

ON THE CONTROL OF CONVECTION IN THE SOLIDIFICATION OF ALLOYS USING TAILORED MAGNETIC FIELDS

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The effect of magnetic fields and magnetic field gradients on the solidification of alloys is investigated here. Solidification of alloys is invariably accompanied by macro-segregation, which in turn is caused by thermo-solutal convection in the melt. A magnetic field when applied along with a magnetic field gradient produces both Lorentz and Kelvin forces in the melt. The latter is independent of the magnitude and direction of velocity and can be used to control flow in conducting as well as non-conducting materials. The main aim of the current investigation is to substantially reduce convection and consequently macrosegregation during solidification of metallic, non-metallic and semi-conductor alloys through the application of magnetic fields and gradients. A single domain model along with volume-averaged governing transport equations is used for our all numerical studies. Stabilized finite element techniques are used to discretize the thermal, solutal and momentum transport equations of the coupled system. The direct alloy solidification problem is first solved in two- and three-dimensions with the magnetic field and gradients kept constant. An optimal control problem is then considered where the design variable is the time history of the magnetic field imposed over a constant magnetic gradient. The cost functional is taken as the L_2 norm of the deviation of the melt velocity from conditions corresponding to diffusion-dominated growth and the design problem is posed as an unconstrained optimization problem. The continuum sensitivity method (CSM) is used to determine the sensitivities of field variables like temperature, solute concentration and melt velocity. The cost functional minimizing process is realized through the use of the conjugate gradient method via finite element solutions of the continuum direct and sensitivity problems and the time history of the imposed magnetic field is determined. A number of computational solidification design examples will be presented.

References

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