Effect of Sc Content on Microstructure and Mechanical Properties of Cast Al-2.5Li-1.5Cu Alloy

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Abstract: Casting Al-Li alloys are widely used in the aerospace industry due to their advantages such as low density, high stiffness, and high elastic modulus. However, poor toughness is a significant bottleneck for the application of cast Al-Li alloys. In this study, a high-strength and tough Al-2.5Li-1.5Cu-xSc alloy was successfully prepared by ultrasonic-assisted squeeze casting, and the influence of different Sc contents (x=0, 0.15, 0.2, 0.25, 0.3wt.%) on the microstructure and mechanical properties of cast Al-2.5Li-1.5Cu alloy was systematically investigated. The research indicates that with the continuous increase of Sc content, the grain size of the as-cast alloy significantly refines, and the grains transform from coarse dendrites to equiaxed grains. Meanwhile, as Sc content increases, the variation trend of the mechanical properties is consistent with the microstructural evolution. The Al-2.5Li-1.5Cu-0.3Sc alloy exhibits the best mechanical properties after ultrasonic treatment, with tensile strength, yield strength, and elongation of 338.2MPa, 182.4MPa, and 12.2%, respectively. Compared to the 0Sc alloy, its performance has been improved by 45.5%, 62.3%, and 161.1%, respectively.

Keywords: Casting Al-Li alloy, Sc element, Squeeze casting, Microstructure, Mechanical property

1 Introduction

Al-Li alloys are widely used in aerospace applications due to their many advantages such as low density, high stiffness and high modulus of elasticity [1]. In the past few decades, the successful development and commercialization of wrought Al-Li alloys (such as AA2099 and AA2195) have achieved great success. However, the high anisotropy caused by the deformation process and the inability to form complex components at one time have been plaguing researchers. Therefore, researchers have gradually turned their attention to the preparation of Al-Li alloys by casting method to ensure the isotropy of the alloys. Al-Li alloys allow higher Li content, and the advantages of lightweight and high stiffness of the alloys are more obvious. So it is of far-reaching significance to develop light-weight, high-strength and high-toughness cast Al-Li alloys and expand their application prospects.

As a common strengthening element in Al alloys, the addition of Sc in minor quantities can produce considerable strengthening effects and significant grain refinement [2]. However, there are fewer studies on the strengthening mechanism of Sc element in cast Al-Li alloys.

The study aims to develop a new type of high strength casting Al-Li alloy by ultrasonic-assisted squeeze casting forming process by adding Sc elements. The effects of different Sc contents (x=0, 0.15, 0.2, 0.25, 0.3 wt.%) on the microstructure and mechanical properties of cast Al-2.5Li-1.5Cu alloy were also investigated.

2 Experimental procedure

The nominal composition of the Al-Li alloy in this paper is Al-2.5Li-1.5Cu-xSc (x=0, 0.15, 0.2, 0.25, 0.3wt.%).The actual composition of the Al-Li alloy was measured by ICP-OES and the results are shown in Table 1. Pure Al, Cu, Li, and Al-2Sc intermediate alloys were smelted in a vacuum furnace as follows: a graphite crucible with pure Al was placed in the vacuum smelting furnace when the furnace temperature was raised to a certain temperature, pure Al was melted and Cu and Al-2Sc were added to the vacuum smelting furnace, and finally pure Li grains were added under argon atmosphere. After complete melting of the raw materials, the Al-Li alloy slurry was poured into the metal mould cavity preheated to 200 ℃, and the Φ30 mm×90 mm alloy ingots were obtained by squeeze casting. In addition, 0.3Sc alloy was selected and the alloy slurry was prepared by ultrasonic treatment before squeeze casting. The temperature and time of ultrasonic treatment were 660~700 ℃ and 1~2min, respectively.

Table 1 Composition of Al-2.5Li-1.5Cu-xSc alloys

Alloys	Measured compositions (wt%)			
	Li	Cu	Sc	Al
Base	2.46	0.48	—	Bal.
0.15Sc	2.48	0.50	0.12	Bal.
0.2Sc	2.55	0.53	0.19	Bal.
0.25Sc	2.42	0.46	0.23	Bal.
0.3Sc	2.52	0.52	0.30	Bal.

3 Result and discussion

1.The effect of Sc content on the microstructure of cast Al-2.5Li-1.5Cu alloy

Fig.1 shows the as-cast microstructure of Al-2.5Li-1.5Cu alloys with different Sc contents(x=0, 0.15, 0.2, 0.25, 0.3 wt.%). As shown in Fig.1a, the matrix alloy exhibits obvious dendrites and coarse grains. With the increase of Sc content, the grain refinement of the as-cast Al-Li alloy was obvious, especially when 0.3 wt% Sc was added, the grains became more homogeneous and close to equiaxed grains. Furthermore, when 0.3Sc alloy was treated with ultrasound, the grains of the alloy became smaller and more uniformly distributed. Therefore, the addition of Sc and ultrasonic treatment have a positive effect on the microstructure of Al-2.5Li-1.5Cu-xSc alloy, which can significantly refine the grains and improve their uniformity.

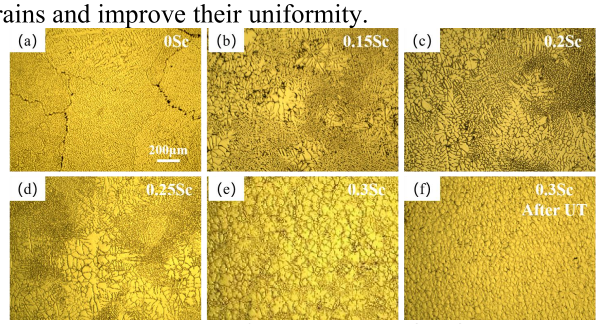

Fig. 1 Microstructures of cast Al-2.5Li-1.5Cu-xSc alloys with different Sc contents: (a-e) Squeeze casting alloy; (f)

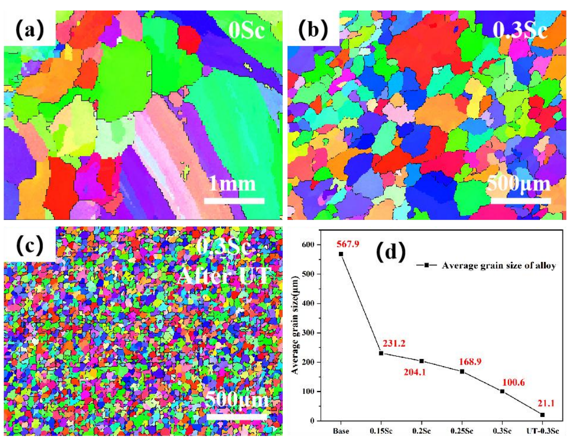

Fig. 2 Fig. 2 EBSD results of cast Al-Li alloys: (a) Base alloy, (b) 0.3Sc alloy, (c) 0.3Sc alloy after ultrasonic treatment; (d) grain size of the alloys at different Sc contents.

2.The effect of Sc content on the mechanical properties of cast Al-2.5Li-1.5Cu alloy.

Fig.3 shows the stress-strain curves and mechanical properties of cast Al-2.5Li-1.5Cu-xSc alloys with different Sc contents. It can be found that when Sc content reaches 0.3%, the ultimate tensile strength reaches 339.4 MPa, the yield strength is 192.9 MPa, and the elongation reaches 10.7%, which is increased by 46.6%, 40.3%, and 214.2%, respectively, compared with the base alloy. The elongation of 0.3Sc alloy after ultrasonic treatment further reaches 12.2%, an increase of 13.6% Ultrasonic treatment-Squeeze casting of 0.3Sc alloy

Fig.2 shows the EBSD results of cast Al-Li alloys with different Sc contents and the grain size of the alloys. The EBSD results show that the grain size of the base alloy is 567.9μm, and the distribution is not uniform. With the increase of Sc content, the grain size of cast Al-Li alloy decreases. When 0.3% Sc is added, the grain size is refined to 100.6μm, which is 82.3% lower than that of the base alloy, and the grain size distribution is more uniform. After ultrasonic treatment, 0.3Sc alloy is further refined, the grain size is 21.1μm, and the grain distribution is more uniform. It is reduced by 96.3% compared with the base alloy and 79.0% compared with the non-ultrasonic alloy. The addition of Sc element and ultrasonic treatment can effectively refine the grain size of cast Al-Li alloy and improve the microstructure of the alloy.

compared to the non-ultrasonicated alloy. The addition of Sc element and ultrasonic treatment have a great positive impact on improving the mechanical properties of cast Al-Li alloy.

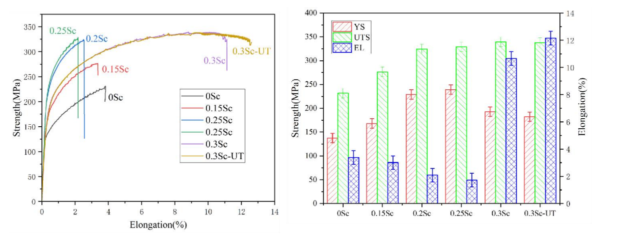

Fig.3 Stress-strain curves and mechanical properties of cast Al-2.5Li-1.5Cu-xSc alloys with different Sc contents.

4 Conclusion

(1) The addition of Sc and ultrasonic treatment have a significant effect on the microstructure of Al-2.5Li-1.5Cu alloy, especially in the refinement of grains and the reduction of dendrite formation. When Sc content reaches 0.3 % and after ultrasonic treatment, the grain size of the alloy is further refined to 21.1μm, which is 96.3 % smaller than that of the base alloy.

(2) When the Sc content reaches 0.3%, the ultimate tensile strength reaches 339.4 MPa, the yield strength is 192.9 MPa, and the elongation reaches 10.7%, which is increased by 46.6%, 40.3%, and 214.2%, respectively, compared to the base alloy. The elongation of the 0.3Sc alloy after ultrasonic treatment further reached 12.16%.

References

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