

A coupled thermomechanical, thermal transport and segregation analysis of the solidification of aluminum alloys on molds of uneven surface topographies

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A coupled thermomechanical, thermal transport and segregation analysis of Aluminum alloys solidifying on uneven surfaces is presented. The uneven surfaces are modeled as sinusoids with different wavelengths and amplitudes. Phenomena occurring during early stages of solidification play an important role in the formation of surface defects. Various coupling mechanisms between solid-shell deformation, heat transfer, fluid flow and segregation near the mold-metal interface are studied during the early stages of Aluminum alloy solidification on uneven mold topographies.

At the mold-metal interface, formation of air gaps leads to variations in heat flux from the solidifying shell to the mold. The heat flux is either determined using the liquid contact pressure during perfect contact or through air gap sizes during imperfect contact (air gap nucleation). The effects of inverse segregation, arising from shrinkage driven flow in the melt, on nucleation of air gaps and evolution of stresses in the solidifying shell are examined.

The present finite element based numerical model consists of a volume-averaged solidification model coupled with a hypoelastic rate-dependent deformation model combining elasto-viscoplastic deformation in the solidifying shell with air-gap nucleation and imperfect contact at the metal-mold interface. Densities of the solid and liquid phases are assumed to be constant but unequal, thereby giving rise to shrinkage driven flow in the melt that in turn causes inverse segregation in the evolving solid shell.

For different sinusoidal topographies, an amplitude-wavelength combination that leads to reduction in equivalent stresses, segregation and growth front morphology unevenness, in the evolving solid shell, is sought for a number of aluminum alloys. One of the main aims of the current analysis is to gain a better understanding of surface defect formation in Aluminum alloys and explore the role of tuned mold surface topographies in minimizing these defects thereby leading to desired cast surface morphologies.