Effects of La and Mg on Microstructure and Mechanical Property of Al-15Si Alloy

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ABSTRACT: The effects of La on the microstructures and mechanical properties of Al-15Si alloy were investigated, and the results showed that 0.3\% La could availably modify the Al-15Si alloy. The morphology of the eutectic Si obviously changed into the short flake and the dot shape, and the angle of primary Si was refined to bluntness with the contents of La increasing from 0.1\% to 0.3\%. In addition, the effects of Mg on the microstructures and mechanical properties Al-15Si-0.3La alloy were studied. The optical micrographs showed that the eutectic Si were further refined to the shorter bar the dot shape, and the amount of primary Si reduced with the increase of Mg addition. The formation of Mg\textsubscript{2}Si strengthening phase improved the mechanical properties of the modified Al-15Si-0.3La alloy. Compared with Al-15Si alloy, the tensile strength and the elongation of Al-15Si-0.3La-2.0Mg alloy increased 41.4\% and 40\%, respectively.

1. INTRODUCTION

Hypereutectic Al-Si alloys own the properties of lower density, excellent corrosion resistance and wear resistance, higher thermal stability and higher specific strength, and they were widely used in the automotive and aerospace industries. Nevertheless, the exhibition of the primary Si of plate-like and polygon shape in hypereutectic Al-Si alloys, as well as the eutectic Si of coarse acicular and flake-like shape are undesirable, because these irregular primary and eutectic Si have detrimental effects on the mechanical properties of the alloys. Therefore, primary and eutectic Si must be effectively modified to obtain the alloys with desirable properties. It was reported that the rare earth elements can modify eutectic Si and primary Si in Al–Si alloys. In addition, the addition of Mg can produce the strengthening phase Mg\textsubscript{2}Si, thereby, improving the hardness, the tensile strength and the wear resistant of the Al–Si alloys.
La was employed as the modifier in this paper, and the effects of the addition of La on the microstructures and mechanical properties of Al-15Si alloy were investigated. In addition, the effects of the addition of Mg on the microstructures and mechanical properties of the modified Al-15Si-0.3%La alloys were also studied.

2. EXPERIMENTAL

The industrial pure aluminum (99.7%), the silicon (99.4%), the magnesium (99.9%) and the intermediate alloy of Al-10La alloys were employed in the experiment. The smelting process of alloy is as follows: (1) the aluminum block packed by the graphite crucible were put into an electrical furnace and hold the temperature of 800 °C for 10 min, then Si, Mg and Al-10La were added and kept the temperature of 800 °C for 20 min, after that the melt was stirred for 6 min to ensure the homogeneity of the composition; (2) C6Cl6 was then added into the melt to degasify for 6 min at the temperature of 680 °C; (3) the melt were poured into the iron mould preheated to 200 °C, and the samples were obtained. The samples without Mg or La were produced by the same procedures as above.

The microstructures of samples were investigated by the optical microscopy after the samples were prepared as the standard metallographic procedures. The phases of Al-15Si-0.3La-3.0Mg alloy were detected through the XRD analysis, and the tensile strength tests were tested on an electronic universal testing machine (AG-X).

3. RESULTS AND DISCUSSIONS

3.1 Effects of La on microstructure and mechanical property of Al-15Si alloy

Figure 1 shows the optical micrographs of Al-15Si alloys modified with series contents of La (wt%). As shown in Figure 1 (a), the block primary Si with the sharp angle and the coarse flake eutectic Si are found in the unmodified sample. With the contents of La increasing from 0.1% to 0.3% (as shown in Figure 1 (b) and (c)), the morphology of eutectic Si obviously changes into the short flake shape and the dot shape. In addition, the primary Si is refined to bluntness, and the size of the primary Si is diminished. The short flake shape eutectic Si and bluntness primary Si provide the Al-15Si alloys the higher resistance to the external stress. However, as shown in Figure 1 (d), the size of both primary Si and eutectic Si rises while the contents of La exceed 0.3%. Hence, 0.3% La could availably modify the Al-15Si alloys.

The effects of different contents of La on tensile strength and elongation of Al-15Si alloys are presented in Figure 2. For the content of La ranges from 0% to 0.3%, the tensile strength and elongation of Al-15Si alloys was enhanced. The tensile strength and elongation of the
Al-15Si-0.3La alloy reach to 180.5MPa and 2.3%, respectively. Compared with that of the Al-15Si alloy, the tensile strength and elongation of the Al-15Si-0.3La alloy increase 17.3% and 109.1%. The mechanical properties of Al-15Si alloys while the content of La exceeds 0.3%, and the over modification by the excess addition of RE can account for this phenomenon.

Figure 1. Optical micrographs of Al-15Si alloys modified by different contents of La. (a) 0% La, (b) 0.1% La, (c) 0.3% La, (d) 0.5% La.

Figure 2. Mechanical properties of hypereutectic Al-15Si with series contents of La alloys.

3.2 Effects of Mg on microstructure and mechanical property of Al-15Si-0.3La alloy
The microstructures of the Al-15Si-0.3La alloys alloyed by series addition of Mg are shown in Figure 3. With the additional amount of Mg increasing, the eutectic Si are further refined to the shorter bar shape and the dot shape, the amount of primary Si reduce and the angle of the primary Si is refined to bluntness (Figure 3 (b) - (d)). The new phase of Mg\textsubscript{2}Si appears, and it was reported Mg\textsubscript{2}Si can increase the mechanical properties of the Al-Si alloys [12]. The XRD pattern of Al-15Si-0.3La-3.0Mg alloy is presented in Figure 4, which proves that the generation of the new phase is Mg\textsubscript{2}Si. In Figure 3 (b) the Mg\textsubscript{2}Si phase presents Chines characters shape and the dot shape, however, the Mg\textsubscript{2}Si phase changes in to fishbone shape which can be seen from the local enlarged image in Figure 3 (d). Compared with that of Figure 3 (c), the amount of the fishbone shape Mg\textsubscript{2}Si phase increases, which will reduce the mechanical properties of Al-15Si-0.3La alloy.

The effects of Mg on tensile strength and elongation of Al-15Si-0.3La alloys are presented in Figure 5. For the content of Mg ranges from 0% to 2.0%, the tensile strength and elongation of Al-15Si alloys enhance with the content of Mg rising, but for the content of Mg exceeds 2.0%, the tensile strength of the alloys slows down. However, the elongation of Al-15Si-0.3La alloys decreases with the increase of Mg content. More Mg\textsubscript{2}Si particles will seriously affect the mechanical properties of Al-Si alloys. Al-15Si-0.3La-2.0Mg alloy reaches the highest tensile strength of 216.4 MPa. Compared with that of Al-15Si alloy, the tensile strength and the elongation of Al-15Si-0.3La-2.0Mg increased 41.4% and 40%, respectively. Therefore, La and Mg can efficiently improve the mechanical properties of Al-15Si alloy.
Figure 3. Optical micrographs of Al-15Si-0.3La alloys alloyed with various content of Mg. (a) 0.5% Mg, (b) 1.5% Mg, (c) 2.0% Mg, (d) 3.0% Mg.

Figure 4. XRD pattern of Al-15Si-0.3La-3.0Mg alloy.

Figure 5. Effects of series contents of Mg on mechanical properties of Al-15Si-0.3La alloys.

4. CONCLUSIONS

(1) The addition of 0.3% La could modify the Al-15Si alloys available, the morphology of the eutectic Si obviously changed into the short flake shape and the dot shape, in addition, the primary Si is refined to bluntness, the size of the primary Si is diminished. The tensile
strength and elongation of the Al-15Si-0.3La alloy reached to 180.5MPa and 2.3%, respectively, Compared with that of the Al-15Si alloy, the tensile strength and elongation of the Al-15Si-0.3La alloy increase 17.3% and 109.1%.

(2) Compared with Al-15Si alloy, the tensile strength of Al-15Si-0.3La-2.0Mg alloy increased 41.4%, and the tensile strength was 216.4 MPa. In addition, the elongation of Al-15Si-0.3La alloy improved 40% compared with Al-15Si alloy. Optical micrographs showed that the eutectic Si was further refined to the shorter bar shape the dot shape, in addition, the amount of primary Si reduce and the angle of the primary Si is refined to bluntness with the additional amount of Mg increasing.

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REFERENCES


