Effect of Al_2Y on the Microstructure and Properties of Continuous Squeeze Casting-Extrusion Mg-Y-Al Alloy

Shilong Li, Dijia Zhao, Jianyu Li, Shusen Wu, Shulin Lü*
State Key Lab of Materials Processing and Die & Mould Technology, School of Materials Science and Engineering,
Huazhong University of Science and Technology, Wuhan 430074, China
* Corresponding Author, shulin317@hust.edu.cn

Abstract: The evolution of mechanical properties and microstructure of continuous squeeze casting-extrusion Mg-3nY-2nAl (n=0.25, 0.5, 0.75, and 1.0, in wt.%) series alloys was investigated. As the alloy content increases, the microstructure of as-cast state changes from a single Al2Y eutectic to a mixed of primary Al2Y and eutectic Al2Y. In the extruded alloy, the eutectic Al2Y is completely crushed into dispersed small particles, while the larger primary phase is not crushed. As the alloy content increases, the strength first increases and then decreases, reaching a maximum at n=0.75, with ultimate tensile strength and elongation of 314 MPa and 12%, respectively. The study of EBSD results indicates that the reason for the simultaneous increase in strength and plasticity is the heterostructure strengthening brought about by the primary Al2Y particles.

Keywords: magnesium, mechanical property, Al_2Y, continuous squeeze casting-extrusion

1 Introduction

The fine and uniform microstructure of the billet is beneficial for the recrystallization behavior of hot extruded magnesium alloys due to its higher grain boundary density. Zr is the most effective refining element for magnesium alloys. Due to the formation of heat-resistant and stable AlZr phase, Zr cannot refine Al containing magnesium alloys. Therefore, researchers attempted to refine magnesium alloys containing Al by adding heterogeneous nucleating agents such as SiC and ZnO. Al-RE compounds are a very promising class of nucleating agents. The common Al-RE phases in magnesium alloys include two forms: $Al_{11}RE_3$ and Al_2RE. Among them, Al_2RE, such as Al_2Y, Al_2Gd, etc., has been proven to have a good coherent relationship with magnesium matrix, therefore Al_2RE is considered a promising nucleating agent for magnesium alloys [1]. In addition, Al_2Y phase, as a high hardness and large-sized second phase, is generally considered to have a PSN effect, which can effectively promote recrystallization behavior and obtain a uniform hot extruded microstructure. However, in existing research, few researchers have discussed the influence of different Al_2Y forms on the microstructure and properties of deformed alloys, and have not ruled out the influence of other second phases and solid solution elements on the deformation process behavior of alloys. Therefore, the Mg-Y-Al series alloy was designed to control the ratio of yttrium and aluminum elements, so that only Al-Y phase exists in the alloy and reduce the influence of solid solution

2 Experimental procedure

The raw materials were composed of industrial pure magnesium, pure aluminum, and Mg-70Y intermediate alloy. Under the protection of N_2-SF_6(1vol.%), after pure magnesium was melted using a resistance furnace, Mg-70Y intermediate alloy was added. After the intermediate alloy was completely melted, stir the melt evenly, cool it to 720℃, and then add pure aluminum preheated to 500℃. High-purity argon gas was injected for 10 minutes to refine the melt. The melt was cooled to 705℃ and held for 20 minutes before being ready for casting. After the melt was poured into a continuous squeeze casting-extrusion mold preheated to 150℃, a compression pressure of 100MPa was applied to completely solidify the melt under the pressure [2]. Subsequently, the billet was extruded from the mold mouth with an extrusion ratio of 16:1.

Table 1 Composition of Mg-Y-Al alloys

Code name	Mg	Y	Al
WA0.5	Bal.	0.75	0.5
WA1.0	Bal.	1.5	1.0
WA1.5	Bal.	2.25	1.5
WA2.0	Bal.	3.0	2.0

3 Result and discussion

3.1 Effect of alloy content on the microstructure of WA series alloy

Fig.1 shows the as-cast microstructures of WA series alloys with different alloy contents. When the alloy content is low, the microstructure is composed of α-Mg and eutectic Al_2Y, and the area fraction of eutectic structure increases with the increase of alloy content. When the alloy content increases above WA1.5, massive primary Al_2Y phases begin to appear in the microstructure. Further increase in alloy content does not increase the content of primary phases, but increases the size of primary phases and decreases the number density. The results of EDS analysis indicate that there are no intermetallic compounds of other components in the WA series alloys, and no solid solution of aluminum or yttrium elements are detected in the matrix magnesium.

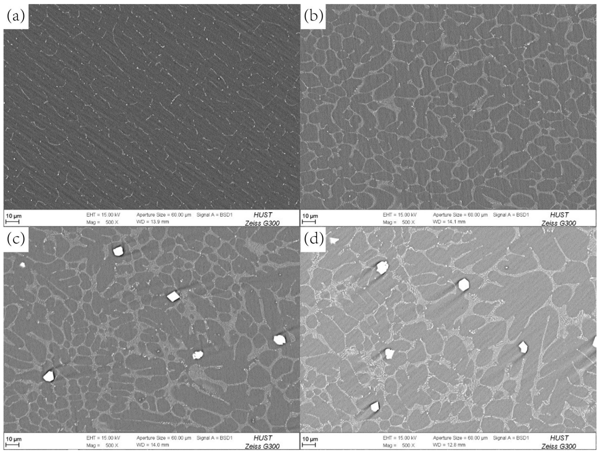

Fig. 1 SEM images of WA series alloy: (a) WA0.5; (b) WA1.0; (c) WA1.5; (d) WA2.0.

Fig.2 shows the IPF diagram of the extruded alloy. After hot extrusion, the microstructure is significantly refined, and the average grain size is refined to about 2μm. The average grain size of the WA0.5 alloy is the smallest, reaching 1.8μm. It is worth noting that although the average grain size is similar, the grain size distribution and recrystallization degree of the alloy are not the same. As the alloy content increases, the recrystallization fraction first increases and then decreases. The WA1.0 alloy has the highest recrystallization fraction (62.5%), while the WA1.5 and WA2.0 alloys have similar recrystallization fractions, both around 31%, which are lower than the 42% of WA0.5. The formation of primary phases does not significantly promote the recrystallization of the alloy, but rather reduces the recrystallization fraction, resulting in a mixed structure of coarse elongated grains + fine recrystallized grains.

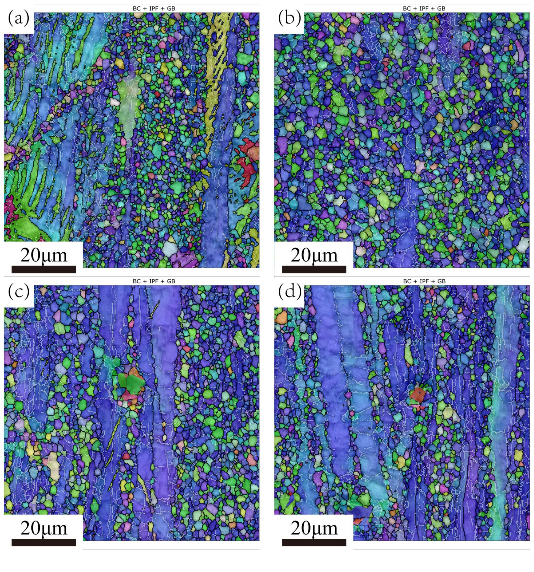

Fig. 2 IPF of WA series alloy: (a) WA0.5; (b) WA1.0; (c) WA1.5; (d) WA2.0.

3.2 Effect of alloy content on the mechanical properties of WA series alloy

The mechanical properties of extruded alloys reach their best at WA1.5. When the alloy content increases from WA0.5 to WA1.0, the strength increases and the plasticity decreases. But when the alloy content further increased to WA1.5, not only did the yield strength increase by 17MPa, but the plasticity increased by more than 60% compared to WA1.0, exceeding the lowest alloy content of WA0.5 alloy. However, higher alloy content did not lead to higher mechanical properties, but instead slightly decreased alloy strength and plasticity. WA1.5 and WA2.0 have similar strain hardening rates and mechanical properties. The HDI strengthening ability of WA1.5 alloy was tested through cyclic tensile tests, and the results showed that the HDI strengthening caused by heterostructure was about 180MPa, accounting for about 70% of the yield strength.

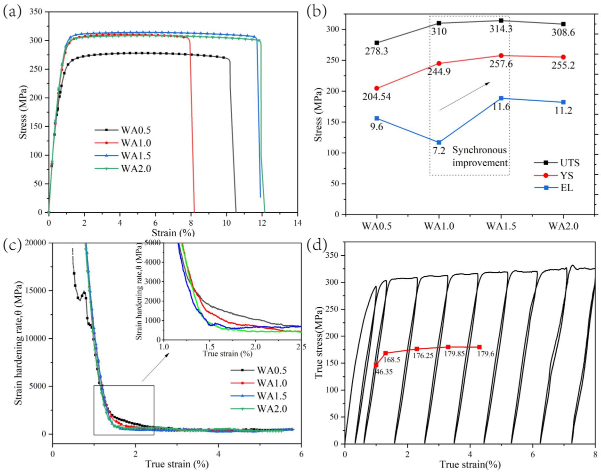

Fig. 3 (a)stress-strain curve of WA alloy; (b) mechanical properties of WA alloy; (c) strain hardening rates of WA alloy; (d)HDI strengthening of WA alloy.

4 Conclusion

(1) The formation of primary Al_2Y phase reduces the recrystallization fraction of the deformed alloy, resulting in a bimodal heterostructure of the alloy.

(2) The formation of primary Al_2Y enhances both the strength and properties of extruded alloys, while excessive alloy content leads to a decrease in mechanical properties of the alloy.

References

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