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Acceleration of RBF-FD meshless phase-field modelling of dendritic solidification by space-time adaptive approach. (English) Zbl 07608994

Summary: A novel adaptive numerical approach is developed for an accurate and computationally efficient phase-field modelling of dendritic solidification. The adaptivity is based on the dynamic quadtree domain decomposition. A quadtree decomposes the computational domain into rectangular sub-domains of different sizes. Each sub-domain is extended to ensure overlap communication between neighbouring sub-domains. In each sub-domain, uniform distribution of computational nodes is generated. The product between the node density and the sub-domain area is fixed to ensure the h-adaptivity. The adaptive approach provides the highest density of computational nodes at the solid-liquid interface and the lowest density in the bulk of the phases. The meshless radial basis function generated finite difference (RBF-FD) method is applied for the spatial discretisation of the partial differential equations which arise from the phase-field model. The RBF-FD method is especially appealing since it allows straightforward spatial discretisation of partial differential equations on scattered node distributions. The use of scattered node distribution reduces the discretisation-induced anisotropy in the phase-field modelling of dendritic growth. The forward Euler scheme is used for temporal discretisation. The adaptive time-stepping is employed to speed up the calculations further. The performance of the novel numerical approach is tested for dendritic solidification of supercooled pure melts and supersaturated dilute binary alloys at arbitrary preferential growth directions. The impact of the numerical parameters on the accuracy and computational efficiency is thoroughly analysed. It is shown that the RBF-FD method, defined on scattered node distribution, together with the space-time adaptive approach, represents an accurate and efficient technique for solving the phase-field models of dendritic solidification.

MSC:
82C80 Numerical methods of time-dependent statistical mechanics (MSC2010)
76A99 Foundations, constitutive equations, rheology, hydrodynamical models of non-fluid phenomena
82C26 Dynamic and nonequilibrium phase transitions (general) in statistical mechanics
76M99 Basic methods in fluid mechanics
65Z05 Applications to the sciences

Keywords:
dendritic solidification; phase-field method; meshless methods; space-time adaptivity; scattered nodes

Software:
Matlab

Full Text: DOI

References:


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