A high precision extrapolation method in multiphase-field model for simulating dendrite growth

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Abstract

The phase-field method coupling with thermodynamic data has become a trend for predicting the microstructure formation in technical alloys. Nevertheless, the frequent access to thermodynamic database and calculation of local equilibrium conditions can be time intensive. The extrapolation methods, which are derived based on Taylor expansion, can provide approximation results with a high computational efficiency, and have been proven successful in applications. This paper presents a high precision second order extrapolation method for calculating the driving force in phase transformation. To obtain the phase compositions, different methods in solving the quasi-equilibrium condition are tested, and the M-slope approach is chosen for its best accuracy. The developed second order extrapolation method along with the M-slope approach and the first order extrapolation method are applied to simulate dendrite growth in a Ni-Al-Cr ternary alloy. The results of the extrapolation methods are compared with the exact solution with respect to the composition profile and dendrite tip position, which demonstrate the high precision and efficiency of the newly developed algorithm. To accelerate the phase-field and extrapolation computation, the graphic processing unit (GPU) based parallel computing scheme is developed. The application to large-scale simulation of multi-dendrite growth in an isothermal cross-section has demonstrated the ability of the developed GPU-accelerated second order extrapolation approach for multiphase-field model.

Keywords: Extrapolation method; Phase-field; Dendrite growth; GPU computation