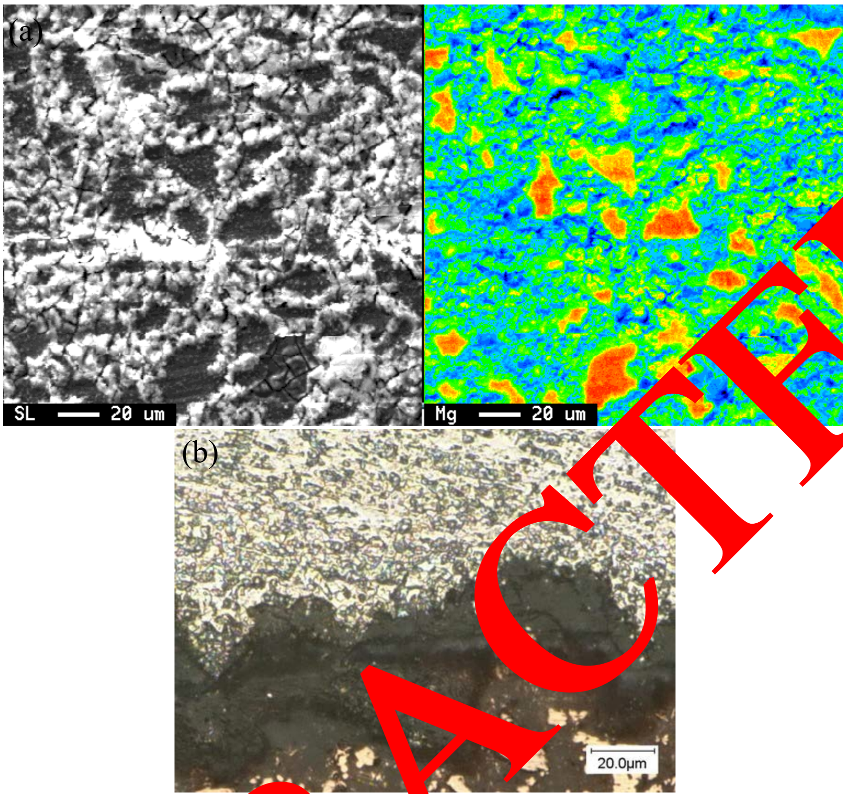

Fig.3. (a) Surface corrosion state and Mg element distribution after immersion—AZ31 sheet. (b) Depth of the corrosion layer of the AZ31 sheet.

Mg-RE alloy shows the best corrosion resistance among the current two alloys. As shown in Fig.4, the grain boundaries can still be identified clearly after immersed in 3.5% NaCl solution for 48h at 50℃ and only a very small amount of corrosion sites could be found. Grain boundary-like cracks generated at the black areas shown in Fig.4(a) and make the sample surface appears local transgranular fracture. Fig.4(b) shows the SEM image in transverse section of the Mg-RE alloy specimen. The corrosion film is too thin to be detected.

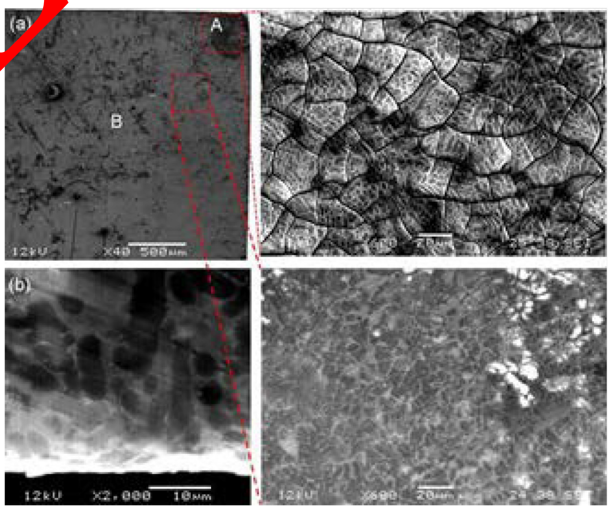

Fig.4. SEM image of the Mg-RE alloy sheet after corrosion: (a) surface; (b) transverse section.

In order to evaluate the depth of the tiny cracks, the specimen was processed by FIB tool. SEM images of the prepared specimen were shown in Fig.5(a). We can see that the tiny cracks generated after immersion have a depth of less than 1μm. As shown in Fig.5(b), the SEM image of the Mg-RE surface (left) and element mapping of magnesium after immersion (right) were analyzed. We can find that magnesium content decreased in the surface with cracks.

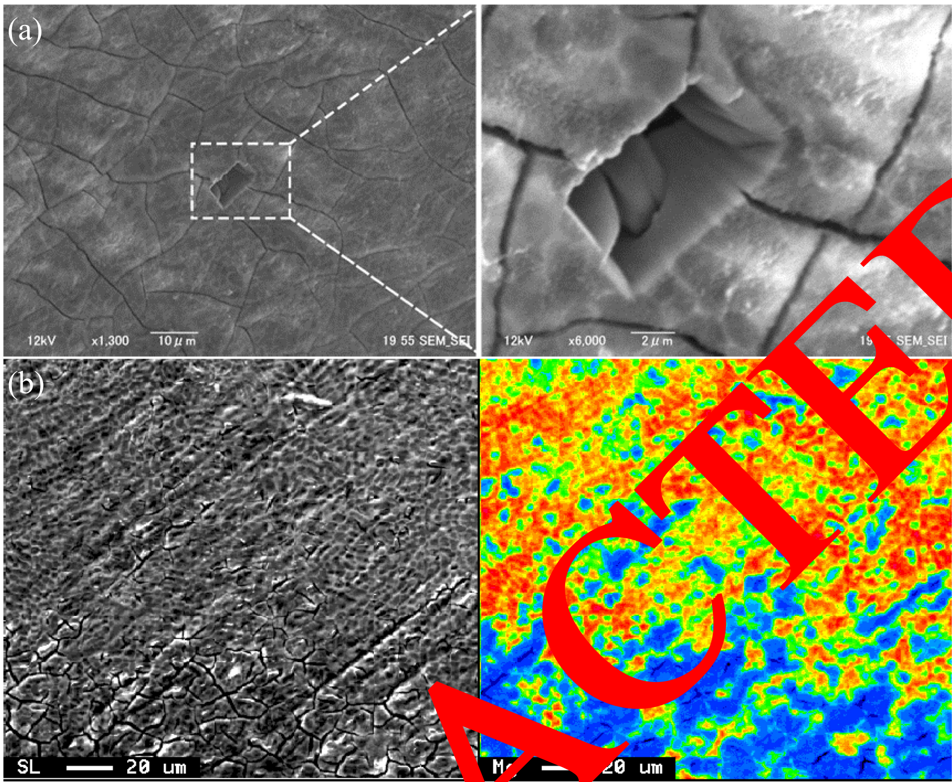

Fig. 5. (a) Tiny crack depth of the corrosion layer. (b) SEM image and surface magnesium distribution of the Mg-RE sample after immersion.

Mechanical properties of the dual phase Mg-RE alloy. Microstructure of the specimen surface and SEM image of the tensile fracture surface were shown in Fig.6. In some place of the fracture surface, it showed a dimpled pattern, which implies a ductile fracture feature, the size of dimples varied slightly. Most of place reveals cleavage facets, which implies a brittle fracture feature.

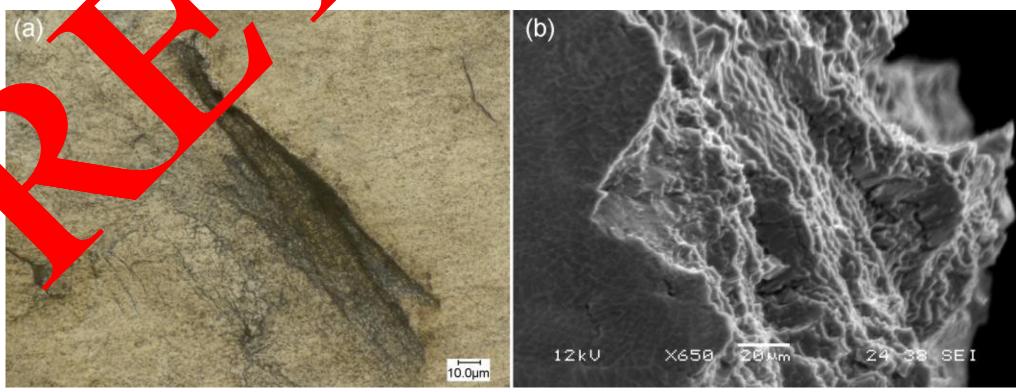

Fig.6. Surface microstructures (a) and tensile fracture (b) of the specimen after tension test.

Table 2. listed the ultimate tensile strength (UTS) of AZ31 as-cast strips at different casting conditions and the corresponding strips under different heat treatment. These AZ31 alloy strips were produced by the seniors in our laboratory. We list the average data of these as-cast AZ31 strips here in order to compare these average data with the Mg-RE alloy strip produced by rapid solidification process.

Through the comparison, it is found that the elongation of Mg-RE alloy strip is high than the AZ91 and ZK61 under powder metallurgy processing and the ductility of the Mg-RE alloy made by rapid solidification TRC process was improve.

Table 2. Comparison of mechanical properties of AZ31 homogenized 1h strips with Mg-RE alloy made by rapid solidification TRC process.

Materials	Casting speed (m/min)	Pouring temp. (K)	Strip Thickness (mm)	Homogenization temperature (K)	UTS (MPa)	Elongation (%)	Ref.
AZ31	8	973		673	183.7	9.25	
AZ31	13	953		673	181.4	9.32	
AZ31	18	953		673	225	11.61	
AZ31	30	973		673, 2h	82	[illegible].6	
Mg-RE	30	953	1.1	As-cast	215.88	12[illegible]	
AZ91 Powder metallurgy	—	—	—	—	432	6	[8]
ZK61 Powder metallurgy	—	—	—	—	400	7	

4. Conclusion

Rapid solidification of TRC experiments were conducted. The Mg-RE alloy strip with the quasi-amorphous phased and fine crystalline phase dual-phase exhibited good corrosion resistance and higher ultimate tensile strength and elongation comparing to the as-cast AZ31 alloy strips. The elongation of Mg-RE alloy strip is also high than the AZ91 and ZK61 under powder metallurgy processing. These indicate that Mg-RE alloy produced by [illegible] method has a better ductility.

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