Effects of thermal compression on thermal conductivity and mechanics of Mg-Zn-Cu alloys

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Abstract: In order to meet the requirements of thermal conductivity materials, the Mg-Zn-Cu magnesium alloy with better thermal conductivity was selected, and the thermal conductivity and mechanical properties were improved by reducing the alloying degree and combining with hot extrusion deformation. After hot extrusion deformation, the grain is obviously refined, and the morphology of the second phase changes from a reticular structure to a granular distribution along the extrusion direction. After hot extrusion deformation, Mg-2Zn-2Cu alloy obtains the highest thermal conductivity and mechanical properties, thermal conductivity is 153.5 (W/(M·K)), yield strength is 162.9 MPa, tensile strength is 277.8 MPa, and elongation is 37.7 %.

Keywords: Mg-Zn-Cu alloy; hot extrusion; thermal conductivity; mechanical properties

1 Introduction

In the 5G communication era, all kinds of intelligent terminal products are constantly upgrading, and the power consumption is getting higher and higher, which also put forward higher requirements for the thermal conductivity of materials[1]. Magnesium, as the lightest density engineering structural material, has high specific strength, specific stiffness and good heat dissipation performance, which has the potential to meet the demand of thermal conductive materials in the 5G era[2].

Mg-Zn-Cu alloy due to the precipitation of MgZnCu phase reduces the solid solution atoms in the matrix, because the negative effect of the second relative thermal conductivity is much less than that of the solid solution atoms, so Mg-Zn-Cu alloy has excellent thermal conductivity, but its mechanical properties in the as-cast state are low and cannot meet the application requirements[3]. Therefore, this study uses hot extrusion deformation to enhance the thermal conductivity and mechanical properties of the alloy while reducing the degree of alloying[4].

2 vExperimental procedure

The original ingot was prepared by melting high-purity Mg, Zn, and Cu at 750 °C in a resistance furnace under an argon atmosphere, and the nominal composition of the ingot was Mg-1Zn-1Cu, Mg-2Zn-Cu, and Mg-3Zn-3Cu. Then, the molten temperature was reduced to 730°C, and it was poured into the mold preheated to 200°C.

Before undergoing hot extrusion, the cast alloy was homogenized at 430 °C for 60 hours. During the hot extrusion experiment, the sample was preheated at 240°C for 1 hour to achieve uniform temperature. Following this, it was extruded at 240 °C with an extrusion speed of 0.4mm/s and an extrusion angle of 30°, utilizing a die with an extrusion ratio (Re) of 25.

3 Result and discussion

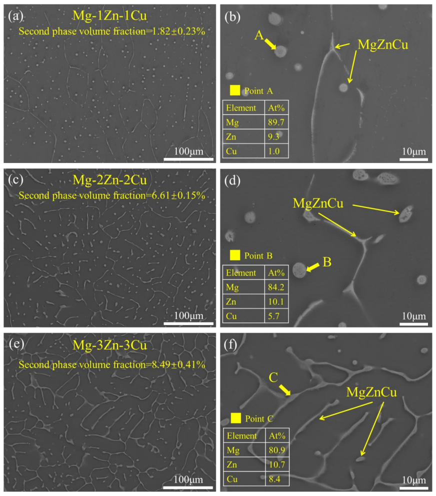

Fig 1. The SEM image of as-cast Mg-Zn-Cu alloy. (a, b) Mg-1Zn-1Cu, (c, d) Mg-2Zn-2Cu, (e, f) Mg-3Zn-3Cu. EDS results are annotated in the lower left corner of the picture.

As shown in Fig.1, in the as-cast alloy, the alloy is composed of α-Mg and eutectic structure. With the increase of Zn and Cu content, the volume fraction of eutectic structure gradually increases, and gradually changes from a semi-continuous network structure to a continuous network structure. In the extruded alloy, it can be observed that the microstructure of as-extruded alloys α-Mg and a kind of second phases which positioned along the extrusion direction in Fig. 2. The second phase changes with the content of Zn and Cu in the extruded alloy have the same trend as that in the cast alloy. Fig.2 show that the grains of the alloy are obviously equiaxial, and second phases are distributed on the grain boundaries. Combined with EDS analysis, the second phase in the alloy is MgZnCu.

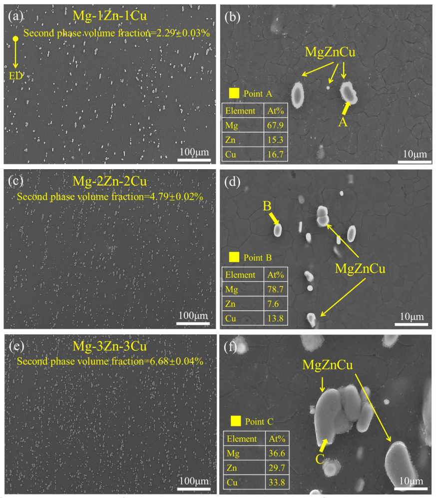

Fig 2. The SEM image of as-extruded Mg-Zn-Cu alloy. (a, b) Mg-1Zn-1Cu, (c, d) Mg-2Zn-2Cu, (e, f) Mg-3Zn-3Cu.

Table 1. Thermal conductivity and mechanical properties of extruded alloys

Alloys	Thermal conductivity (W/(m·K))	YS (MPa)	UTS (MPa)	EL (%)
Mg-1Zn-1Cu	115.3	124.8	237.3	40.2
Mg-2Zn-2Cu	153.5	162.9	277.8	37.7
Mg-3Zn-3Cu	136.4	148.2	248.3	34.2

Table 1 shows the thermal conductivity and mechanical properties of the extruded alloy, and the highest thermal conductivity of the Mg-2Zn-2Cu alloy is 153.5 W/(m·K). At the same time, the mechanical properties of the alloy increase firstly and then decrease with the increase of Zn and Cu content, and on the whole, the mechanical properties gradually increase with the increase of alloy content., and the Mg-2Zn-2Cu alloy achieves the best combination of mechanical properties, with yield strength of 162.9 MPa, ultimate tensile strength of 277.8 MPa and elongation of 37.7%.

According to the microstructure, after hot extrusion deformation, the grain size of the alloy is greatly reduced, and the number of grain boundaries is increased. The resistance of grain boundaries to dislocation movement increases and the yield strength of the alloy is improved. At the same time, during the hot extrusion process, the second phase changes from a reticular structure to a dispersed granular structure in the matrix, which effectively hinders the dislocation movement and improves the tensile strength of the alloy. As for the thermal conductivity, casting defects have a great influence on the thermal conductivity. Hot extrusion can reduce the defects in the as-cast alloy and improve the thermal conductivity of the alloy. On the other hand, during the extrusion deformation process, the solute atoms are dynamically precipitated from the magnesium matrix to form the second phase, which reduces the content of alloying elements in the matrix and improves the thermal conductivity of the alloy.

4 Conclusion

(1) After hot extrusion, the MgZnCu phase in the Mg-Zn-Cu alloy changes from a network structure in the as-cast state to an island distribution at the grain boundaries along the extrusion direction

(2) After extrusion deformation, the casting defects and the content of solute atoms in the matrix are reduced, and the thermal conductivity of the alloy is improved. The highest thermal conductivity of the Mg-2Zn-2Cu alloy is 153.5 W/(m·K)

(3) Mg-2Zn-2Cu alloy obtained the best combination of strength and plasticity after hot extrusion deformation. The yield strength was 162.9 MPa, the tensile strength was 277.8 MPa, and the elongation was 37.7 %.

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