Effect of Cu Addition and Heat Treatment on the Microstructure and Properties of ZL114A

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Abstract: This research investigated the impact of varying Cu content and heat treatment on the microstructure and mechanical properties of ZL114A using optical microscope, scanning electron microscope (SEM), transmission electron microscope (TEM), differential scanning calorimeter (DSC), Vickers hardness tester, and room temperature tensioning machine. The findings revealed that the mechanical properties of ZL114A could be enhanced by incorporating different Cu content, with the optimal effect observed at 1.2% Cu content. The hardness post heat treatment was measured at 143.1HV, marking a 13.9% increase, while the tensile strength reached 326MPa, reflecting a 33.4% improvement. The introduction of Cu did not alter the microstructure of ZL114A. Furthermore, heat treatment transformed the eutectic Si morphology from sharp long rod shape to elliptic shape, fractured the dendrites, eliminated stress concentration at the eutectic Si edge, and ultimately enhanced the mechanical properties.

Keywords: Cast aluminum; Eutectic silicon; Grain size; Heat treatment

1 Introduction

ZL114A is a cast Al-Si alloy, which is a significant series of cast aluminum alloys. Many Al-Si alloys have a relatively low crystallization temperature and contain numerous eutectic components in their structure. This series of aluminum alloys offers several advantages, such as low density and high strength. Additionally, Al-Si aluminum alloys exhibit strong casting and mechanical properties, making them suitable for various casting methods and the production of products with diverse characteristics like different shapes, thin walls, high corrosion resistance, strong air tightness, or high temperature resistance, making them widely utilized. Aluminum-silicon casting alloys with high toughness generally demonstrate excellent performance. After undergoing metamorphic treatment and heat treatment, they exhibit favorable physical properties, mechanical properties, and processing properties. These alloys are primarily used for intermediate parts' shell structures and load-bearing components with complex shapes, finding extensive applications in aerospace, transportation, and other industries. Copper serves as one of the primary strengthening elements in aluminum alloys. The addition of copper significantly enhances the tensile strength and hardness of the alloy by forming Al_2Cu through a reaction with aluminum. This second phase contributes mainly to the solid solution strengthening and dispersion strengthening of the matrix. Therefore, incorporating copper and subjecting the alloy to solution and aging treatment can notably enhance its tensile strength and hardness.

2 Experimental procedure

ZL114A alloy was prepared using metal mold casting and smelted in a crucible furnace at 750℃. Once the alloy was completely melted, an Al-50Cu intermediate alloy was added. Various amounts of Cu ranging from 0% to 1.5% were added. Following the dissolution of the intermediate alloy, 1% Al-5Ti-B was added for refining and held for 20 minutes. Subsequently, 1% C_2Cl_6 was used for refining and degassing, and the ingot was obtained through slagging after a 10-minute hold. The chemical composition of the alloy is detailed in Table 1. The alloy underwent solution and aging treatments consecutively, with a quenching temperature of 60℃ and a transfer time of less than 10 seconds. The solution and aging treatments were conducted in the SX2-2.5-10A Muffle furnace and the 101A-1 aging furnace, respectively. The heat treatment process parameters were set at 540℃×12h+160℃×8h (T6 treatment). Mechanical properties of each sample were assessed using a tensile test machine, while the microstructure was examined using an FEI Quanta scanning electron microscope and analyzed via energy spectrum.

Table 1. Composition of Alloy ZL114A %

Mg	Si	Cu	Ti	Be	Zn	Al
0.7	6.25	0~1.5	0.18	0.07	0.08	Bal.

3 Result and discussion

Subheads 1

The mechanical properties of ZL114A alloy in T6 state with varying Cu content are presented in Table 2. The data illustrates that the addition of Cu enhances the alloy's mechanical properties. Specifically, with a Cu content of 0.3%, there is minimal impact on the tensile strength of the ZL114A alloy. However, as the Cu content increases to 0.9%, the tensile strength significantly rises to 325 MPa. At 1.2% Cu content, the alloy exhibits peak mechanical properties, with a Vickers hardness of 143.1 HV. In comparison to no Cu presence, the tensile strength increases by 13.9% to 326 MPa, a 33.4% improvement, with negligible changes in elongation. Beyond 1.2%, at 1.5% Cu content, a decrease in mechanical properties occurs, likely due to the solubility limit of Cu in the alloy.

Table 2. Mechanical properties of ZL114A alloy T6 state without Cu concent

Cu%	Tensile strength MPa	Hardness HV
0	293	124.3
0.3	301	130.1
0.6	310	132.8
0.9	325	133.6
1.2	326	143.1
1.5	321	133.7

Subheads 2

The cast ZL114A exhibits a coarse dendritic microstructure, with the eutectic Si appearing as long rods with sharp edges. The addition of Cu has minimal impact on the morphology of the eutectic Si. Through heat treatment, the long rod Si can be transformed into fine ellipses, effectively reducing stress concentrations at the edges of the eutectic Si and enhancing the mechanical properties of the alloy.

4 Conclusion

With increasing Cu content, the mechanical properties of the alloy improve. At a Cu content of 1.2%, the alloy exhibits maximum Vickers hardness of 143.1HV, a 13.9% increase in hardness, and a tensile strength of 326MPa, representing a 33.4% increase. Additionally, the elongation remains relatively unchanged. Furthermore, the addition of Cu shows minimal impact on the morphology of eutectic Si.

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