Effect of Strontium (Sr) and Iron (Fe) on Solidification Process of Recycled Aluminum LM-25 Alloy

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Abstract - *Nowadays, aluminium is widely used in various sectors for its material properties like ductility, corrosion resistivity, conductivity, machinability and recyclability due to which it finds multiples of application in cast and wrought alloy form in automobile, aerospace, construction, energy, food, etc. The recycle of aluminium that has a ferrous content of 0.25 to 0.5% cause major defects in core of the aluminium castings during sand and permanent mould die casting. This excess Fe increases the density and has decremental effect on the hardness and tensile properties of the secondary aluminum alloy. To determine these ill effects on actual recycling process strontium a rare earth element known to cause Fe sedimentation was added to the secondary aluminium recycling process of LM-25 aluminum alloy with high Fe content and the effect of solidification and flow rate of the molten alloy is simulated. Die characterization was done to determine the flowability and mechanical behaviour of cast aluminium scrap by mechanical and microstructural characterization in comparison with FEA model by simulation. Analysis of the die was done in ProCAST software and comparisons were made between the actual and analysed ProCAST results*

Key Words: Fe Reduction, Simulation, Solidification, Aluminum Alloys, Hardness, Characterization,....

1. INTRODUCTION

Effective way for recycling Aluminum without introducing much of the virgin metal into the process by achieving optimal energy consumption and high-quality yield in the process with high quantity of scarp is in huge demand. In the process developed through experiment various process parameters that controls the end result were identified and based on such paraments as the scarp type, size, composition, melting time, degassing effects, scarp dissolving method for diluting without much losses inform of oxides and dross were studied.

The current technological trends and individual scientific results on various cases linked to the field of aluminum recycling opened up new avenues, to introduce and combine various methods into single process which has high success rate in terms of energy consumption, high quality yield, continuous quantitative scope of recycling and additional consumption of green-house reduction and less carbon footprint in the process, here casting simulation of LM-25 melt was experimented to see the efficiency of data obtained by simulation and compared with physical data obtained by actual casting extermination

2. EXPERIMENTATION

The process involves melting of machined and turned LM-25 aluminium alloy chips with a minimal percentage of Fe content in an electric induction furnace at 750°C. These scarps are washed and pre-heating at 250°C to remove coolant liquid and oil deposits from the machining process [1]. The preheated scrap is introduced into the furnace and melted at 750°C and degassed by Hexachloroethane tablets to remove the dissolved hydrogen to reduce porosity in the melt. Strontium powder is added to the melt at a holding temperature at 680°C-720°C in an attempt to reduce the excess Fe content occurred by tool wear in the machining of LM-25 aluminum alloy and to improve the sedimentation rate and mechanical properties by grain refining effect. The molten alloy is poured into a preheated - graphite coated Mild Steel rectangular die of (XX mm) and the excess is poured into standard sized ingots [2].

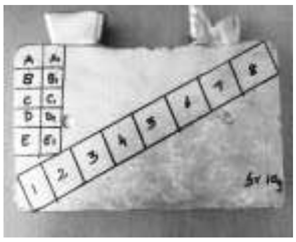


Figure.1: Sectional marking made for solidification characterization

The figure.1 shows the sectioning of the rectangular shaped cast made using the molten L-25 aluminum alloy for studying the solidification pattern of the die and the effect of strontium made on the sedimentation of excess Iron (Fe) and mechanical property of the material

3. RESULT AND DISCUSSION

The below table.1 Shows the optical Emission Spectroscopy results of LM-25 scarp alloy at various point of interest along the diagonal section of the box die and is compared with the standard commercial grade LM-25 alloy composition.

Sample ID	Si	Mn	Mg	Fe	Ni	Ti	Cu	Zn	Pb	Sn
Standard LM-25	6.5-7.5	0.3 max	0.2-0.6	0.5 max	0.1 max	0.2 max	0.2 max	0.1 max	0.1 max	0.05 max
LM-25Remelt Diagonal-8	8.53	0.02	0.26	0.21	0.03	0.12	0.03	0.03	0.04	0.04
LM-25 Remelt Diagonal-5	7.14	0.03	0.35	0.19	0.03	0.12	0.03	0.03	0.04	0.04
LM-25 Remelt Diagonal-1	7.29	0.02	0.34	0.16	0.03	0.15	0.02	0.03	0.04	0.04

Table -1: Optical Emission Spectroscopy (OES) result of the LM-25 remelt

It is evident from the result below that high content of Fe in the melt is due to the wear of Fe based tools used in the machining operations like milling and turning of host material from which the LM-25 chips are collected as scarps. Along the diagonal there was a gradual reduction of Fe from 0.21% by weight at diagonal-8 (Top part) to 0.16% by weight at diagonal-1 (Bottom part) of the solidified melt. This reduction in Fe is due to the addition of minimalistic addition of 10g of Strontium (Sr) to the melt of 20 Kg [3].

3.1. Optical Emission Spectroscopy (OES) result of the LM-25 remelt

The sample is taken from the Diagonal-1 (Bottom Part) of LM 25 secondary aluminium alloy and initially polished through emery sheets followed by disc polisher to attain better surface finish. Then the sample is finally etched with Kellers etchant followed by washing and drying prior to observation in Metallurgical microscope and the obtained microstructure is displayed.

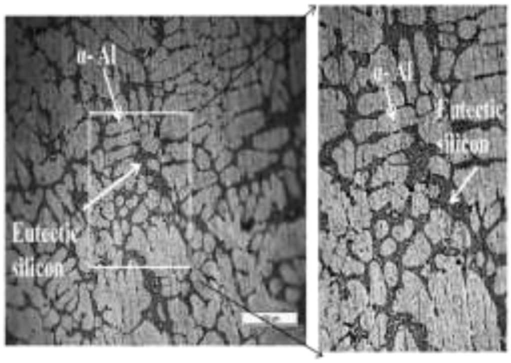
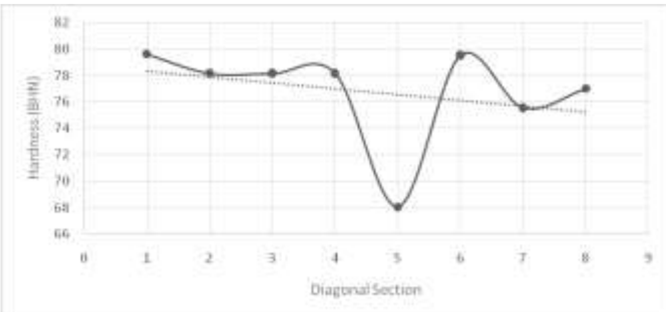


Figure.3.1: Microstructure of the LM-25 remelted aluminium alloy.

The secondary aluminium alloy reveals dendritic type of microstructure. Primary aluminium (α) is observed elongated in the secondary aluminium alloy. The solute eutectic silicon displays coarse acicular morphology in the interdendritic region of the alloy. When high strength is required in the alloys, the eutectic silicon can be modified by adding rare earth alloying elements like Sr or by inducing external fields like ultrasonic treatment. Since the solidification of the secondary aluminium alloy takes place in normal condition in the present study, segregation of the silicon atoms occurs generally in front of the solid-liquid boundary and consequences in the development of long eutectic silicon needles [4].

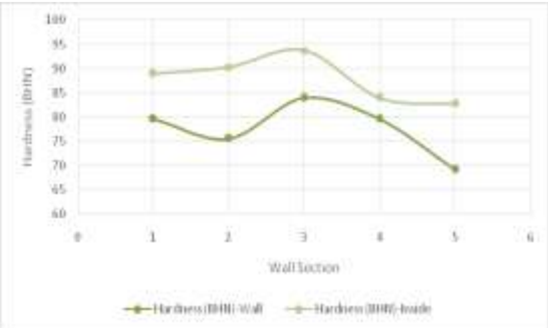
3.2 Effect On Hardness

To know about the change in mechanical property of the material only the harness of the alloy is studied which is majorly affected by the presence of Fe [5]. Brinell hardness test was performed on the test specimens cut in the designated sectional test area and are studied to know the impact of solidification of die and added strontium in reducing the excess Fe in the melt.



Graph.1: Hardness along the Diagonal Section of the Die.

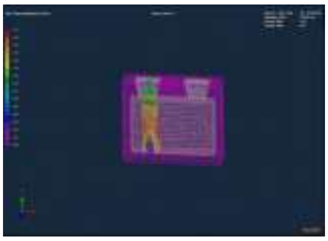
The graphs.1 above shows a downwards trendline with a dip in the mid-section of the diagonal at point 5 which was the last point to be cooled if the solidification starts from the die wall to the center of the melt leading to porosities and gas entrapments. There was a steep reduction of harness from top to bottom which may be due to the sedimentation of Fe at the bottom of the die. The graphs.2 below also indicate that the hardness along the walls is higher on the inside that to the exterior wall section which and may be occurred due to the shrinkage and uneven cooling of the wall closer to the die and the interaction of the molten alloy while it swirls around and reached the midsection of the vertical poring side [6].

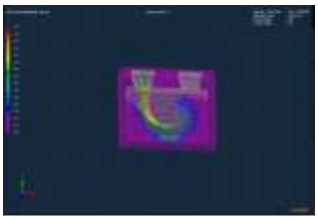


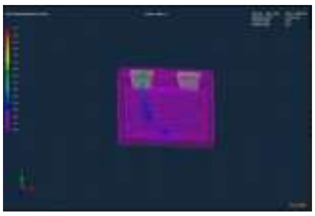
Graph.2: Hardness along the Wall Section of the Die.

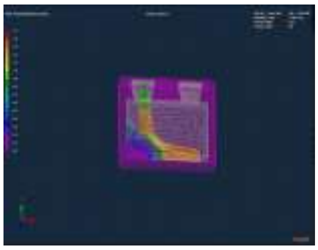
3.3 proCAST ANALYSIS

ProCAST is a finite element analysis-based casting simulation tool that focus on the basics of casting process like solidification rate, effect of die thickness, material shrinkages, and porosity prediction. The rectangular die used to cast the scarp LM-25 alloy was designed to the same dimension using the ProCAST software to determine the flowability and behaviour of cooling at various sections of the die and on the mechanical properties of the resultantalloy.









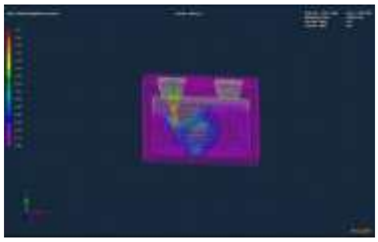


Figure.3.3: ProCAST Analysis result of die with LM-25 Aluminum Scarp Melt.

The parameters of the simulation include the die material, die temperature, runner and raiser selection and the type of aluminum alloy poured selected by the inbuilt database of material with Fe content changed from the actual composition in the software. The mesh selected was tetra hederal shape for accuracy with course mesh for the die and fine mesh for core area to reduce processing time. Inbuilt mathematical fluid flow model for gravity casting was selected to run the simulation. The model predicted the fluid flow and the rate of solidification time for the Fe contaminated LM-25 aluminum alloy is less than the commercial alloy by 30 seconds. The high solidification rate may be the cause of anomaly in the hardness characterises along the diagonal and wall section of the physical melt and it is occurred due the high amount of Fe present in the melt which was sedimented to an extent by Sr addition.

4. Conclusion

The process for recycling/reprocessing the heavily Fe contaminated aluminium scrap using direct melting process using rare earth element was deployed to know about the solidification, fluidity and cooling rate of the resultant alloy and was simulated using the ProCAST simulation tool for concurrence. From the above results by the simulation and the mechanical characterization, the alloy under study LM-25 with high Fe content behaves in the same pattern in the both cases. The cooling of molten alloy follows the same in the physical die as in the simulation from outside to the core of the die and the mechanical properties reduces from outside to the centre of the die and the hardness decreases from bottom to top. This may be caused by the gas entrapment and less cooling rate of the metal due to Fe contamination. The addition of rare earth element reduces the Fe content of the material by sedimentation to a minimalistic extent but not in a significant amount. By increasing the content of Sr there may be a possibility to reduce Fe significantly without affecting the standard quality of the recycled aluminum LM-25 scrap.

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