Simulation of Multiscale Industrial Solidification Problems under Influence of Electromagnetic Fields by a Meshless Methods

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ABSTRACT

Simulation and control of macrosegregation, deformation and grain size under electromagnetic (EM) processing conditions is important in industrial solidification systems, since it influences the quality of the casts and consequently the whole downstream processing path. Respectively, a multiphysics and multiscale model is developed for solution of Lorentz force, temperature, velocity, concentration, deformation and grain structure of the casts. The mixture equations with lever rule, linearized phase diagram, and stationary thermoelastic solid phase are assumed, together with EM induction equation for the field imposed by the low frequency EM field or Ohm's law and charge conservation equation for stationary EM field. Turbulent effects are incorporated through the solution of a low-Re turbulence model. The solidification system is treated by the mixture-continuum model, where the mushy zone is modeled as a Darcy porous media with Kozeny-Karman permeability relation and columnar solid phase moving with the system velocity. Explicit diffuse approximate meshless solution procedure [1] is used for solving the EM field, and the explicit local radial basis function collocation method [2] is used for solving the coupled transport phenomena and thermomechanics fields. Pressure-velocity coupling is performed by the fractional step method [3]. The point automata method with modified KGT model is used to estimate the grain structure [4] in a post-processing mode. Thermal, mechanical, EM and grain structure outcomes of the model are demonstrated for low frequency EM casting of aluminium billets and continuous casting of steel. A systematic study of the complicated influences of the process parameters on the microstructure can be investigated by the model, including intensity and frequency of the electromagnetic field.

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