The Impact of Marangoni and Buoyancy Convections on Flow and Segregation Patterns during the Solidification of Fe-0.82 wt% C Steel	
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Abstract: Due to the high computational costs of the Eulerian multiphase model, which solves the conservation equations for each considered phase, a two-phase mixture model is proposed to reduce these costs in the current study. Only one single equation for each the momentum and enthalpy equations has to be solved for the mixture phase. The Navier–Stokes and energy equations were solved using the 3D finite volume method. The model was used to simulate the liquid–solid phase transformation of a Fe-0.82wt%C steel alloy under the effect of both thermocapillary and buoyancy convections. The alloy was cooled in a rectangular ingot (100 × 100 × 10 mm3) from the bottom cold surface to the top hot free surface by applying a heat transfer coefficient of h = 600 W/m2/K, which allows for heat exchange with the outer medium. The purpose of this work is to study the effect of the surface tension on the flow and segregation patterns. The results before solidification show that Marangoni flow was formed at the free surface of the molten alloy, extending into the liquid depth and creating polygonized hexagonal patterns. The size and the number of these hexagons were found to be dependent on the Marangoni number, where the number of convective cells increases with the increase in the Marangoni number. During solidification, the solid front grew in a concave morphology, as the centers of the cells were hotter; a macro-segregation pattern with hexagonal cells was formed, which was analogous to the hexagonal flow cells generated by the Marangoni effect. After full solidification, the segregation was found to be in perfect hexagonal shapes with a strong compositional variation at the free surface. This study illuminates the crucial role of surface-tension-driven Marangoni flow in producing hexagonal patterns before and during the solidification process and provides valuable insights into the complex interplay between the Marangoni flow, buoyancy convection, and solidification phenomena.

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