Nonlinear Dynamics of Unsteady-State Crystallization of a Binary System

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Abstract:

Quite often, when the materials solidify between a purely liquid and a purely solid phase, a zone of a two-phase state of matter (liquid and solid) is formed. Its formation is a reaction of the system to the onset of instability of a planar front and the appearance of constitutional supercooling. Equations describing the processes of heat and mass transfer in a two-phase zone are complex nonlinear partial differential equations. The boundary conditions for these equations should be formulated at two moving boundaries, the positions of which are unknown. Thus, the problem of determining the fields of temperature and concentration in a two-phase zone, its dimensions and position, is a complex nonlinear system of thermophysical equations with moving boundaries [1,2].

The present paper is concerned with analytical description of self-similar crystallization regime in the presence of a phase transition layer (two-phase zone) filled with the growing solid phase and liquid. A nonlinear heat and mass transfer model is simplified to describe the case of small variations of the solid phase fraction in the two-phase zone. An exact analytical solution of simplified model is obtained. We show that this solution is in good agreement with the previously known theory. An important point is that the obtained solution has a wider scope of applicability than the asymptotic solution previously found in the vicinity of the bifurcation point.

Keywords: Moving boundary problem, partial differential equations, self-similar variables, two-phase layer

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