Effect of Electro-Pulse on Microstructure of Al-Cu-Mn-Zr-V Alloy During Aging Treatment

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Abstract: The effects of electro-pulse on microstructure and mechanical properties of Al-Cu-Mn-Zr-V alloy were investigated. As the current density increases, the size and quantity of precipitates gradually transit from continuous aggregation to dispersion at grain boundaries, and the mechanical properties are improved. When the current density is 15 A·mm^{-2}, the precipitates are smallest and the mechanical properties are best. The tensile strength is 443.5 MPa and the elongation is 8.1%, which are 51.7% and 42.1% higher than those of conventional ageing treatment, respectively. An electro-pulse with a current density of 15 A·mm^{-2} can rapidly nucleate the second phase at 463K while the precipitates are relatively small after growth.

Keywords: Electro-pulse; Current density; Ageing treatment; Al-Cu-Mn-Zr-V alloy

1 Introduction

Al-Cu alloy is one of the representative high-strength cast aluminum alloys, and was widely used in the fields of aerospace, defense industry and civil tools [1]. Their mechanical properties can be greatly improved by the heat treatment [2]. The electro-pulse can not only improve microstructure and mechanical properties of alloys, but also reduce the heat treatment time. Some researches have been conducted to improve mechanical properties by adopting electro-pulse [3]. Bian *et al.* [4] synchronously applied an electro-pulse to the steady-state creep aging of Al-Cu alloy, and the hardness and corrosion resistance of alloy are improved. Kang *et al.* [5] concluded when the electro-pulse is used for the ageing of Al-Zn-Mg-Cu alloy, the tensile strength and elongation are 14.1 MPa and 4.45% higher than those of conventional ageing.

In this study, the conventional ageing (CA) and the ageing with electro-pulse (AEP) was performed on Al-Cu-Mn-Zr-V cast alloy, respectively. The mechanical properties and microstructures were analyzed.

2 Experimental procedure

The alloy for experiments is Al-5.02Cu-0.33Mn-0.15Zr-0.11V, and the sample size was shown in Figure 1. By DSC analysis, the solid solution process is set as 495±5°C/5±0.5 h and 530±5°C/24±0.5 h. The CA process is 190±2°C/26±0.5 h, and AEP process is CA + 10 s electro-pulse every 5 min. The density of electro-pulse is set as 0, 5, 10, 15, 20, 25 A·mm^{-2} with fixed duty ratio 1% and frequency 100 Hz.

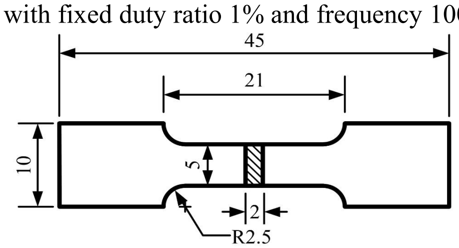

Fig. 1 Sample size of Al-5.02Cu-0.33Mn-0.15Zr-0.11V alloy

3 Result and discussion

Microstructure

Figure 2 indicates there is a Cu-gathering at the grain boundary while there are small amounts of Mn, Zr, V, Ti-gathering at the grain boundary. All elements are uniformly and diffusely distributed within the grains. The EDS expressed that point 1 is taken as θ (Al_2Cu) phase, point 2 may be a mixed phase of Al_3(Ti, Zr, V), and point 3 is a dispersed phase distributed within the grain and it should be $Al_{12}CuMn_2$.

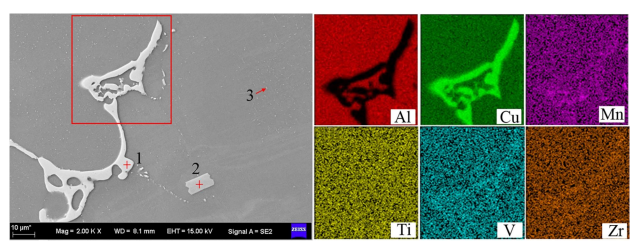

Fig.2 SEM and map scanning of Al-Cu-Mn-Zr-V alloy after conventional ageing treatment

The microstructures indicate the electro-pulse has a significant influence on the size and number of θ (Al_2Cu) phase during ageing process. For the CA, the size of the precipitates is larger, and they are continuously aggregated at the grain boundary. For AEP, the size of the precipitates decreases with the increase of the current density when the current density is below 15 A·mm^{-2}, and the precipitates gradually changes from continuous aggregation distribution to the dispersed distribution at the grain boundary.

Figure 3a and 3b express that the θ' (Al_2Cu) phase is uniformly distributed in the α(Al) phase after ageing treatment, and it is needle-like and vertically precipitated along the two directions of $[010]_{Al}$ and $[001]_{Al}$, which is semi-coherent with α(Al) phase. The precipitates in Figure 3b are very concentrated and even some overlap partially. If the current density further increases, the precipitates will be layered, causing the stacking distribution and weakening the strengthening effect of precipitates on the matrix. Figure $3b_1$ indicates that the θ' phase after CA has better coherent relationship with the α(Al) phase, which results in greater degree of lattice distortion and better strengthening on the alloys.

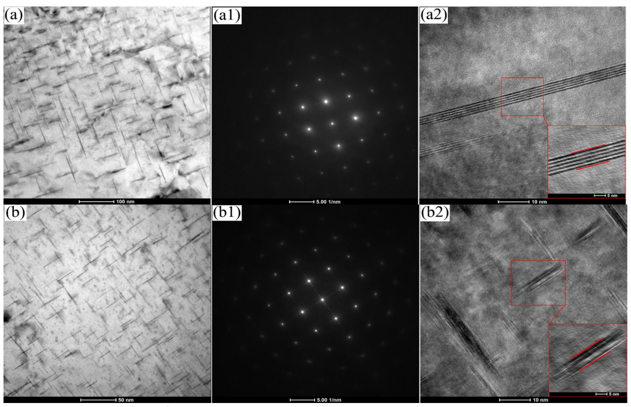

Fig.3 TEM for CA and AEP treatment: (a)CA treatment, (b) AEP treatment with current density of 15 A·mm^{-2}

Mechanical properties

The mechanical properties were shown in the Figure 4. With the increase of current density, the tensile strength and elongation of samples generally increase to the maximum and then decrease. When the current density is 15 A·mm^{-2}, the tensile strength and elongation of samples reach the peak. The tensile strength and elongation for CA treatment are 292.4 MPa and 5.7%. However, for AEP treatment with 15 A·mm^{-2}, they are 443.5 MPa and 8.1%, respectively, which are 51.7% and 42.1% higher than those of CA treatment.

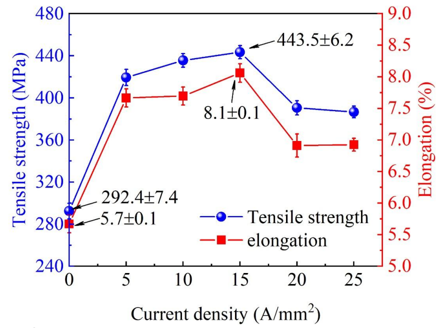

Fig.4 Effect of current density on mechanical properties of Al-Cu-Mn-Zr-V alloy

4 Conclusion

As the current density increases, the precipitates gradually transform from continuous aggregated distribution at grain boundary to dispersed distribution, and mechanical properties increase. When the current density is 15 A·mm^{-2}, the mechanical properties is the best with tensile strength of 443.5 MPa and elongation of 8.1%, which are 51.7% and 42.1% higher than CA, respectively. When the current density exceeds 15 A·mm^{-2}, the size and quantity of precipitates begin to increase again and aggregate at grain boundaries. The electro-pulse of 15 A·mm^{-2} makes the second phases to more rapidly nucleate while growing into smaller particles.

References

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