

Level set method for simulating multi-phase multi-component dendritic solidification

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A level set method combining features of front tracking methods and fixed domain methods is presented to model microstructure evolution in multi-phase multi-component alloy systems. The 'constraint-based level set flows' algorithm is implemented to solve multiple interface motions for different phases/crystals. Several techniques including fast marching, narrow band computing and adaptive meshing are utilized to speed up computation. The multi-phase multi-component system is solved using input from a commercial thermo-dynamic database.

To explicitly track the interface growth and shape of the solidifying dendrites, a front tracking approach based on the level set method is used with a finite element implementation. To easily model the energy, species and momentum transport, a fixed domain method is implemented assuming a diffused freezing front where the liquid fraction is defined in terms of the level set function.

Volume-averaging equations for energy, species and momentum transport are adopted based on liquid fraction. To compute the freezing front morphology, an extended Stefan condition is considered. The fixed domain approach, by avoiding the explicit application of essential boundary conditions on the freezing front, leads to an energy conserving methodology that is not sensitive to the mesh size.

The developed algorithms are tested extensively with unstructured grids, various geometries and various alloy systems. Applications to several classical Stefan problems and two- and three-dimensional crystal growth show good agreement with available analytical solutions as well as with numerical solutions based on the phase-field method and front tracking techniques including other implementations of the level set method.