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NUMERICAL HEAT-MASS TRANSFER IN TIAL-NB DIRECTIONALLY SOLIDIFYING ALLOY UNDER THE EARTH- AND ZERO-GRAVITY ACTIONS

Abstract

The applied paper addresses the problem of numerical modeling of directional solidification of γ-TiAl intermetallic alloys at the preparation of experiments to be launched aboard the ESA MAXUS 8 sounding rocket in 2010. Particular attention is paid to columnar-to-equiaxed structure transition (CET) phenomena, segregation of Al and Nb constituents, mushy zone formation and evolution in Ti-46Al-8Nb (at%) multi-component system under the heat conditions realized in the unique high-temperature (up to 1700 degr.C) automatic spaceborne directional solidification furnace. The specific feature of this three-zone resistive furnace is application of “bent” axial temperature profile with sufficiently different thermal gradients along the sample, allowing the achieving of benchmark CET conditions within the solidification process at the 12-minute on-board microgravity duration. The numerical studies of heat-mass transfer and temporal solidification dynamics of TiAl-Nb under the earth- and zero-gravity approximations are performed and compared correspondingly. The method used for numerical solution of Navier-Stokes equations and phase transition (Stefan) problem accounts both the conductive/diffusive and convective heat-mass transfer development in a melt and mushy zone in dependence on the gravity level. It is shown numerically that current position of liquidus isotherm, its velocity rate and nearby local axial temperature gradient value in a melt will correlate with continuously varied mushy zone elongation and latent fusion heat release within its volume. The influence of thermo-gravitational convection on the evolution of 2D thermal field map of solidifying system and on the convection-induced segregation effects is traced with the particular attention to estimation and control of undesired radial temperature gradient value. The comparison is performed of some numerical model predictions with the real microstructure of TiAl-Nb reference samples being solidified on-ground in the counter-gravity direction in the course of microgravity campaign preparation.

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