Effects of Ni Contents on Microstructure and Mechanical Properties of Al-8Ce Alloy

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Abstract: The microstructures and properties of Al-8Ce-yNi alloys were investigated. The results show that with the increase of Ni content, the range of solid-liquid phase zone of Al-8Ce-yNi alloy was narrowed. The ternary eutectic group network structure composed of Al_3Ni and $Al_{11}Ce_3$ was formed. The ultimate tensile strength (UTS) of Al-8Ce-yNi alloys at room temperature and elevated temperature (350°C) are increased with the increase of Ni content. When the Ni content is 6%, the UTS of the alloy at room temperature and elevated temperature reach the maximum value, which are 189 MPa and 72 MPa, respectively.

Keywords: Ni Contents; Al-8Ce alloy; Microstructure; Mechanical Properties

1 Introduction

Ce is an excellent alloying element that can purify melt and improve alloy fluidity [1-2]. Existing studies have shown that Al-Ce alloy has fluidity and casting properties comparable to Al-Si alloy [3]. The eutectic $Al_{11}Ce_3$ phase produced by the eutectic reaction of Ce in Al has excellent high temperature stability. And the higher the Ce content, the better the high temperature performance of the alloy [4-5]. Therefore, Al-Ce alloy has great development potential due to its excellent casting performance and high temperature stability, but there are few relevant studies on Al-Ce alloy at present. In this paper, the effect of Ni content on the microstructure and mechanical properties of Al-8Ce alloy was studied.

2 Experimental procedure

Al-8Ce-yNi alloys with different Ni contents were prepared by pure Al (99.9%, mass fraction, the same below), Al-20Ce and Al-10Ni master alloys. The nominal chemical composition of the alloys is shown in Table 1. First, the prepared materials were fully melted by electrical resistance furnace with graphite crucible. Then the melt was degassed with high-purity argon gas and was cooled down to a temperature of 710 °C after degassing. After that, the melt was poured into a permanent casting mold preheated to about 200 °C, and the standard tensile samples with diameter of 8 mm were obtained. The phase compositions were evaluated by D8 ADVANCE XRD analyzer. Microstructural characterization was revealed and analyzed by ZEISS GeminiSEM300 field emission scanning electron microscope attached with EDS. DSC experiments were performed on a differential scanning calorimeter (NETZSCH STA449F3) at the cooling rate of 10 °C/min. The room and elevated temperature mechanical properties were examined on SHIMADZU AG-IC100KN universal material testing machine and the tensile rate is 1 mm/min.

Table 1. Nominal chemical composition of the alloys (wt.%)

Alloys	Ce	Ni	Al
Al-8Ce	8	-	Bal.
Al-8Ce-2Ni	8	2	Bal.
Al-8Ce-3Ni	8	3	Bal.
Al-8Ce-4Ni	8	4	Bal.
Al-8Ce-5Ni	8	5	Bal.
Al-8Ce-6Ni	8	6	Bal.

3 Result and discussion

As-cast microstructure of Al-8Ce-yNi alloy

Figure 1 shows the XRD pattern of as-cast Al-8Ce-yNi alloy with different Ni content. It can be seen that Al-8Ce alloy is mainly composed of α-Al and Al11Ce3 phases.

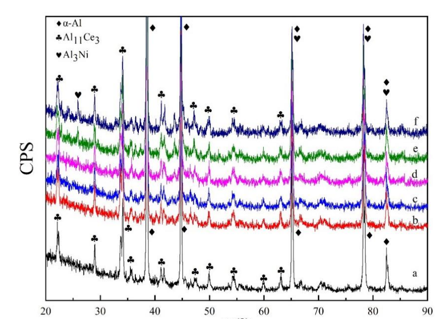

Fig.1 XRD spectrums of as-cast Al-8Ce alloys with different Ni contents: (a) Al-8Ce, (b) Al-8Ce-2Ni, (c) Al-8Ce-3Ni, (d) Al-8Ce-4Ni, (e) Al-8Ce-5Ni, (f) Al-8Ce-6Ni

Al-8Ce-yNi alloy is mainly composed of α-Al, $Al_{11}Ce_3$ and Al_3Ni phases. Fig. 2 shows the BSE micrographs of the microstructure of the as-cast Al-8Ce-6Ni alloy. Combined with the results of XRD and energy spectrum analysis shown in Table 2, it can be seen that in addition to the bright white lamellar $Al_{11}Ce_3$ phase (orange dashed line frame indicated by arrow 1 in Fig. 2) and the light gray fine irregular multilateral Al_3Ni phase (yellow dashed line frame indicated by arrow 2 in Fig. 2), a new network structure composed of the eutectic Al_3Ni phase and $Al_{11}Ce_3$ phase appears in the alloy (red dashed line frame indicated by arrow 3 in Fig. 2).

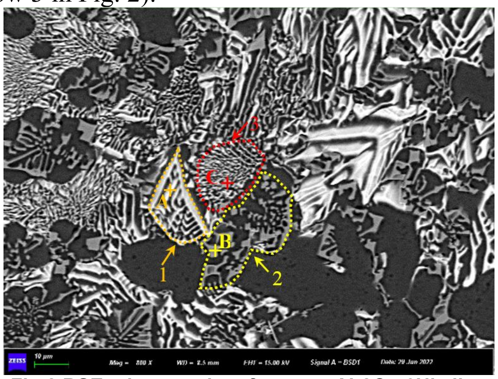

Fig.2 BSE micrographs of as-cast Al-8Ce-6Ni alloy

Table 2 EDS results of corresponding points in Fig. 2 (at%)

Points	Al	Ce	Ni
A	83.97	16.03	0
B	64.15	0	35.85
C	94.01	4.23	1.76

Fig. 3 shows the DSC curve of the temperature rise process of Al-8Ce-yNi alloy, and it can be seen that an obvious heat absorption peak appears on the DSC curve. It can also be seen that with the increase of Ni content, the melting endothermic peak of the primary α-Al in Al-8Ce-(2,3,4,5,6)Ni alloy shifts to the left. This means that with the increase of Ni addition, the liquidus temperature of Al-8Ce-(2,3,4,5,6)Ni alloy is decreased and the solid-liquid two-phase region is narrowed. Therefore, the addition of Ni changes the solidification characteristics of the alloy.

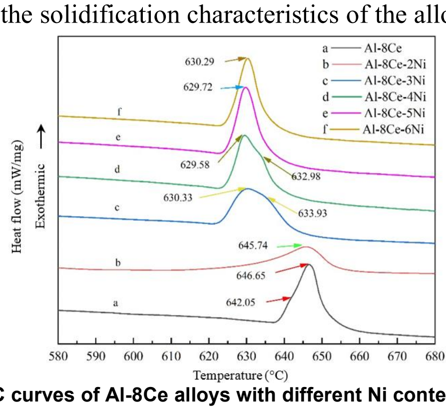

Fig.3 DSC curves of Al-8Ce alloys with different Ni contents during heating process

Mechanical properties of Al-8Ce-yNi alloy

With the increase of Ni content, the ultimate tensile strength (UTS) and yield strength (YS) of the alloy at room temperature are both increased gradually. When the Ni content is 6%, the UTS and YS at room temperature reach the maximum values, which are 189MPa and 59MPa, respectively. The elevated temperature (350°C) UTS and YS of the alloy are also increased with the increase of Ni content. When the Ni content is 6%, the elevated temperature UTS and YS of the alloy reach the maximum value, which are 72MPa and 53MPa, respectively. However, the elongation is decreased with the increase of Ni content either at room temperature or elevated temperature. The very low diffusion rates of Ce and Ni make $Al_{11}Ce_3$ and Al_3Ni phases less prone to dissolution or coarsening at high temperature, and these phases have excellent high temperature stability. Thus, the compact ternary eutectic structure can strengthen the alloy matrix and improve the heat resistance of the alloy.

4 Conclusions

(1) With the increase of Ni content, the liquidus temperature of Al-8Ce-yNi (y=2,3,4,5,6%) alloy is decreased, the solid-liquid two-phase zone is narrowed. And the addition of Ni elements changes the solidification characteristics of the alloy.

(2) The UTS of Al-8Ce-yNi (y=2,3,4,5,6%) alloy at room temperature and elevated temperature (350°C) is increased with the increase of Ni content. When the Ni content is 6%, the UTS of the alloy at room temperature and elevated temperature reaches the maximum value, which are 189MPa and 72MPa respectively, and the elongation decreases with the increase of Ni content.

Acknowledgments

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