Control of Interdendritic Convection by the Application of Steady and Time-Dependent Magnetic Fields during Directional Solidification of Aluminium Alloys

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The incorporation of fluid flow effects in solidification models is nowadays one of the challenging issues. Difficulties arise due to the numerous causes for fluid flow during alloy solidification and the plurality of physical scales which have to be considered in the model development. Hence, although the focus of the model applications is usually on industrial processes, benchmark experiments with defined process conditions are required in order to support the model development and validation.

The goal of this paper is to analyse numerically the resulting macrosegregation due to the application of different magnetic fields during directional solidification of cylindrical AlSi7 and AlSiMg samples. We consider columnar solidification from the bottom to the top with a fixed growth velocity of v=0.1mm/s and a fixed temperature gradient of G=4K/mm ahead of the mushy zone. One advantage of this configuration is that the occurring physical mechanisms leading to macrosegregation can be easily understood, which is not always the case for complex industrial processes. A well known option to control the fluid flow is the application of electromagnetic fields. Whereas steady fields usually damp certain flow components, time-dependent fields can be applied to create certain flow conditions. In the case of the utilization of rotating magnetic fields (RMFs), the primary flow is in the azimuthal direction. Nevertheless, due to the interaction of the primary bulk flow with the mushy zone radial pressure imbalances occur at the tip of the mushy zone leading to the development of secondary flows. The resulting interdendritic convection is creating a segregated zone at the axis of the samples. Another field configuration is a travelling magnetic field (TMF). In this case the Lorentz force is directly acting in or opposite to the growth direction. In consequence macrosegregation occurs either at the axis or near the outer wall of the samples.

The macrosegregation computations are performed utilizing a classical volume averaging model, which was implemented in the software package CrysVUn [1,2]. The sensitivity of the model predictions regarding the applied permeability law and process conditions, e.g., the magnetic field strength, is investigated. Emphasis is put on the possibility to control the amount of the resulting macrosegregation, e.g., by combinations of steady and time-dependent fields. Complementary studies are currently performed utilizing a recently developed multi-phase solidification model [3]. The model is implemented in the CFD software FLUENT (FLUENT is a trademark of Fluent, Inc., USA) and allows to consider additional effects, like the undercooling ahead of the solidification front and shrinkage driven flow. Another striking feature of the model is the possibility to predict the transition from a columnar to equiaxed growth under convective conditions, which was observed in several experiments for certain process conditions. First applications of the multi-phase solidification model are reported in this paper and the simulation results are compared to our previous studies.

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Poster

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