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# 3D modeling of macro-segregation and formation of freckles in solidification based on the fully decoupled enthalpy-porosity method

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The problem of solidification with macro-segregation and the formation of freckles is usually a complicated one that involves mass, momentum, heat, and species transfers between the solid, mushy, and liquid phase regions [1]. In several natural and industrial applications, the quantitative description of phase change, chemical heterogeneities, and multi-phase and multi-component flows serve an essential role in this process. In the aerospace industries and civil engineering, where materials with high strength, heat-treatable capacity, and fatigue resistance are in high demand, this naturally sets very strict requirements for internal compositions and their distribution in parts and workpieces [2]. For the petroleum industry, the efficient and economical recovery of natural gas hydrate from the subsurface and the safe operation of natural gas pipelines to prevent hydrate or wax blockage are also based on a deeper understanding of solidification and phase change [3,4]. Even on an interstellar scale, the deposition of planetary components during cooling constitutes a kind of separation [5]. Nonlinearities and interactive multi-physical fields are the major challenges in modeling this topic, and they raise the high computational costs associated with its 3D simulations. Our work proposes an operator-splitting and matrix-oriented method based on the enthalpy-porosity model to avoid non-linear systems. Also, the combination of vectorization and forward techniques to assemble the matrix of the linear system enhances the implementability of extensions to 3D applications. Finally, a number of 2D and 3D benchmark cases are presented to validate the accuracy and effectiveness of this scheme [6-8]. This numerical method also shows its ability to capture physical processes, such as channel segregation and freckle formation, caused by solutely and thermally driven flow.

## Participation

In-Person

## References

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