Development and Application of Rare Earth in Magnesium Alloy

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Abstract： There are currently a series of "bottleneck" difficulties and pain points in magnesium alloy, such as the high chemical activity and poor plastic deformation ability, which greatly affect their melting and casting preparation and stable forming. In addition, the insufficient strength and poor heat resistance of magnesium alloys also limit their application in specific service environments. Rare earth elements, as alloying elements, have the reputation of "industrial MSG" in magnesium alloys and play an extremely important role in improving the performance of magnesium alloys. The development of high-performance magnesium alloys mostly relies on rare earth additives. The development and application of magnesium alloy materials is also a highly valued field for the comprehensive utilization of rare earth resources. The close combination and mutual promotion of magnesium and rare earths are the inevitable path for the development of the industry. This article focuses on the research and application of rare earth magnesium alloys, and further explores new ideas for the comprehensive utilization of rare earths.

Keywords: rare earth; magnesium alloy; high performance; research and development; application

1 Introduction

Currently, China's rare earth industry is facing the problem of low utilization rate of light rare earths and serious imbalance in the amount of light and heavy rare earths used. Magnesium and rare earth are both important advantageous minerals in China and valuable resources with significant strategic value. However, there are currently a series of "bottleneck" difficulties and pain points in the preparation and application of magnesium alloy materials, such as the high chemical activity and poor plastic deformation ability of magnesium alloys, which greatly affect their melting and casting preparation as well as stable forming; In addition, the insufficient strength and poor heat resistance of magnesium alloys also limit their application in specific service environments.

Rare earth elements, as alloying elements, play an extremely important role in improving the properties of magnesium alloys. Rare earth addition has significant effects on inhibiting high-temperature oxidation and combustion of magnesium alloy melt, improving the purity of magnesium melt, refining solidification structure, weakening deformation texture, etc. It can greatly improve the formability, mechanical, corrosion resistance, and high-temperature performance of magnesium alloy. The development and application of magnesium alloy materials is also a highly valued field for the comprehensive utilization of rare earth resources. The close combination and mutual promotion of magnesium and rare earths are the inevitable path for the development of the industry. This article focuses on the work of our research group in the development of rare earth magnesium alloys.

2 Experimental procedure

This article aims to improve the comprehensive properties of magnesium alloys, including mechanical properties, corrosion resistance, and heat resistance, by adding rare earth elements such as La, Ce, Y, Nd and Gd to different magnesium alloys. The preparation of casting samples is first carried out by melting the alloy in a small resistance furnace in the laboratory, and then poured into a 3kg metal circular mold to form a casting billet. The preparation of homogenized samples involves subjecting the ingot to high-temperature and long-term heat treatment in a muffle furnace. The billet size for the extrusion experiment is Φ46×10mm, the extrusion speed is 1mm/s, and the extrusion ratio is 17.

3 Result and discussion

The influence of La and Ce on the microstructure and mechanical properties of AZ alloy

After hot extrusion deformation, the tensile strength UTS of AZ110-1.5LC alloy is greater than 370MPa, the yield strength YS is greater than 260MPa, and the elongation at break δ is greater than 15% [1]. Meanwhile, due to its high m value, small and equiaxed grains, weak basal texture, and GBS deformation mechanism, the alloy can achieve low-temperature superplasticity.

The influence of Ce on the microstructure and mechanical properties of Mg-Zn alloy

Based on the coordinated deformation of basal texture grains, a high plasticity and high energy absorption Mg-2Zn-0.4Ce-0.4Mn alloy was designed, which significantly refined the microstructure and weakened the texture [2]. This alloy has good plasticity, and after extrusion, the elongation can reach 33%, exhibiting superior cold bending performance compared to AZ31.

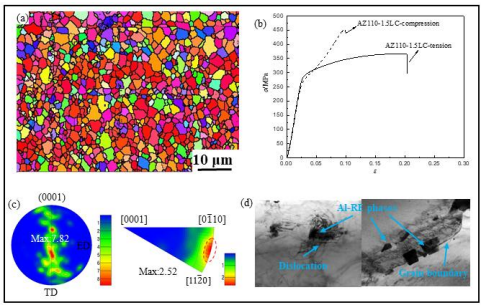

Fig. 1 Grain structure, mechanical properties, texture, and rare earth phases of extruded AZ110-1.5LC alloy [1]

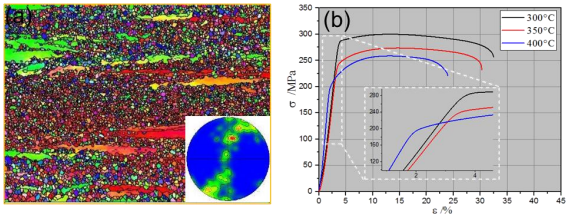

Fig. 2 Microstructure and stress-strain curves of Mg-Zn-Mn-La-Ce alloy[2]

Developed Mg-2Zn-1Al-Ca-Gd magnesium alloy capable of low-temperature extrusion

ZA21EX has excellent comprehensive mechanical properties, with a wide temperature range for thermal/hot extrusion deformation. This is because the decrease in extrusion temperature refines and disperses the Al_2Ca phase, promotes DRX occurrence, weakens the basal texture, and hinders grain growth [3].

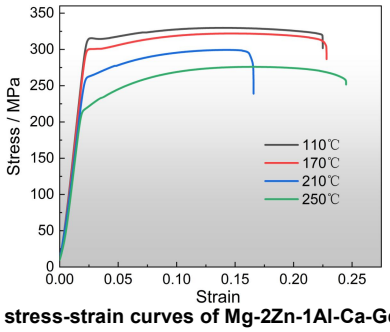

Fig. 3 The stress-strain curves of Mg-2Zn-1Al-Ca-Gd alloy[3]

The influence of Y/Nd on the high-temperature oxidation kinetics behavior of AZ alloy

Both Y and Nd can reduce and refine β-$Mg_{17}Al_{12}$ in AZ80, and precipitate Al_2Y phase and Al_2Nd, increasing the oxidation activation energy, significantly reducing the oxidation rate of the alloy, and improving the oxidation film-forming properties of the alloy [4]. The oxidized surface becomes smooth and dense.

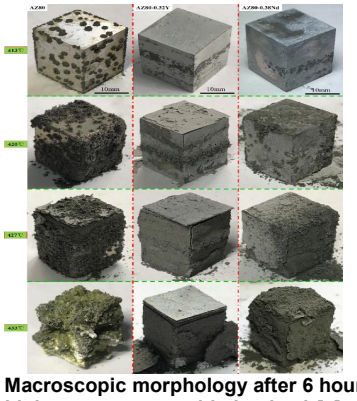

Fig. 4 Macroscopic morphology after 6 hours of high-temperature oxidation in air[4]

4 Conclusion

Rare earth elements can greatly improve the comprehensive performance of magnesium alloys and provide strong support for their application in structural components. At present, there has been in-depth research on the design and development of rare earth magnesium alloys. However, the large-scale application of rare earths in magnesium alloys in China is severely limited by the high material and preparation costs of rare earth magnesium alloys. Therefore, it is necessary to focus on the entire industry chain from rare earth extraction to alloy preparation and processing, and develop new processes and methods aimed at achieving efficient and low-cost preparation of high-performance rare earth magnesium alloys.

5 Acknowledgments

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References

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