Effect of Rare Earth Aluminum Titanium Boron Refiner on the Microstructure and Mechanical Properties of Aluminum Alloys

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Abstract： The effect of different proportions of mixed rare earth LaCe and Al-Ti-B composite addition on the microstructure and grain refinement of 6061 aluminum alloy, the existence form of rare earth and its effect on the second phase of the alloy were discussed. The synergistic effect of rare earth and Al-Ti-B on the tensile properties, fracture morphology, and thermal conductivity of the alloy was analyzed. After adding rare earth and Al-Ti-B intermediate alloy, the grain size of the alloy decreased; Rare earths are mainly distributed at grain boundaries in the form of AlFeSiREMg phase and AlSiTiMgRE. In addition, the addition of rare earths promotes the transformation of β - AlFeSi phase to α - AlFeSi phase, reduces the size of Mg2Si phase, forms various complex compounds such as AlFeSi and AlFeSiREMg, and reduces impurities in the iron rich phase at grain boundaries. Compared with 6061 alloy without rare earth elements, 6061 aluminum alloy with 0.05% LaCe and 0.2% Al-Ti-B (mass fraction) intermediate alloy showed an increase in tensile strength, elongation, and thermal conductivity of 15.3%, 80%, and 9%, respectively; At the same time, after the combination of rare earth and Al-Ti-B intermediate alloy, the rough and irregular dimples in the fracture morphology transform into small dimples, and the fracture form is ductile fracture.

Keywords: Al-Ti-B-RE refining agent; refining effect; mechanical properties;

1 Introduction

Addition of grain refiners has become a common industrial practice to obtain microstructure with fine equiaxed grains and thus enhances the quality of a casting . The most widely used grain refiner for Al alloys is the Al-5Ti-1B master alloy, which contains both soluble TiAl3 intermetallic compound and insoluble TiB2 particles in an aluminum matrix. Grain size and morphology of TiAl3 and TiB2 phases have an important influence on the grain refinement efficiency . But, there are some problems for Al-5Ti-1B as a refiner, such as agglomeration of boride, low refining efficiency, and poisoned by certain elements like Zr, V and Cr. All these are related to the morphology and distribution ofTiB2 phase .

2 Experimental procedure

The experimental raw materials are 6061 aluminum alloy semi continuous cast bars produced by Baotou Huize Aluminum Industry and its provided Al-Ti-B intermediate alloy, as well as Al-20LaCe, Al-20La, Al-20Ce intermediate alloys produced by Baotou Rare Earth Research Institute. The effect of rare earth elements is evaluated through grain refinement experiments and SEM testing

3 Result and discussion

The Effect of Rare Earth Elements on the Microstructure of 6061 Alloy

The XRD analysis results of 6061 alloy indicate that there are mainly phases such as α - Al, Mg2Si, AlFeSi in the alloy. After adding LaCe (1:1) composite rare earth, AlSiMgREFe phase was added to the alloy. From the SEM image of the alloy, it can be seen that there are large coarse and thin straight stripes at the grain boundaries of the alloy. The larger coarse strip-shaped phase at the grain boundary is Mg2Si phase, and the elongated straight strip-shaped phase is AlFeSi phase.

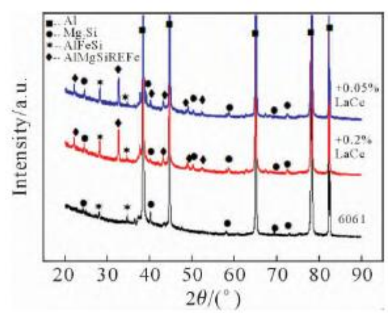

Fig. 1 XRD analysis results of 6061 alloy

The Effect of Rare Earth Elements on the Tensile Strength and Elongation of 6061 Alloy

Many small dispersed phases are formed in the alloy, mainly due to the addition of rare earth elements, which form more high melting point compounds, increase the strengthening effect, and lead to an increase in strength after heat treatment. But with the increase of rare earth content, the number of strengthened Mg2Si particles decreased, forming complex rare earth rich compounds. These compounds are non coherent with the matrix, have high interfacial energy, and are in an unstable state, resulting in a slight decrease in strength.

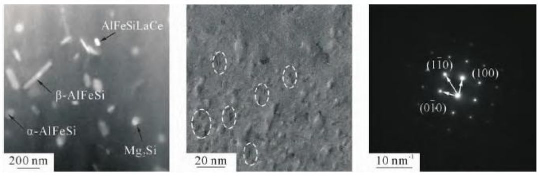

Fig. 2 TEM analysis

The Effect of Rare Earth Elements on the Thermal Conductivity of 6061 Alloy

Aluminum alloy wheels have a great demand for alloy heat dissipation. The frictional heat generated by car braking and the frictional heat between the tire and the road surface can cause the wheel temperature to become too high, increasing the risk of tire blowouts. Therefore, in addition to utilizing structural characteristics in surface design to improve heat dissipation capacity, another way for aluminum alloy wheels is to enhance their own heat dissipation capacity. By improving the heat dissipation capacity of the wheel hub, even in the event of continuous braking during long-distance driving, the wheel system can be ensured to be within a safe range, thereby reducing the risk of tire blowouts and improving safety..

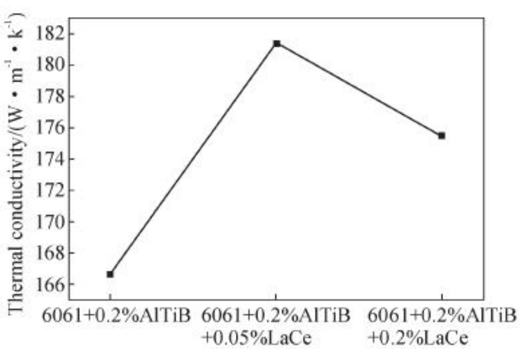

Fig. 3 The Effect of Rare Earth Elements on the Thermal Conductivity of T6 6061 Alloy

4 Conclusion

(1) The effect of rare earths on the thermal conductivity of T6 6061 alloy (1) Different ratios of La/Ce rare earths added separately or mixed with Al-Ti-B have a refining effect on the grain size of 6061 aluminum alloy. But the best refining effect is achieved by the composite of La/Ce=1:1 mixed rare earth and Al-Ti-B intermediate alloy.

(2) Rare earth and Al-Ti-B composite are added to refine 6061 aluminum alloy, and the rare earth is distributed in the form of AlFeSiREMg phase and AlSiTiMgRE at the grain boundaries. In addition, the addition of rare earths promotes the transformation of β - AlFeSi phase to α - AlFeSi phase, reduces the size of Mg2Si, forms various complex compounds such as AlFeSi and AlFe SiREMg, and reduces impurities in the iron rich phase at grain boundaries.

(3) The refinement of rare earth and Al-Ti-B composite improves the tensile strength, elongation, and thermal conductivity of the alloy. The tensile strength of 6061 aluminum alloy cast rod with 0.05% LaCe (1:1)+0.2% Al-Ti-B added reached 198.5 MPa, and the elongation rate reached 23.74%. After extrusion heat treatment, the tensile strength reached 369 MPa and the elongation rate was 18.3%.

(4) The addition of rare earth elements plays an important role in improving the fracture surface. At the same time, after adding rare earth and Al-Ti-B intermediate alloy to 6061 aluminum alloy, the rough and irregular dimples appearing in the fracture morphology transformed into small dimples, and the fracture form was ductile fracture.