

Abstract

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An improved Rayleigh number criterion for freckle prediction incorporating the effect of carbides

Freckle chains are lines of equiaxed grains which may form during the directional solidification of single crystal Ni-base superalloys. In single crystal alloys freckles form as a result of convective flow of the lighter interdendritic liquid that tends to flow upward towards the heavier bulk composition liquid. Both the interdendritic liquid density and the permeability of the mushy zone affect freckle formation. The Rayleigh number, which is the ratio of the buoyancy to the drag forces in the liquid, is used to assess the likelihood of freckle occurrence. The addition of carbon has been shown to significantly reduce the number of solidification defects, including freckles. The formation of carbides in the interdendritic region will influence both the effective density of the fluid and the structure's permeability. Using a combination of mesoscale solidification modeling and thermodynamic calculations, these two effects were incorporated into an improved Rayleigh number criterion and compared to experimentally observed freckles as a function of the carbon content.