Experimental setup allows us to achieve up to 0.6 T DC magnetic field, while AC magnetic field at 50 Hz frequency is 0.05 T. We use solidification velocities from 10 μm/s to 1 mm/s. Effect of electromagnetic vibrations under various magnetic fields are solidification velocity has been studied. However, result interpretation is difficult, because there are not always direct link between solidified microstructure and melt flow during solidification.

CONCLUSIONS

Electromagnetic effects can have significant impact on the solidification structure and impurity distribution. Results of these experiments show that superimposed AC and DC magnetic fields can be used to affect the melt flow near the solidification interface during directional solidification and to refine the grain structure, and to improve particle dispersion.

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REFERENCES

[1] I. Kaldre, Y. Fautrelle, J. Etay, A. Bojarevics, L. Buligins, "Influence on the macrosegregation of binary metallic alloys by thermoelectromagnetic convection and electromagnetic stirring combination," Journal of Crystal Growth, Vol. 402, pp. 230-233, 2014.

[2] I. Kaldre, A. Bojarevičs, I. Grants, T. Beinerts, M. Kalvāns, M. Milgrāvis, G. Gerbeth, "Nanoparticle dispersion in liquid metals by electromagnetically induced acoustic cavitation," Acta Materialia, Vol. 118, pp. 253-259, 2016.

New contactless aluminum degassing system - GaInSn model experiments with a numerical study

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***Abstract*—Molten aluminum in metallurgy environment collects hydrogen from ambient air and water vapor thus after crystallization causing porosity. Therefore hydrogen concentration must be reduced below a certain threshold before the final metal product is made. The most common way is gas purging when inert gas is injected in the melt which absorbs dissolved hydrogen and leaves the metal through the free surface. The existing methods need a mechanical contact with hot and chemically aggressive aluminum which leads to higher maintenance costs. We propose a novel contactless degassing method which uses electromagnetic forces to drive the flow and split the injected inert gas bubbles. Numerical analysis is used to study permanent magnet driven flows and to optimize the degassing process. The problem is solved by coupling OpenFoam for hydrodynamic calculations and Elmer for electromagnetic calculations. According to them, the most promising design is chosen for GaInSn experimental scale model (see Fig. 1). In experiments the velocity field and the developed pressure in different operating regimes has been obtained and later compered to the numerical model. Results show that the iron yokes can be used as a cost effective tool for magnetic flux concentrators even on rotating permanent magnet machinery providing at least a 30 $\%$ pressure increase. Overall, the system can achieve large velocities which when scaled to industrial sized setup would be sufficient for the argon dissipation to take place. The developed pressure head is high enough to lift aluminum several meters, allowing device to be integrated in a manufacturing line.**

***Index Terms*—Aluminum degassing, MHD modelling, GaInSn experiment, Permanent magnet pump, Bubble flow**

I. Introduction

In industrial processes aluminum inevitably dissolves hydrogen from air and water vapor present in environment. Dissolved hydrogen causes porosity even in trace amounts and that leads to worse mechanical properties [5]. Therefore degassing is a necessary step in most aluminum manufacturing operations. Here we propose a novel degassing system based on inert gas injection. Classically a rotary gas impeller is used [3] but here metal is driven by electromagnetic forces. A rotating permanent magnet system in a contactless way can achieve a rapid and turbulent flow in which the gas is injected. Empirically, gas purging studies have shown for best degassing efficiency bubble sizes should be refined to size around $2-3\ mm$ [4] since smaller bubbles rise slower and have larger surface/ volume ratio. Analysis of mechanically stirred water [2] show that Reynolds number of at least $2\cdot10^4$ is necessary for bubble breakup of that size to take place. One of the challenges is to have a flow that maximizes argon bubble rising time to improve degassing efficiency since hydrogen trapping by inert gas bubbles is a physical process. Flow that meats these constraints is achieved by using permanent magnet dipole stirrer under the volume of molten metal. Compared to inductors rotating permanent magnet machinery is more efficient in generating low frequency magnetic field due to absence of Joule losses in coil. We have shown that with permanent magnet stirrer it is possible to achieve metal velocities up to 4 m/s in GaInSn alloy in size relevant for industrial processes [1]. In this paper we analyze and optimize a specific stirring setup (see figure 1) which differs other rotating permanent magnet machines because of the magnetic

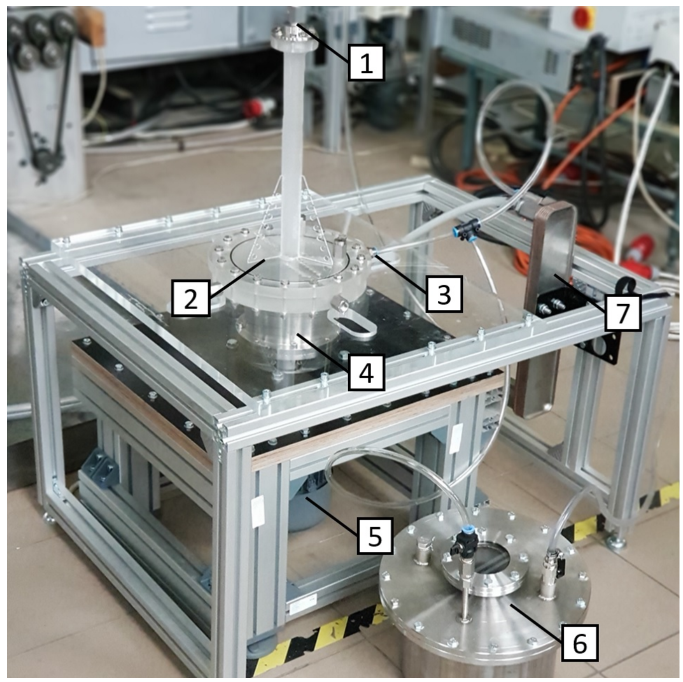

Fig. 1. GaInSn experimental model. The lower frame holds the rotating permanent magnet. The top structure contains the metal reservoir, a cooling loop and a vertical loop for pressure head. 1 - inlet 2 - plexiglass vessel for GaInSn; 3 - outlet; 4 - permanent magnet rotor; 5 - electric motor; 6 - GaInSn storage; 7 - heatsink