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Effects of Cooling Rate and Wall Inclination on the Solidification of Pure Tin in a Quasi-2D Trapezoidal Cavity

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Controlling how metals solidify is a key challenge in thermal engineering and materials processing, since it directly shapes the microstructure, mechanical strength, and overall quality of the final product. In this study, we explore the impact of natural convection on the solidification of pure tin metal inside a quasi-2D trapezoidal cavity. The horizontal walls of the trapezoidal cavity are insulated and two side walls kept at constant but different temperatures. Our objective is to observe the wall inclination and cooling rate effects during the solidification process. To capture the physics of the process, we use the enthalpy–porosity model, which accounts for the release of latent heat and treats the mushy zone as a porous medium described by the liquid fraction. The equations governing heat transfer and fluid flow are solved using the finite element method. The results reveal the evolution of the flow field, temperature distribution, and solid–liquid interface over time. We find that both the inclination angle and the cooling rate play important roles in controlling how quickly the metal solidifies. The numerical results agree well with experimental data, confirming the reliability of our approach. Moreover, the proposed quasi-2D (2D½) model successfully reproduces the behaviour of a full three-dimensional cavity, capturing not only the thermal and flow patterns but also the shape and position of the solidification front.

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