Phase-field method for computationally efficient modeling of the solidification of binary alloy with magnetic field effect

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Key words: Numerical procedure and applications, phase-field model, magnetic field, binary alloy, solidification, dendrites

We present a new 2D phase-field model with anisotropy, applied to the dynamics and structure of free dendrite growth during solidification process of binary alloys under the action of magnetic field. The physics of solidification problem of Ni-Cu alloy such as conditions for crystal growth rate are discussed and show good qualitative agreement with numerical simulations.

In order to improve the quality and properties of mixtures, the major industrial challenges lie in the possibility to control the metal structure and defects, that occur during the solidification process. It has been observed experimentally that hydrodynamic motions in liquid phase have a considerable influence on structure and dynamic behavior of developing dendrites. Moreover, it has been shown that the velocity of the melt and direction of flow can be controlled by applying magnetic field and electric current. To study the effect of magnetic field on the evolution of microstructure of dendrites, we have constructed a phase field model to simulate directional solidification and dendritic crystal growth under the action of magnetic field. The mathematical formulation for the model is composed of magnetohydrodynamic, concentration and phase-field systems which are time-dependent, non-linear and coupled systems.

The modeling, the numerical procedure and details of assigning the numerical parameters are provided. The nature of the problem constrains us to use very fine meshes in some physical regions. The results demonstrate that the physics of solidification process can be simulated and captured by using our approach.