Phase-field investigation of non-isothermal solidification coupled with melt flow in powder bed fusion

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Phase-field model has emerged as a powerful tool for describing complex microstructure evolution and intricate multi-physics phenomena in the powder bed fusion (PBF) process [1, 2]. However, the interactive nature of the underlying physical mechanisms, coupled with various assumptions made during modeling and simulations, often complicates the ability to accurately capture specific features of physical processes. As the properties of PBF-produced parts are related to solidification behavior, a detailed understanding of the solidification microstructure development in PBF is crucial for process optimization. In this work, we present a non-isothermal phase-field model that couples the solidification process, heat transfer, and melt flow dynamics. This model is developed based on a thermodynamic consistent framework [1, 3, 4] while also maintaining the quantitative validity of fluid dynamics, particularly by satisfying the fluid no-slip boundary condition. Using an equiaxed dendritic solidification microstructure as a benchmark, we investigate the effects of thermal capillarity and temperature gradients across the solid-liquid interface on the resultant dendrite microstructure. Additionally, we examine how fluid flow influences the solidification behavior of dendrites, specifically the effects of average fluid velocities on dendritic growth and morphology.

References

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