Effect of Cu and Mg Content on Microstructure and Mechanical Properties of Cast Al-Si-Cu-Mg Alloy

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Abstract: The wide application of traditional cast Al-Si alloy in related industries is seriously restricted because of its low room temperature strength and high temperature performance attenuation. By adding Cu and Mg elements, the effect of Cu and Mg element content on the type and morphology of the second phase in cast Al-8.5Si-xCu-yMg alloy was systematically studied, and its mechanical properties were tested. The results show that when the content of Mg is constant, with the addition of Cu, blocky Q-Al5Cu2Mg8Si6 phase and reticular θ-Al2Cu phase appear in the alloy. When the Cu content is constant, with the increase of Mg content, the size and number of reticular and blocky θ-Al2Cu phases in the alloy decrease, while the blocky Q-Al5Cu2Mg8Si6 phase changes from a small blocky phase to a large flake phase, and the number increases. The tensile strength of Al-8.5Si-2Cu-0.9Mg at room temperature and 250 ℃ is 335.3 MPa and 170.3 MPa, respectively. The yield strength is 254.6 MPa and 147.2 MPa, respectively. The elongation after breaking is 4.0% and 8.8%, respectively.

Keywords: Cast Al-Si alloy, Cu, Mg, Aging treatment, Microstructure, Mechanical properties

1 Introduction

Cast Al-Si-Cu-Mg alloy is an alloy developed by adding Cu and Mg elements on the basis of cast Al-Si alloy. Besides eutectic Si phase, there may exist the second phases such as θ-Al_2Cu and Q-$Al_5Cu_2Mg_8Si_6$ in the alloy. The types, morphology and distribution of these second phases will have an impact on the mechanical properties of the alloy at room temperature and high temperature [1]. The addition of Cu element in Al-Si alloy can improve the microstructure of the alloy, thereby increasing its strength and contributing to its high temperature mechanical properties. Therefore, the existence forms of these two Cu-rich phases in alloys can be effectively regulated by adjusting the content of Cu element, which is of great significance for the research of high-performance Al-Si-Cu-Mg alloys [2].

The content of Mg element determines the content, morphology and distribution of Q-$Al_5Cu_2Mg_8Si_6$ phase in the alloy. Compared with the θ phase, the Q phase can improve the strengthening effect of the alloy more significantly [3]. Therefore, based on the optimal Cu content, the content of Mg element in the alloy can be adjusted to further improve the quantity, morphology and distribution of the second phase in the alloy [4]. Furthermore, the mechanical properties of the alloy at room temperature and high temperature can be improved, which is of great significance for the expansion of the practical application scenarios of casting Al-Si-Cu-Mg alloy.

2 Experimental procedure

The test alloy was prepared by metal type gravity casting method in the paper. The well resistance furnace was used to melt the alloy. The mold used for smelting was metal mold, the crucible was graphite crucible, and the total mass of the raw material was 1000 g. When melting, it was necessary to put the slag scoop, bell jar, crucible tongs, metal mold and other experimental equipment and raw materials into the oven and heat up to 200℃ for 2 hours. First, when the well resistance furnace was heated to 730℃, industrial pure aluminum and Al-Si intermediate alloy were placed in the graphite crucible. After being kept warm until completely melted, the temperature of the resistance furnace was raised to 750 ℃ , and Al-40Cu intermediate alloy, industrial pure magnesium, Al-10Sr modifier and Al-5Ti-1B refiner were added to the graphite crucible in turn. After complete melting, the temperature of the resistance furnace was lowered to 730℃, and the refining was carried out with C2Cl6. After the refining was completed, the slag was scraped. After standing for 10 minutes, the metal liquid was poured into a metal mold preheated to 200℃. After the ingot was completely cooled, the test alloy was obtained in the same position and a part of it was subjected to T6 heat treatment. The nominal composition of the alloy was shown in Table 1.

Table 1. Nominal composition of alloy

Alloy	Si	Cu	Mg	Al
1#	8.5	0	0.7	Bal
2#	8.5	2	0.7	Bal
3#	8.5	2	0.9	Bal

3 Result and discussion

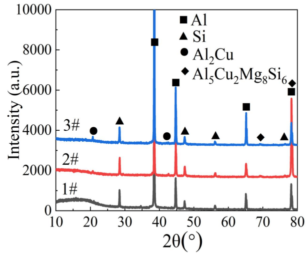

Figure 1 XRD patterns of cast alloys.

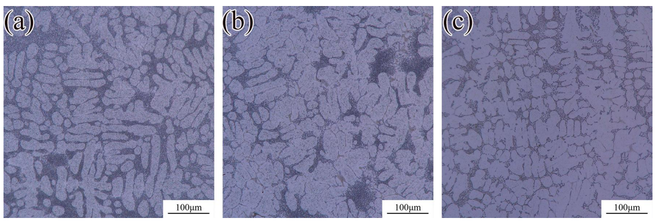

Figure 2. Optical micrographs of alloys in as-cast state (a) 1# (b) 2# (3) 3#.

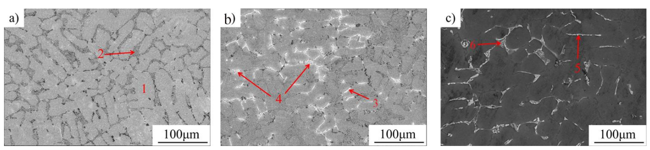

Figure 3. SEM images of as-cast alloys (a) 1# (b) 2# (3) 3#.

Table 2. Mechanical Properties of Al–Si–Cu–Mg Alloy After T6 Heat Treatment

Alloy	Room temperature			250℃		
	UST/ MPa	UST/ MPa	Elongation/%	UST/ MPa	UST/ MPa	Elongation/%
1#	154.6	72.6	14.5	79.3	53.3	20.4
2#	320.3	248.7	4.4	168.1	144.4	9.1
3#	335.3	254.6	4.0	170.	147.2	8.8

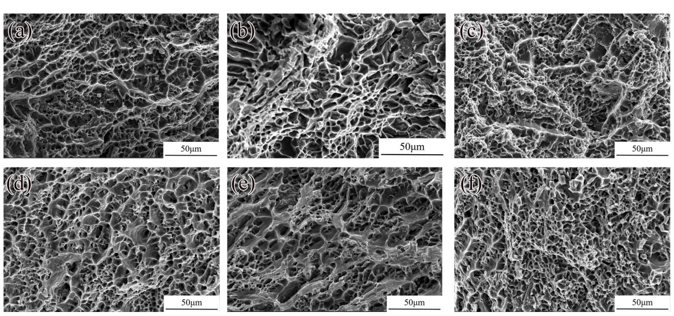

Figure 4. SEM micrographs of fracture surface of alloys tensile specimens (a) 1#, (b) 2#, (c) 3#, (d) 1# 250℃, (e) 2# 250℃, (f) 3# 250℃,

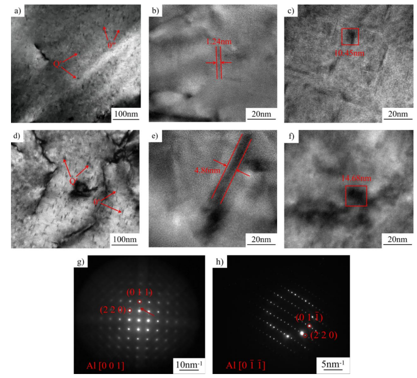

Figure 1TEM images and SAED pattern (a)-(c) 175℃ 5h, (d)-(h) 175℃ 8h.

4 Conclusion

(1)The microstructure of cast Al-Si-Cu-Mg alloy is mainly composed of α-Al grains, eutectic Si phase, θ-Al_2Cu phase and Q-$Al_5Cu_2Mg_8Si_6$ phase.

(2)With the addition of Cu, the bulk Q-$Al_5Cu_2Mg_8Si_6$ phase and the network θ-Al_2Cu phase appear in the alloy. With the increase of Mg content, the size and number of θ-Al_2Cu phase in the alloy decrease, and the morphology of the light-colored Q-$Al_5Cu_2Mg_8Si_6$ phase changes from a small block to a large sheet, and the number increases.

(3)When the content of Cu and Mg elements is 2% and 0.9% respectively, the alloy achieves the best mechanical properties. At room temperature, the tensile strength, yield strength and elongation of the alloy are 335.3 MPa, 254.6 MPa and 4%, respectively. At 250 °C, the tensile strength, yield strength and elongation of the alloy are 170.3 MPa, 147.2 MPa and 8.8%, respectively.

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