Microstructure and mechanical properties of recycled AA6111 alloys processed by direct chill casting with melt conditioning

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1. Introduction

Recycling of scrap Al requires 5% of energy and saves 95% of CO_2 emission as compared to the production of primary Al. Hence, there is an increasing demand to exploit the use of recycled Al alloys to reduce energy consumption and carbon footprint associated with the manufacturing processes. However, the major technical challenge to the widespread use of recycled Al is the presence of high impurity content such as Fe, which can severely deteriorate its mechanical performance. Hence, the development of a new technology is crucial to the production of good quality recycled Al alloys from metal scraps. A melt conditioned direct chill (MC-DC) technology has been developed at BCAST which is based on the application of a high shear dispersive mixer in the molten alloy prior to solidification to produce a fine as-cast microstructure in the absence of any grain refiners. Although grain refiners are commonly used in industry during direct chill casting (DC-GR) of Al alloys to provide active sites for the nucleation of α-Al phase from the molten alloy, the presence of solutes could cause poisoning effect, making grain refiners less ineffective as heterogeneous nucleation sites [1], especially for high impurity secondary Al alloys. This study is concerned with the microstructure/properties of recycled AA6111 Al alloy billets produced from Incinerator Bottom Ash (BA) using both novel MC-DC and traditional DC-GR routes. The formability of these recycled Al alloys was assessed using extrusion and cold rolling processes. This paper gives detailed description of microstructure and mechanical performance of recycled Al alloy processed by a combination of direct casting, extrusion and rolling processes.

2. Experimental

The recycled AA6111 was prepared by 50% Incinerator Bottom Ash (BA) and 50% HSA6 alloy. The final composition of the recycled AA6111 is (wt%): Si: 1.17, Fe: 0.36, Cu: 0.76, Mn: 0.39, Mg: 0.75, Cr: 0.05, Ni: 0.15, Zn: 0.26, Ti: 0.03, Pb: 0.01, Sn: 0.005 and Al remaining. Each casting produced a billet of 152mm in diameter and weighed 300kg. A combination of OM, SEM, EBSD, DSC, hardness and tensile testing methods were used to characterise the resultant microstructures and mechanical properties of both as-cast and downstream processed Al alloys before and after T6 heat treatment.

3. Results and Discussion

The as-cast billets consist of dendritic microstructure for both of MC-DC and DC-GR alloys. It has been found that the average grain size ranged from 146μm to 254μm for BA MC-DC and 255 μm to 217μm for BA DC-GR at positions from the centre to the edge of the as-cast billet. Results show that MC-DC can effectively refine the grains of as-cast alloys at the absence of any grain refiners, especially in the centre of the billets. In the high shear melt conditioning process, it can disperse oxide films and other inclusions in the melt to provide potent nuclei for the development of refined microstructure and allows a uniform temperature in the sump to be maintained [1, 2]. Moreover, the forced convection caused by this melt conditioning process can give rise to dendrite fragmentation which enhances the heterogeneous nucleation, leading to grain refinement [3]. Vickers hardness of both as-cast samples varied from 60 to 75 at positions from centre to edge of the billet. After the hot extrusion, cold rolling and T6 heat treatment, BA MC-DC and BA DC-GR alloys show similar strength. For BA MC-DC, the yield strength, tensile strength and ductility were found to be 278 MPa, 331 MPa and 18% respectively. They are similar to BA DC-GR with the yield strength, tensile strength and ductility of 290MPa, 339MPa and 15.7%, respectively. Therefore, high shear melt conditioning technology demonstrates an alternative method for producing billets of recycled Al alloys at industrial-scale without the need for grain refiners.

4. Conclusions

Recycled AA6111 alloy has been successfully produced by melt conditioned direct chill (MC-DC) casting technology. MC-DC can effectively refine the grain size of as-cast alloys in the absence of any grain refiners, especially in the centre of the billets. The following downstream metal processing shows that similar tensile properties can be achieved by MC-DC route as compared to those processed by DC casting with grain refiners (DC-GR). This indicates that high shear melt conditioning technology can offer an alternative method for producing billets of recycled Al alloys at industrial-scale.

5. References

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