Influence of Rare Earth Elements Erbium and Europium Addition on Microstructure and Mechanical Properties of Al-Cu-Mg-(Ag) Alloys

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Abstract: The alloying behavior of rare earth Erbium (Er) and Europium (Eu) at different ratios in Al–Cu–Mg (A206) and Al-Cu-Mg-Ag (A201) alloys with/without T7 heat treatment on mechanical properties were investigated. The potential effect of Er and Eu on the tensile and hardness of the alloy was characterized by optical metallographic examination, SEM and EDS examinations. The mechanical properties first increased with the addition of alloying element, however decreased with the increase in the amount of alloying element. Even after 0.2 wt%, the mechanical properties have decreased considerably. In SEM and EDS analyses, the increase in the number and size of intermetallic with the addition of Er and Eu is associated with negative mechanical properties.

Keywords: Al-Cu-Mg-(Ag), Rare earth, Er, Eu

1 Introduction

The precipitation of fine Ω phase in Al–Cu–Mg (A206) and Al-Cu-Mg-Ag (A201) alloys provides attractive strength and excellent creep resistance at elevated temperatures. These excellent properties make Al-Cu alloys very suitable for aerospace applications [1-4]. The microstructure and mechanical properties of Al-Cu alloys can be changed with different amount of Mg addition. These changes are achieved by the precipitation of Ω phases in the Al-Cu alloy with the addition of Mg [1]. The amount of precipitation of Ω phases is significantly increased by addition of Ag to Al-Cu-Mg alloys. On the other hand, adding Ag to Al-Cu alloys does not provide this effect. As a result, adding Mg and Ag together to Al-Cu alloys can shape Mg-Ag co-clusters, precipitating a considerable amount of Ω phases [2]. In addition to this, the small addition of Ag to Al-Cu-Mg alloys improves the aging hardening response by the precipitation of the fine and uniform Ω phase on the $\{111\}_\alpha$ planes [3].

Lately, it has been shown that trace additions of rare earth elements can greatly improve the mechanical properties of aluminum alloys and provide enhanced capabilities [1-4]. The present work investigates the effect of the addition of erbium (Er) and europium (Eu) to Al-Cu-Mg and Al-Cu-Mg-Ag alloys on the microstructure and mechanical properties of the as-cast and T7 heat-treated condition.

2 Experimental procedure

In the experimental work, Al-Cu4-Mg commercial purity alloy was used, and the chemical composition is given in Table 1.

Table 1. Composition of Al-Cu4-Mg base alloy

Cu	Fe	Si	Mn	Mg	Ti	Al
4.79	0.12	0.14	0.36	0.23	0.25	Bal

15 kg base alloy (Al-Cu-Mg) were melted in SiC crucible at 750°C in induction furnace. After the alloy was melted, an appropriate amount of Ag was added so that the content was 0.6 wt% Ag. Before the addition of master alloys, it was held for 15 minutes for the added Ag to be dispersed homogeneously. Al-3 wt% Er and Al-10 wt% Eu master alloys were used for alloying in appropriate proportions (0.1 and 0.3 wt% combinations). Degassing was carried out with N_2 gas for 300 seconds. Sand molds, which provide 10 cylindrical test bars were prepared with 60 AFS sand, 2 wt% resin and 0.5 wt% hardener. 7 out of 10 bars are heat treated. Regarding T7 state, base alloy and alloyed bars were solution treated for 22 hours at 540 °C at resistance furnace. Following by the cold water quenched at room temperature, the alloys were natural aged at room temperature for 24 hours then artificial aged at 160 °C for 13 hours and cooled in the air. Tensile test sample was machined according to the ASTM E8. The hardness test was employed. Sanding and polishing were applied to the samples for metallographic and SEM examination.

3 Result and discussion

Tensile test was employed for each parameter, with 3 samples in as-cast and 7 samples in T7 state. Yield Stress (YS), Ultimate Tensile Stress (UTS) and Elongation at fracture results were given at Figure 1.

In the case of as-cast condition, although the elongation decreases with the addition of alloying elements, there is a small fluctuation from the YS and UTS values. On the other hand, YS and UTS values have generally doubled with T7 heat treatment, while percentage elongations have decreased by more than half. The best mechanical properties were achieved in T7 heat treated samples without rare earth elements in the base alloy. YS was 381 MPa, UTS was 450 MPa and elongation was 4%. The mechanical properties decreased with the increase of the alloying elements.

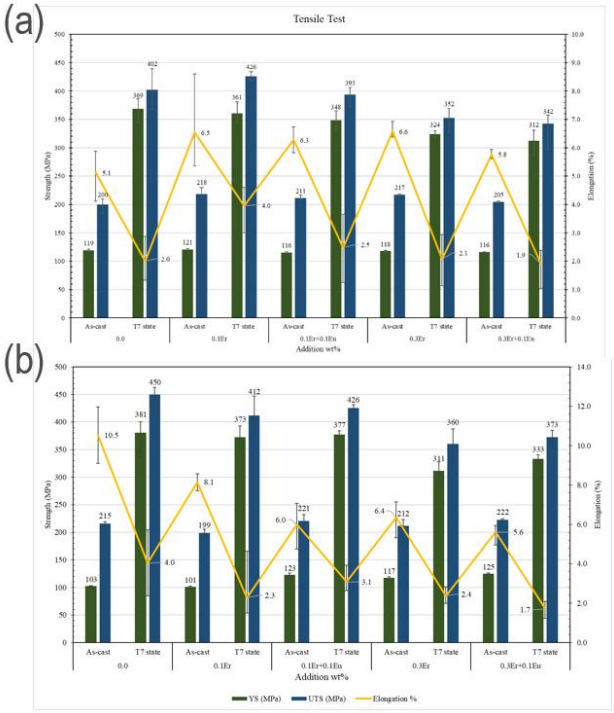

Figure 1. Mechanical properties of (a) Al-Cu-Mg and Al-Cu-Mg-Ag alloys with different master alloy addition ratios.

Figure 2 showed SEM micrographs and EDS analysis of as-cast Al–Cu-Mg-Ag alloys. In the SEM photograph of the Al-Cu-Mg-Ag alloy with 0.1 wt% Er and 0.1 wt% Eu added, it was seen in the Figure 2a that the dendritic intermetallic surround the structure. It was determined by EDS analysis that the intermetallic formed were Al-Cu-Er-Eu. (Figure 2b). In the SEM photograph of the Al-Cu-Mg-Ag alloy with 0.3 wt% Er and 0.1 wt% Eu added, it was seen in the Figure 2c that with the increase of alloying element, intermetallic structures such as spine skeleton or fish bone-like and a structure resembling a flower petal are seen. It was determined by EDS analysis that the intermetallic formed were Al-Cu-Er-Eu. (Figure 2d). The weight ratios of Er and Eu added are in agreement with the EDS analysis results.

The number and shape of intermetallic grew with the increase of alloying elements. As a result of the incompatibility between the main structure and intermetallic and the increase in the amount and size of the intermetallic, the mechanical properties decreased with the addition of the alloying element.

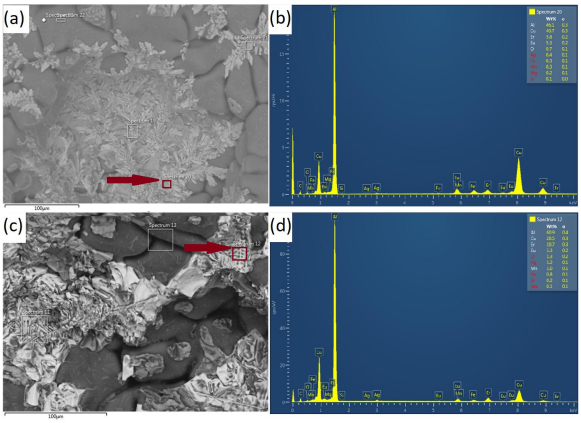

Figure 2. SEM micrographs of Al-Cu-Mg-Ag alloys a) 0.1 wt% Er and 0.1 wt% Eu, b) EDS analysis of marked area in (a), c) 0.3 wt% Er and 0.1 wt% Eu, d) EDS analysis of marked area in (c)

4 Conclusion

The mechanical properties of Al-Cu-Mg alloy with T7 heat treatment were greatly improved compared to the as-cast state. On the other hand, the mechanical properties decreased with the increase in the amount of rare earth elements Er and Eu added as alloying elements in T7 heat-treated samples. The mechanical properties decrease with the increase of alloy addition. The reason for this decrease was observed by SEM and EDS analyzes that the number and size of noncoherent needle-like intermetallic increased with the increase of alloy element addition.

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