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Investigations of continuous casting extrusion on the microstructures and properties of Zn-Al and Zn-Al-Ti alloys

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Abstract. The microstructures and mechanical properties of Zn-Al and Zn-Al-Ti alloys wires prepared by continuous casting and extrusion (CASTEX) were studied in detail. The Al_3Ti intermetallics in Zn-Al-Ti alloy distribute homogeneously at α matrix of Zn-Al eutectics/eutectoid phase, and can effectively refine microstructure and enhance mechanical properties. The metastable AlxTi phase formed during the non-equilibrium crystallization of CASTEX Zn alloys, having close structure to Al-rich α phase, can act as the nucleation site of α phase, and increase the nucleation rate of α phase and refine microstructure further. The CASTEX Zn-27Al-0.1Ti alloy has the comprehensive properties.

Introduction

Continuous casting and extrusion (CASTEX) uses liquid metal as blank and belongs to a new extrusion technology combined casting and extrusion, can produce high performance products of tube, rod, type and wire of non-ferrous metal and its alloy [1-5]. The basic principle of the continuous casting and extrusion is that the molten metal is poured into the wheel groove formed between CASTEX shoe surface and CASTEX wheel, and it gradually solidifies through the cooling effect of inner wall of groove, and at the same time it moves at the friction force of the wheel groove wall, and completely solidifies when arriving the block, is finally extruded into products [6]. Continuous casting and extrusion technology has the advantages of: (1) compact equipment, less investment, small occupation, convenient installation and maintenance; (2) products of infinitely long, high precision, smooth surface, 90% finished product rate; (3) liquid metal blank, no casting process, saving ingot reheating, reducing energy consumption; (4) as a flexible processing technology, using channel combined die [5, 7-9] and extended forming die, producing special and large size products.

Zinc alloy has rich resources, low melting point, good casting performance, low raw material prices, excellent mechanical properties comparable to the ordinary brass ($\sigma_b \geq$400MPa). Therefore, zinc alloy is an ideal substitute for copper alloy.

As a technology of efficient, low cost and short process, continuous casting and extrusion has been widely used in the production of aluminum alloy, and is rarely reported in producing zinc alloy products. The first aim of the continuous casting and extrusion of zinc alloy is to ensure the establishment of a stable friction force [5]. One of the key factors of the technology is the quick establishment of the friction force due to the reaction between zinc aluminum alloy and cast iron alloy steel. That is to say, there exist metallurgical reactions between liquid Zn, Al and Fe, and the bonding strength of interface layer should be good, the dynamics must be very easy to implement, however the addition of alloying elements prevents interface reaction to improve the service life of CASTEX wheel. Metallurgical reactions between Fe and Al, as well as between Fe and Zn [10, 11], indicate that the establishment of friction force of CASTEX Zn-Al can be realized.

In this paper, the microstructure and mechanical properties of Zn-Al alloy and Zn-Al-Ti alloy without or with CASTEX were studied, and the effect of the addition of Ti on the comprehensive properties of zinc alloy products was determined. The forming rule of zinc alloy in the continuous casting and extrusion process was revealed to provide technical support for processing CASTEX Zn-Al alloy and its composites.

Experimental

Materials and Equipment. The materials used in present work are Zn-Al alloys (Zn4Al, Zn12Al, Zn27Al and Zn4Al0.1Ti) and Zn-Al-Ti alloys(Zn12Al0.1Ti and n27Al0.1Ti), were prepared by commercial aluminum, pure Zn and as well as mater alloy Al-5Ti. The test alloys were cast at 530°C.

The experimental device is a DZJ-300 type CASTEX machine. The diameter of CASTEX wheel is 300mm. The wheel speed is 5-15rpm. The maximum torque is 1.96×10^{3}Nm. The angle of CASTEX shoe is 90°.

Experimental Methods. The alloy was heated to 530°C for 20 minutes before the start of CASTEX extrusion machine, the speed of CASTEX wheel was set to 10rpm using PLC controller, and then the test alloy was poured into wheel groove formed by CASTEX wheel and sealing block. The diameter of wire product is 9.5mm.

Results and Discussion

Properties of CASTEX Zn-Al and Zn-Al-Ti Alloys. Fig. 1 illustrates the tensile properties of CASTEX Zn-Al and Zn-Al-Ti alloys at room temperature. It can be seen that, with increasing Al content of Zn-Al alloy, the ultimate tensile strength (σ_b) increases significantly, while the elongation (δ) increases slightly. The σ_b, yield strength ($\sigma_{0.2}$) and δ of Zn-Al-Ti alloy increase further when adding 0.1%Ti.

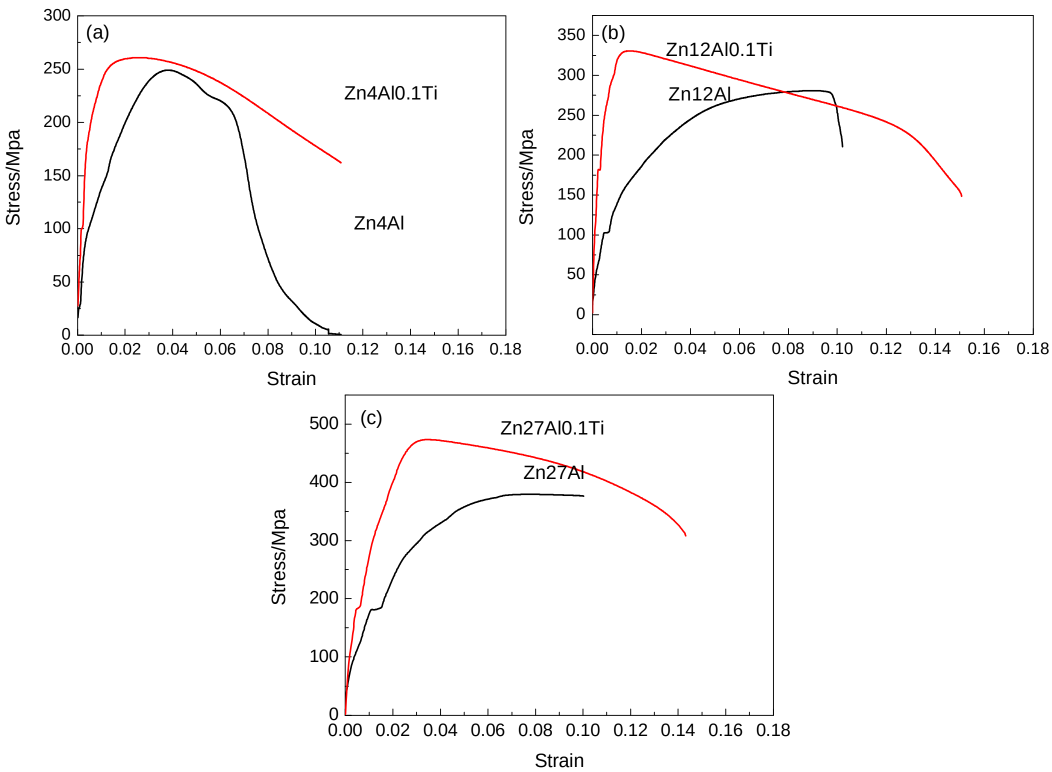

Fig. 1 The engineering stress-strain curves of CASTEX Zn-Al and Zn-Al-Tialloys
(a) Zn-4Al and Zn-4Al-0.1Ti, (b) Zn-12Al and Zn-12Al-0.1Ti, (c) Zn-27Al and Zn-27Al-0.1Ti

The Zn-4Al alloy belongs to the hypoeutectic alloy and has good flow properties. When adding

0.1%Ti, the δ increases from 8% to 12%, and the $\sigma_{0.2}$ increases slightly from 245MPa to 265MPa. However, the improvement of the properties is not obvious.

The σ_b and $\sigma_{0.2}$ of Zn-12Al and Zn-27Al alloys increase significantly after adding 0.1%Ti. The δ of the two alloys increases significantly to 15.7% and 14.5%, respectively, are larger than that of the Zn-4Al alloy. Therefore, the addition of minor Ti has a better effect on the mechanical properties of Zn alloys containing high Al content.

The back scattered electron images of Zn-Al and Zn-Al-Ti alloys and the corresponding EDS analysis of phases are demonstrated in Fig. 2 and Fig. 3. It can be seen that the microstructure of Zn-Al alloy contains light contrast Zn-rich solid solution η phase and dark contrast Al-rich α phase. As shown in Figs. 2 (a), (c) and (e), with increasing Al content, the number and size of Al-rich α phase increase, while the number of the Zn-rich solid solution η phase decreases and the size of it reduces. From Figs. 3 (b), (d) and (f), it can be seen that the size of Al-rich α phase reduces obviously and it distributes more homogeneously after adding Ti.

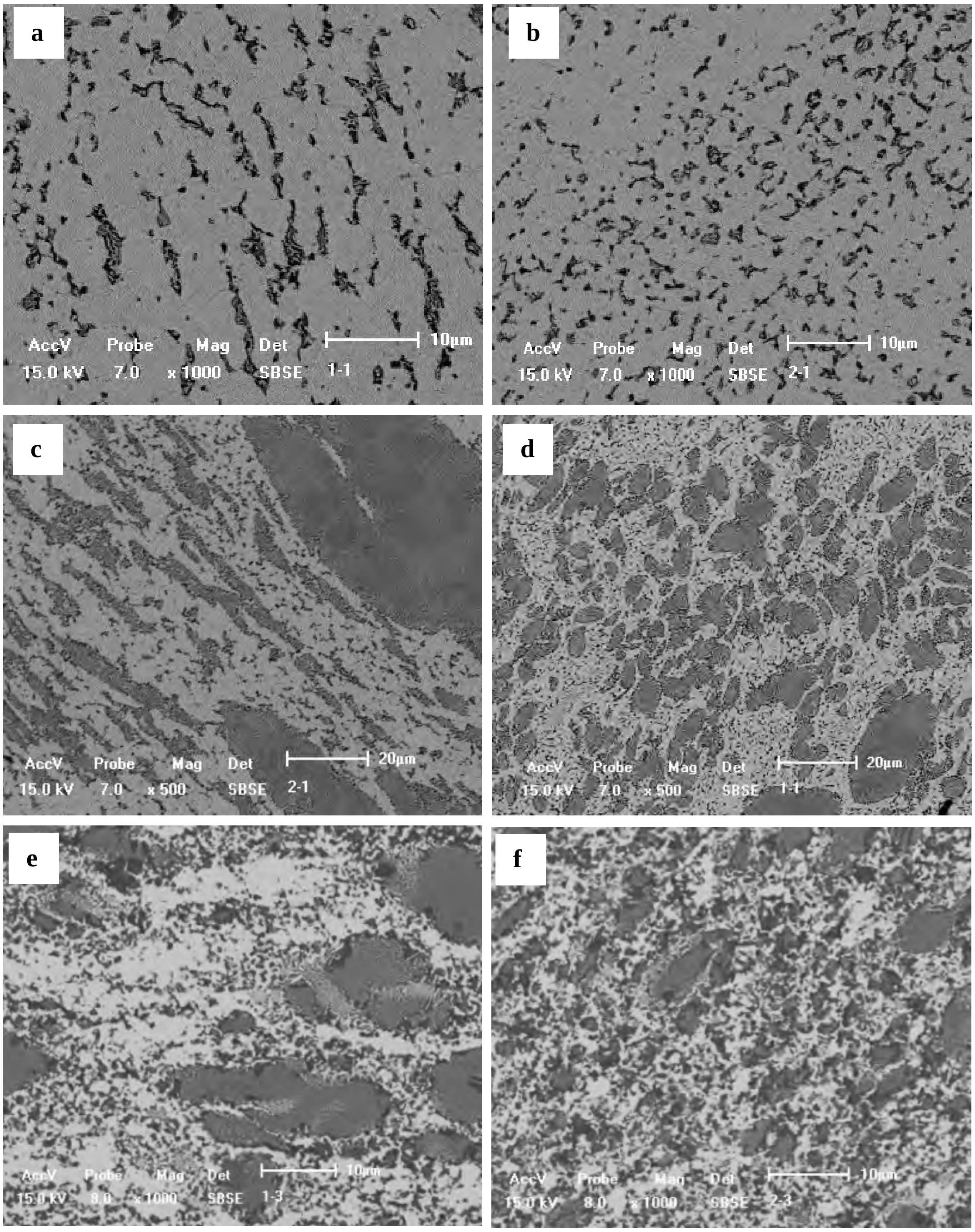

Fig. 2 The back scattered electron images of the Zn-Al and Zn-Al-Ti alloys processed by CASTEX (a) Zn4Al, (b) Zn4Al0.1Ti, (c) Zn12Al, (d) Zn12Al0.1Ti, (e) Zn27Al, (f) Zn27Al0.1Ti

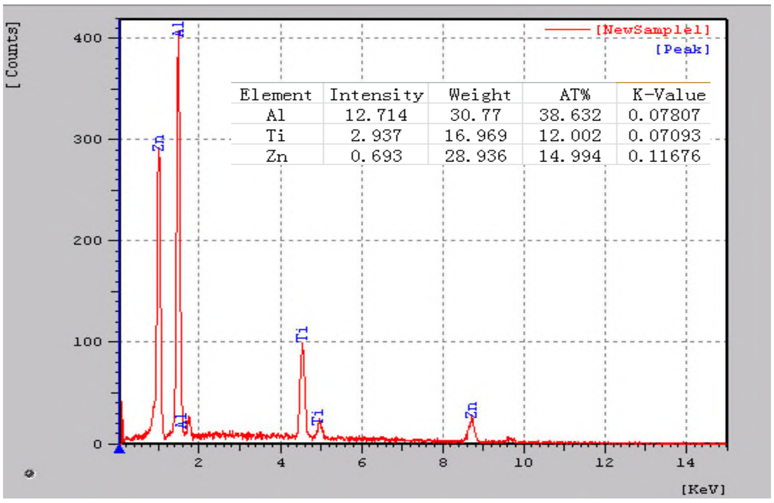

Fig. 3 EDS analysis of the Zn-Al-Ti alloy processed by CASTEX.

Meanwhile, the Al_3Ti intermetallic compound forms due to the addition of Ti, disperses on the α matrix due to the effect of shear deformation of CASTEX process, which can pin the grain boundaries and prevent grain boundary movement, thus suppress grain growth, and finally leads to a fine microstructure in the Zn alloy.

The refinement effect of Ti is related to Al_xTi (X=2.6-2.9), a transitional phase of Al_3Ti. The lattice parameter of the metastable Al_xTi phase is close to that of the Al solid solution, thus can act as the nucleation site of Al-rich α phase [15], this will enhance the nucleation rate of Al-rich α phase.

The Zn-27Al-0.1Ti alloy exhibits comprehensive properties after comparing the mechanical properties and microstructure refinement of the Zn-Al and Zn-Al-Ti alloys.

Summary

Zn-Al-Ti alloys contain Zn-rich solid solution phase, Al-rich α phase and Al_3Ti phase. The ultimate tensile strength σ_b and yield strength $\sigma_{0.2}$ of Zn-Al alloys increase significantly after adding 0.1%Ti. The mechanical properties of Zn alloy containing high Al content are greatly improved by minor addition of Ti. The Al_3Ti compound disperses on the α matrix of Zn-Al eutectic (eutectoid) phase due to the effect of shear deformation of CASTEX, can pin grain boundaries, prevent grain boundary movement, thus suppress grain growth, and finally leads to a fine microstructure in Zn alloys. The lattice parameter of the metastable Al_xTi phase is close to that of the solid solution, can act as the nucleation site of Al-rich α phase, this will enhance the nucleation rate of Al-rich α phase and refine it.

Acknowledgements

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