Influence of Rare Earth Modification and Homogenization on the Microstructure and Mechanical Properties of Recycled Can 3004 Aluminum

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Abstract: The microscopic structure of waste can aluminum material was researched by adding Al5TiB refining agent, La-Ce rare earth and mixed rare earth modifiers, and the microstructure and mechanical performance of the modified aluminum material were studied. The experimental results show that the optimal refiner addition amount is 1.1wt%; the material performance can be significantly improved when the content of La-Ce rare earth ranges to a certain degree, but the mixed rare earth barely affects the refinement effect of the aluminum. When being homogenized, the mixed rare earth plays more obvious role in refining the aluminum material than La-Ce rare earth. The optimal plan is modifying the aluminum material with 3wt% mixed rare earth and homogenizing with annealing temperature of 580 °C, annealing time of 12 hours and heating rate of 5 °C/min while refining the material with 1.1wt% Al-5Ti-1B.

Key words: modification; homogenization; microstructure; mechanical performance; recycled can aluminum

1 Introduction

The recycling of aluminum has a huge reduction of environmental impact and great energetic savings if it is compared with the conventional manufacturing process. Unfortunately, the success in aluminum recycling process mostly depends upon the starting condition of raw materials[1]. The presence of surface contaminants, like organic matters, oxides, ashes, rusts, is one of the main drawbacks[2] which reduces the quality of the recycled aluminum. Laser, water jets, concentrated sulfuric acid[2-4] and fire have been used in removing the surface of can, and there are many technologies including modifying and homogenizing etc, to remove the impurities and improve the mechanical performance of the recycled aluminum can. Qiu et al[5] added samarium (0-0.9wt%) into Al-7Si-0.7Mg alloys to improve the microstructures, mechanical properties, eutectic temperature and the latent heat $\Delta H-R$ on remelting behavior. Yao et al[6] reported the influence of lanthanum on the solidification structure of a casting Al-Cu alloy. Wannasin J et al[7] researched the effect of inoculation and dynamic nucleation on the grain refinement behavior of aluminum alloy. WANG Aiqin et al[8] prepared P and rare earth (RE) complex modifier to improve the microstructure and mechanical properties of hypereutectic Al-21%Si alloy. CHEN Chong[9] researched the influence of P and RE complex modification on the the microstructure and mechanical properties of Al-Si alloys.

Homogenization heat treatment is another important step in the manufacturing of 3xxx alloys as it influences the deformation, recovery and recrystallization behaviors (i.e., grain size, grain morphology and crystallographic texture) during subsequent thermo-mechanical processes[10-13]. Huang et al[10] compared the effects of two-step and one-
step homogenization treatments on the precipitated dispersed phase. Chen et al\cite{11} reported the influences of the critical technical parameters of homogenizing annealing on the precipitation phase states of Al-Mn-Mg alloy after high-efficient melt treatment. Sun\cite{12} prepared homogeneously microstructured alloys under optimal homogenizing annealing conditions (615 °C/20 h) and assigned the precipitated α-dispersed phase as α-Al12(FeMn)3Si.

In the present experimental work, the synergetic effects of refinement, modification and homogenization treatment on the evolution of the size, distribution of the main second phase were studied. The mechanisms for the evolutions were discussed as well.

2 Experimental

2.1 Refinement process

The experimental alloy for refining was purified waste can aluminum melt. With Al-5Ti-1B grain refiner content 0.6, 1.1, 3.0(mass fraction,%) , the aluminum was refined and casted into standard samples, and the tensile strength and elongation were calculated.

2.2 Modification process

Two kinds of modifier were respectively added into the refined waste can aluminum. The content of La-Ce rare earth blends and mixed rare earth (composed of La, Ce, Pr, Nd ) both were 0.6wt%, 1.6wt%, and 3.0wt%, the tensile strength and elongation were calculated, and the samples height no more than 15 mm were polished for fracture morphology research.

2.3 Homogenization process

The aluminum test bars casted with two kinds of rare earth modifiers were divided into two groups. The first group was not be homogenized, and the other group was respectively homogenized in air furnace, then quenched at room temperature water with annealed temperature of 580 °C, annealed time of 12 hours, and heated rate of 5 °C/min. Then the two group bars were made into tensile test bars and stretched, and the tensile strength and elongation were calculated.

3 Results and discussion

3.1 Refining

The effects on tensile strength and elongation of waste aluminum cans material with refining and without refining are shown in Table 1. From Table 1, when refining the aluminum melt with Al-5Ti-1B grain refiner, the tensile strength and elongation of the aluminum are improved. The tensile strength and elongation of the sample with 1.1% refiner reach the top, when continuously increasing the content of the refiner, the tensile properties gradually decrease.

<table>
<thead>
<tr>
<th>Group</th>
<th>Refiner amount (wt%)</th>
<th>Tensile strength</th>
<th>Elongation</th>
<th>Pre-refine Tensile strength</th>
<th>Elongation</th>
<th>Refined Tensile strength</th>
<th>Elongation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.6</td>
<td>181</td>
<td>17.4</td>
<td>198</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.1</td>
<td>196</td>
<td>17.1</td>
<td>203</td>
<td>20.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1.6</td>
<td>185</td>
<td>20.5</td>
<td>190</td>
<td>17.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.2 Modification

The metamorphism technology of the refined can aluminum material was studied. Stretching the casted standard samples respectively with La-Ce rare earth and mixed rare earth after modification, the tensile strength and elongation of the samples are shown in Fig.1 and Fig.2.

It shows that with the increasing of the content of La-Ce rare earth and mixed rare earth, the tensile strength of the two groups increase firstly then decrease, the tensile strength both reach the maximum when the content of the two kinds of modifier both