Effects of Zn Content and Heat Treatment Process on Microstructures and Mechanical Properties of Al-2Li-1Cu-3Mg-xZn-0.2Zr Cast Aluminum Alloys

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Abstract: In this work, the effect of Zn addition and heat treatment schemes on the microstructure and mechanical properties of cast Al-2Li-1Cu-3Mg-0.2Zr alloy were investigated. The results indicate that with the increase of Zn element will refine the grain of cast microstructure and improve its mechanical properties. The increase in the aging time hardness showed a trend of first increase and then decrease, and the tensile strength with the increase in the content of Zn increased. The hardness of Al-2Li-1Cu-3Mg-xZn-0.2Zr alloy shows a tendency to increase and then decrease during the aging treatment. The optimal comprehensive mechanical properties are obtained in Al-2Li-1Cu-3Mg-0.9Zn-0.2Zr alloy, which exhibits 404 MPa in ultimate tensile strength (UTS) and 12.1% in elongation (EL).

Keywords: Cast Al-Li alloys, Mechanical properties, Heat treatment.

1 Introduction

Al-Li alloys are age-hardening materials known for their low density, high strength, high modulus of elasticity, and fatigue resistance, making them ideal for aerospace applications where lightweight structural materials are crucial [1]. Microalloying with Al-Li-Mg alloys refines the grain structure, thereby improving strength and ductility [2-3]. In this paper, the effect of Zn and heat treatment schemes on the microstructural evolution and mechanical properties of cast Al-Li-Mg alloy were investigated.

2 Experimental procedure

The alloys were prepared in graphite crucible using resistance furnace. Table 1 lists the chemical compositions and densities of the alloys. The alloys underwent a two-stage solution heat treatment (460°C×24h+530°C×24h), followed by quenching into room-temperature water immediately and isothermal artificial aging at 175 °C for various times in an oil bath.

Table 1 ICP-OES results of the alloys compositions, wt.%

Composition	Li	Cu	Mg	Zr	Zn	Al
0.3Zn	2.1	0.97	2.4	0.14	0.31	Bal.
0.6Zn	1.8	0.99	3.1	0.13	0.59	Bal
0.9Zn	1.8	0.92	2.9	0.15	0.86	Bal

3 Result and discussion

3.1 Microstructure and mechanical properties of as-cast Al-2Li-1Cu-3Mg-xZn-0.2Zr alloy

Figure 1 shows the XRD diagram of Al-2Li-1Cu-3Mg-xZn-0.2Zr with different Zn content. The results show that Al-2Li-1Cu-3Mg-xZn-0.2Zr alloy is mainly composed of α-Al matrix, AlLi, T_1 (Al_2CuLi), T_2 (Al_6CuLi_3), θ'(Al_2Cu) and δ'(Al_3Li) phases.

Figure 2 shows the metallographic diagram of the as-cast structure of the alloy. The average grain sizes of 0.3Zn, 0.6Zn and 0.9Zn alloys are 254 μ m, 161 μ m and 99 μ m, respectively.

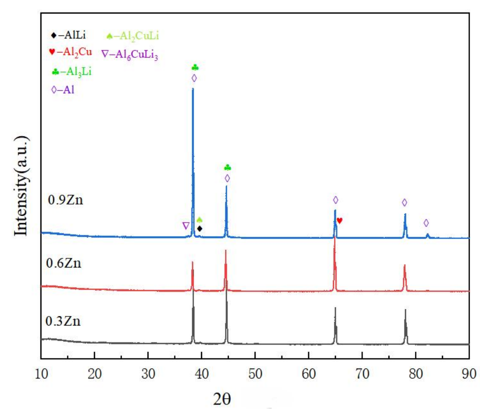

Fig.1 XRD patterns of Al-2Li-1Cu-3Mg-xZn-0.2Zr with different Zn contents

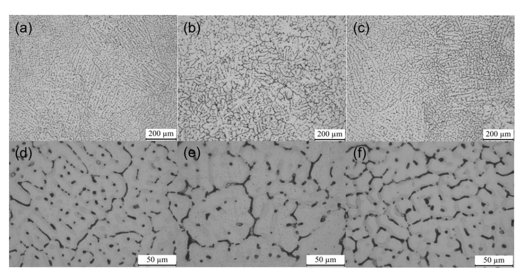

Fig.2 Microstructure of as-cast alloys with different Mg content (a) (d) 0.3Zn, (b) (e) 0.6Zn, (c) (f) 0.9Zn

3.2 Aging Microstructure and Mechanical Properties of Al-2Li-1Cu-3Mg-xZn-0.2Zr Alloy

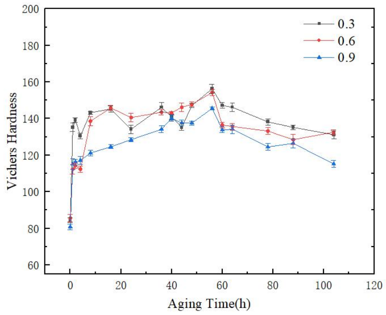

Fig.3 Age-hardening curve of Al-2Li-1Cu-3Mg-yZn-0.2Zr alloy during aging at 175°C.

With the increase of aging time, the microhardness increases at first and then decreases. After aging for 56 h, 0.3Zn, 0.6Zn and 0.9Zn alloys all reached the peak aging, and the microhardness is 156.3HV, 154.3HV and 145.6HV, respectively, indicating that the peak aging hardness did not increase with the increase of Zn content.

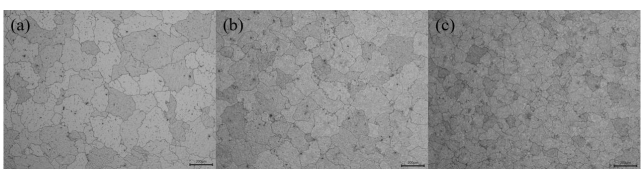

Fig. 4 Optical microstructure of aged alloys (a) 0.3Zn, (b) 0.6Zn, (c) 0.9Zn

Figure 4 shows the optical structure of the aging structure of Al-2Li-1Cu-3Mg-xZn-0.2Zr alloy. With the increase of Zn content, the grains are refined.

3.3 Mechanical Properties of Al-2Li-1Cu-3Mg-xZn-0.2Zr Alloy in the Aging State

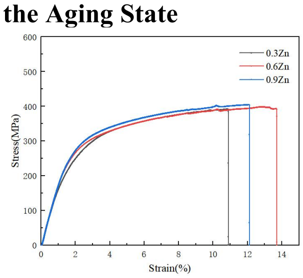

Fig.5 Stress-strain curves of Al-2Li-1Cu-3Mg-xZn-0.2Zr alloy in the aged state

With the increase of Zn content, the tensile strength of 0.6Zn alloy increases to 398MPa, and the elongation (EL) increases to 13.7%. When the Zn content is 0.9wt.%. The tensile strength of 0.9Zn alloy is increased to 404MPa, and the elongation is 12.1%.

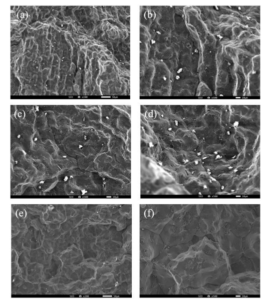

Fig.6 Fracture morphology of as-aged (a)(b)0.3Zn；(c)(d) 0.6Zn；(e)(f) 0.9Zn

The fracture surface of 0.3Zn alloy has obvious long step structure and a large number of granular second phases above the fracture surface. There is no obvious dimple on the fracture surface of 0.9Zn alloy, and the plane is smooth and intergranular fracture, but there are coarse spherical particles on the crystal surface. These precipitates effectively promote the stress concentration of smaller alloys and improve the strength and toughness of the alloys.

4 Conclusion

(1) When the Zn content increases from 0.3wt.% to 0.9wt.%, the average grain size of the as-cast alloy decreases from 254 μm to 161 μm, and the strength and plasticity of the as-cast alloy increase with the increase of zinc content.

(2) The optimal comprehensive mechanical properties are obtained in Al-2Li-1Cu-3Mg-0.9Zn-0.2Zr alloy, which exhibits 404 MPa in ultimate tensile strength (UTS) and 12.1% in elongation (EL).

References

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