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Kh.M. GAMZAEV
Azerbaijan State Oil and Industry University, Baku, Azerbaijan,
e-mail: *gamzaevkhanlar@gmail.com.*

IDENTIFICATION OF THE BOUNDARY MODE IN ONE THERMAL PROBLEM BASED ON THE SINGLE-PHASE STEFAN MODEL

Abstract. The process of melting a one-dimensional block of ice by heating it from the left border is considered. A one-dimensional Stefan model is proposed for the mathematical description of the melting process. It describes the temperature change in the resulting melt zone with a movable boundary. Within the framework of this model, the task is to identify the heating mode on the border of the block, which ensures the movement of the movable boundary of the melt zone according to a predetermined law. The posed inverse problem for the single-phase Stefan model belongs to the class of inverse boundary-value problems. With the use of the method of front straightening, the problem area with a movable boundary is transformed into a domain with fixed boundaries. A discrete analog of the inverse problem is constructed using the finite-difference method, and a special representation is proposed for the numerical solution of the resultant difference problem. As a result, the difference problem for each discrete value of the time variable splits into two independent second-order difference problems, for which the absolutely stable Thomas method is used, and a linear equation with respect to the approximate value of the heating temperature at the left boundary of the block. Numerical experiments were carried out on the basis of the proposed computational algorithm.

Keywords: heat transfer with phase transformation, ice melting process, movable phase interface, front rectification method, boundary inverse problem, difference method.

INTRODUCTION

It is known that the study of heat transfer processes taking into account phase transformations is an important task in many fields of science and technology. Examples of physical phenomena and processes with phase transformations are: the process of melting ice with an unknown time-varying boundary between water and ice, the process of melting a solid with an unknown boundary between solid and liquid phases, the process of concentration redistribution during mutual diffusion in a metal alloy with movable phase boundaries, etc. Such processes occur in a number of modern metallurgical technologies, in the heat treatment of materials, in the cultivation of single crystals, during freezing-thawing of soils, in electric welding, as well as in a number of other fields of science and practice. For the mathematical description of such thermal, diffusion and thermodiffusion processes, accompanied by phase transformations and the absorption or release of latent heat, single-phase or two-phase Stefan models are used [1–4]. The main feature of the Stefan model is that the phase boundary moving in time, which creates time-varying regions in which the determination of temperature fields or concentration of substances is required, is not set a priori and must be determined during the solution process. The questions of the existence and uniqueness of the solution of single-phase and two-phase Stefan problems are studied in [5]. Currently, a large number of analytical and numerical methods for studying the single-phase and two-phase Stefan model are known [6–10].

It should be noted that the efficiency of many technological processes, where heat transfer with phase transformation takes place, largely depends on the law of movement of the movable phase interface. In this regard, the task of regulating the movement of the phase interface in the processes of heat transfer with phase transformation is very important. In this paper, on the example of the ice melting process, the