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Formation of segregated channels in a rotating geometry during the solidification of steel alloy

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A two-phase columnar solidification model considering fluid flow, heat, and solute transport is applied to simulate the solidification in a 3D rotating geometry using the finite volume method. Molten steel alloy is confined within a rectangular cavity, initially at a temperature above the liquidus, with distinct hot and cold surfaces at the top and bottom, respectively. A slow cooling rate of CR = 0.1 K/s was applied to the bottom surface, allowing for the phase transformation as the temperature decreased below the liquidus. The simulated domain is in a rotating frame of reference, rotating about a fixed axis of the original frame with r = 0.9 m radius of rotation. The rotating geometry undergoes a change in rotation speed, therefore, Coriolis, Centrifugal, and Euler are the simulated fictitious forces. Also, a rotating gravity vector, rotating with the frame, is implemented. This study aims to examine the effect of the Coriolis and Euler forces on centrifugal buoyancy-driven convection in a rotating geometry. The key features of solidification phenomena in this process, including solute transport, thermo-solutal convection of the melt, flow driven by buoyancy, Centrifugal forces, and formation of macro-segregation, are simulated. As a result, it is predicted that segregated channels were formed in the vertical direction during the rotation. After the full solidification, segregated cells were developed at different horizontal cut planes of the samples. The formation mechanism of this segregation pattern is discussed. This study provides insights into the underlying mechanisms governing the observed segregation patterns. Furthermore, it delves into the impact of rotation on both flow and segregation patterns, offering valuable insights applicable to a range of industrial processes.

Speaker Country

Austria

Primary author: SARI, Ibrahim (Montanuniversitaet of Leoben)

Co-authors: KHARICHA, abdellah (Montunivesität leoben); WU, Menghuai (Montanuniversitaet Leoben)

Presenter: SARI, Ibrahim (Montanuniversitaet of Leoben)

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