Lattice-Boltzmann method for simulation of the dendritic growth in external flows

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During the last few years, the lattice Boltzmann (LB) method has become a well-established tool for simulation of fluid flows, especially flows in complex geometry (for example, [1]). At the same time, the phase-field approach became the standard tool in computations of dendritic growth [2]. It seems therefore natural to combine these methods in problems where both phenomena are present, such as dendritic growth in an external flow.

We propose a composite phase-field/lattice-Boltzmann scheme to simulate dendritic growth from a supercooled melt. Our approach is similar to the scheme of Miller and Succi [3], but seems to be simpler in the LB part and more consistent in the phase-field part.

The phase change is modelled by the phase-field approach of Karma and Rappel [2], whereas the flow of the liquid is simulated by the lattice-Boltzmann-BGK (LBGK) method into which interactions with solid and thermal convection are incorporated. The symmetric model was used. To simulate conductive and convective heat transfer we use the multicomponent LBGK method. The step of flow simulation can be dropped out in the case of purely diffusional growth.

Test simulations were performed without convection. The resulting tip velocity, radius and branch pattern are the same as in the finite-difference method of Karma and Rappel.

Depending on the level of anisotropy and undercooling, dendrites or doublons were obtained in simulations.

Dendritic growth in a shear flow was simulated for different flow velocities, as well as the growth in presence of natural thermal convection with different orientations of the crystal in the gravitational field.

In shear flow, dendrites essentially keep the growth direction, whereas doublons bend opposite to the flow.

The influence of parallel flow on the operating state of dendritic tip was investigated. At large flow velocities, oscillations of tip velocity were observed, accompanied by enhanced growth of side brances.

References

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