The Study of Extrusion Casting on the Microstructure and Properties of Hypereutectic Al-Si Alloy

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Abstract: In this study, P and Sr composite modified hypereutectic Al-Si alloy samples were prepared by gravity casting and extrusion casting, with extrusion ratios of 400 MPa, 500 MPa, and 600 MPa. The microstructure and properties of hypereutectic aluminum-silicon alloy under gravity casting and different extrusion ratios were studied. The results show that the properties of extrusion cast alloys are better than those of gravity cast alloys, and as the extrusion ratio increases, the refinement effect on the silicon phase becomes better. Under an extrusion ratio of 600 MPa, the refinement effect on primary silicon and eutectic silicon is the best, with the primary silicon partially becoming blunt, decreasing in quantity, and having small dimensional differences with an average size of 29 μm. The density of eutectic silicon increases, and the alloy has good mechanical properties under this condition, with a tensile strength of 316 MPa, an elongation of 1.94%, and a hardness of 115.1 HV.

Keywords: Extrusion Casting; Microstructure; Properties; Hypereutectic Al-Si Alloy

1 Introduction

The hypereutectic Al-Si alloy produced by traditional gravity casting typically exhibits coarse primary silicon and elongated eutectic silicon, both of which, as hard phases, influence the alloy's ductility and wear resistance. The addition of P and Sr composite modification has certain effects: P forms AlP compounds with Al, acting as heterogeneous nucleation sites and dispersing to refine the structure; Sr addition induces an adsorption poisoning mechanism, transforming the elongated eutectic silicon into a coral-like structure. The extrusion casting process significantly reduces defects, increases the density of the alloy structure, further refines the silicon phases, and consequently enhances the alloy's comprehensive mechanical properties. Yong-fei WANG [1]fabricated ZL104 connecting rods using semi-solid extrusion casting and liquid extrusion casting. Comparing with liquid extrusion casting, semi-solid extrusion casting results in higher improvements in tensile strength and elongation of the connecting rods.

2 Experimental procedure

The raw materials used in this study are ZL109 alloy, Al-30Si intermediate alloy, and modifiers including Al-4.5P and Al-10Sr intermediate alloys to melt Al-15Si alloy. The composition of the experimental materials is shown in Table 1.

Table 1. The composition of test alloys

Si	Cu	Mg	Ni	Fe	Al
15	0.9	0.8	0.9	0.9	excess

3 Result and discussion

In the microstructure of the alloy modified by P and Sr composite under gravity casting (Figure 1 (a)), there is a significant difference in the size of primary silicon, with an average size of 24μm. The morphology ofprimary

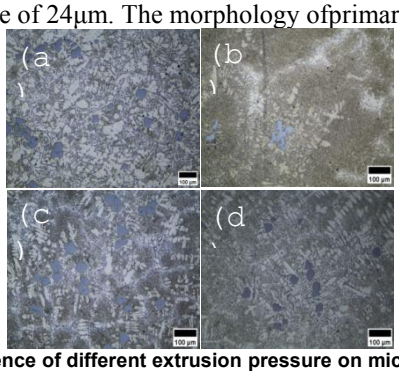

Fig. 1 Influence of different extrusion pressure on microstructure of hypereutectic Al-15Si alloy：（a）unmetamorphism（b）400MPa（c）500MPa（d）600MPa

silicon is mostly sharp-edged plate-like with severe agglomeration, while the eutectic silicon consists of long needle-like and small short rod-like structures. After extrusion, the primary silicon exhibits obvious extrusion cracks and more burrs, undergoing a significant change in morphology, size enlargement, and a substantial decrease in density. Meanwhile, the eutectic silicon noticeably refines into small short rod-like structures with a significant increase in compactness. This is because the eutectic point in the Al-Si binary phase diagram at room temperature shifts to the upper right with an increase in

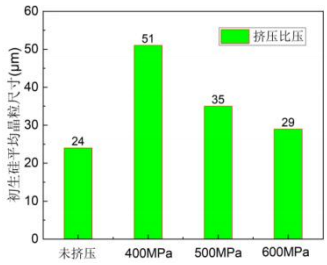

Fig. 2 Average grain size of primary silicon in hypereutectic Al-15Si alloy under different extrusion ratios

extrusion pressure. This leads to an increase in the silicon content in the solid solution at room temperature, an increase in the eutectic temperature of the Al-Si alloy, and the likelihood of generating eutectic structure under pressure, even forming a small amount of subeutectic structure, thereby reducing the quantity of precipitated primary silicon. The eutectic silicon significantly refines into small short rod-like structures with increased compactness, and there are clearly fine α-Al dendrites present in the structure. With the increase in extrusion pressure, the size of primary silicon gradually decreases, attributed to the increase in extrusion force that can enhance the alloy's solidification rate, increase the undercooling of the alloy, and refine the grains.

The extruded alloy exhibits enhanced comprehensive mechanical properties compared to the unextruded alloy. With the increase in extrusion pressure, the tensile strength and elongation of the hypereutectic Al-15Si alloy gradually increase. This is due to the partial improvement in the morphology of primary silicon in the alloy, with reduced size and increased distribution of eutectic silicon, leading to an enhancement in tensile strength through fine crystal reinforcement and an increase in the number of fine α-Al dendrites improving the toughness of the alloy. With the increase in extrusion pressure, the hardness of the alloy initially increases and then decreases, attributed to the increase in compactness of the primary silicon as a hard phase followed by a reduction in compactness.

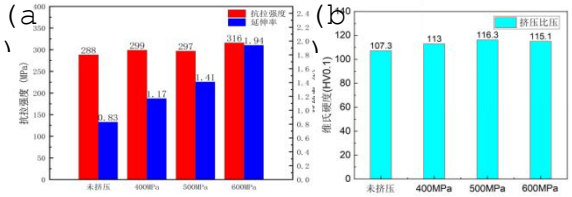

Fig. 3 Mechanical properties of hypereutectic Al-15Si alloy under different extrusion ratios：(a) tensile properties(b) vickers hardness

4 Conclusion

(1) With the increase of extrusion pressure ratio, the average size of primary silicon in Al-15Si alloy decreased, the quantity initially increased and then decreased.

(2) With the increase of extrusion pressure ratio, the tensile strength and elongation of Al-15Si alloy gradually increased, while the hardness initially increased and then decreased.

Acknowledgments

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References

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