

AN EXPERIMENTAL-COMPUTATIONAL SYSTEM FOR THE DETERMINATION OF THERMAL PROPERTIES OF MATERIALS. II. CONCEPTION AND REALIZATION OF COMPUTER CODE FOR EXPERIMENTAL DATA PROCESSING

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Abstract - In this part the conception and realization of a computer code for experimental data processing to estimate the thermal and radiative properties of thermal-insulating materials are given. The main purpose of this study was: to confirm operability and effectiveness of the methods developed and the corresponded software for determining the thermal properties of modern structural and thermal-insulating materials, as temperature-dependent. The most promising direction in further development of methods for non-destructive composite materials using the procedure of inverse problems is the simultaneous determination of a combination of their thermal and radiation properties. The general method of iterative regularization is concerned with application to the estimation of material properties (as example: thermal conductivity $\lambda(T)$, heat capacity $C(T)$ and emissivity $\varepsilon(T)$). Such problems are of great practical importance in the study of material properties used as non-destructive surface coating in objects of space engineering, power engineering, etc.

1. INTRODUCTION

In determining the thermal characteristics of modern structural and thermal-insulating materials, as temperature-dependent, the most effective methods are based on solving coefficient inverse heat conduction problems [1-2]. The initial data for such problems are based on the results of measurements and include boundary conditions (of the first or second kind) and temperature-time measurements at several internal points of the specimen. The types of boundary condition and the number of points of temperature measurement should meet the conditions of uniqueness of the inverse problem solution under analysis [3]. The conditions of uniqueness usually define the minimum number of measurements needed in one experiment. As an example: at the simultaneous determining of the dependencies of thermal conductivity and volumetric heat capacity on temperature, at least at one boundary, it is necessary to measure the non-zero heat flux density entering a specimen and make transient temperature measurements at not less than two internal points. Boundary conditions of the first kind, or a condition of heat insulation on both boundaries, can be assigned, but in this case a specimen should be multi-layered and contain one layer of the material with known thermal characteristics and the number of temperature measurement points in the material layer under study should be not less than two.

The procedure of inverse problems is a simultaneous determination of a combination of thermal and radiation characteristics of the material (thermal conductivity $\lambda(T)$, heat capacity $C(T)$ and emissivity $\varepsilon(T)$) [3-7]. The experimental equipment [8] and the method described below could be applied for the determination of three characteristics of the material; the availability of two specimens of the material allows us to provide uniqueness of the solution.

In designing new thermal-insulating materials, quite a number of comparative heat tests are carried out, the purpose of which is clear from the analysis of the thermal properties of materials in different heating conditions corresponding to service conditions. The experimental specimens for such tests are manufactured in the form of a flat plate of the material analyzed. Owing to the structural version and homogeneous surface heating in specimens, a one-dimensional heat transfer process is realized. In the tests, as a rule, a one-sided heating of specimens is run. To control the assigned heating condition, the temperature of the external heated surface is measured and to estimate the thermal properties of the material in the study, the temperature at two internal points of the specimens and on the internal surface are measured (the temperature of the external surface is also used). In addition, the heat flux density is assumed to be known for the warm-up of a specimen. Realization of this condition is possible through experimental means. The internal surface temperature is used as a boundary condition. In practice it is difficult to realize a uniform initial temperature distribution in specimens, hence the initial temperature distribution is approximated through recorded data at zero time.

2. INVERSE PROBLEM ALGORITHM USED IN COMPUTER CODE

The direct problems for the considered case is given by:

