Macrosegregation Resulting from Directional Solidification through an Abrupt Change in Cross-Setions

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Abstract

Simulations of the directional solidification of two hypoeutectic alloys (Al-7Si alloy and Al-19Cu) and resulting macrosegregation patterns are presented. The casting geometries include abrupt changes in cross-section from a larger width of 9.5 mm to a narrower 3.2 mm width then through an expansion back to a width of 9.5 mm. The alloys were chosen as model alloys because they have similar solidification shrinkages, but the effect of Cu on changing the density of the liquid alloy is about an order of magnitude greater than that of Si. The simulations compare well with experimental castings that were directionally solidified in a graphite mold in a Bridgman furnace. In addition to the simulations of the directional solidification in graphite molds, some simulations were effected for solidification in an alumina mold. This study showed that the mold must be included in numerical simulations of directional solidification because of its effect on the temperature field and solidification. For the model alloys used for the study, the simulations clearly show the interaction of the convection field with the solidifying alloys to produce a macrosegregation pattern known as "steepling" in sections with a uniform width. Details of the complex convection- and segregation-patterns at both the contraction and expansion of the cross-sectional area are revealed by the computer simulations. The convection and solidification through the expansions suggest a possible mechanism for the formation of stray grains. The computer simulations and the experimental castings have been part of on-going ground-based research with the goal of providing necessary background for eventual experiments aboard the ISS. For casting practitioners, the results of the simulations demonstrate that computer simulations should be applied to reveal interactions between alloy solidification properties, solidification conditions, and mold geometries on macrosegregation. The simulations also presents the possibility of engineering the mold-material to avoid, or mitigate, the effects of thermosolutal convection and macrosegregation by selecting a mold material with suitable thermal properties, especially its thermal conductivity.