The 15th INTERNATIONAL SCIENTIFIC CONFERENCE
INFORMATION TECHNOLOGIES AND MANAGEMENT 2017
April 27-28, 2017, ISMA University, Riga, Latvia

The computational algorithm for calculating the thermal properties of the rock mass with inaccurate initial data

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Abstract

The paper discusses the coefficient inverse problem for one-dimensional heat equation with inaccurate initial data. A conjugate difference problem is developed on difference level. The problem is solved by method of interval analysis. Condition of applicability of Thomas method and its computational convergence are obtained. Estimates of the interval width of solutions of difference problems and functions of Thomas method are also gained.

Keywords: inverse problem, difference scheme, inaccurate data, estimation, width of intervals, convergence

1 Introduction

The aim of the work is to find an effective coefficient of thermal conductivity of materials. Methods of finding thermal conductivity have been studied by many researchers, as an example we refer to works [1-5]. However, when it comes to practical application of the developed methods, the new circumstances are found out that are not taken into account in the theoretical development of methods of calculation of thermal properties of materials. For example, composites consisting of a matrix and inclusions of various shapes are widely used as structural and functional materials in various instrumentation devices. Significant number of works are devoted to the research of thermal conductivity of composites. However, calculation formulas in these studies were obtained, as a rule, either as a result of processing of experimental data in relation to specific materials, or by setting a priori distribution of temperature and heat flow in models of the structure of heterogeneous bodies [6]. Material of different inclusions in the composite can have different thermal conductivities [7-11]. In this case, when assessing the effective thermal conductivity composite is considered as multi-phase [12, 13].

Thermal properties of soils are key elements in determining speed of movement and haloe forms of thawing. The thermal conductivity of unfrozen and frozen ground is one of the main parameters that is difficult to determine by indirect method. This parameter is influenced by many factors: genesis, structure of ice, size and configuration of soil particles. Therefore, the actual thermal conductivity may differ significantly from the calculated one [14]. For most materials the thermal conductivity is weakly dependent on temperature, so the sample heating can be neglected. Exceptions are permafrost soil, whose thermal conductivity strongly depends on temperature, and in the range of natural or calculated temperatures close to zero, may vary up to 30% or more [15].

One of limitations of using devices to work with the frozen soil is insufficient limit of thermal conductivity measurement, focused either on working with insulating materials, whose thermal conductivity is significantly lower than the thermal conductivity of the soil, or with building materials [16]. Furthermore, currently a large number of devices use nonstationary method of determining the thermal conductivity, which involves heating and subsequent cooling of the sample, and the resulting speed of propagation of the thermal wave is interpreted by certain thermal conductivity value. This method reduces time needed for measurement and is applicable to materials whose thermal conductivity does not depend on the temperature. Using this method to determine the thermal conductivity of frozen soils can lead to incorrect values because of the wide temperature range in the sample and the phase transition of water in the ground due to excessive heat exposure of device. Consequently, the thermal conductivity of soil is determined in a state which does not exist in nature, and the value may differ up to 30% or more from thermal conductivity under natural conditions [16].

Therefore, in view of above arguments, accurate, well-defined models and algorithms are not suited to solve problems that, by their nature, are too complex and multisided. The most relevant and promising for studying complex thermodynamic systems, under condition of uncertainty, are interval methods. Such methods allow to take into account the uncertainty and inaccuracy in coefficients and parameters of such systems.

2 Conclusions

In the course of work, the following results were obtained:

- An iterative method is developed to find the thermal conductivity coefficient with inaccurate data for the

complex thermodynamic metastable systems;
- Stability of the method of solving the coefficient inverse problem is studied with inaccurate data for the heat conductivity equation.

The obtained results reflect the actual problem of developing elements of the theory of automatic control of interval-specified objects of various classes and the development of interval methods in management theory, which allows to reduce the computational cost. These results can be used for various applications in the management of modern objects of industries in education. Theoretical and practical results will be used in the construction of interval algorithms to study the thermal parameters of metastable rock systems.

References

[1] Williams P J, Smith M W 2015 *The Frozen Earth: Fundamentals of Geocryology* Publisher Cambridge University Press, Cambridge (hardbach) ISBN 0521365341 306 pp

[2] Rysbaiyly B 2015 Stability and Convergence of Iterative Method for Solving the Inverse Problem of Heat Transfer in Multilayer Ground *International Conference on Applied Mathematics, France* **1** 215–21

[3] Beck J, Blackwell B, Saint-Clair Ch 1985 *Inverse Heat Conduction. Ill-Posed Problems* Academic Press

[4] Hasanee A, Lesnic D 2013 Determination of a time-dependent heat source from nonlocal boundary conditions *Engineering Analysis with Boundary Elements* **37**(2013) 936-56

[5] Hasanov A 2012 Identification of spacewise and time dependent source terms in 1D heat conduction equation from temperature measurement at a final time International *Journal of Heat and Mass Transfer* **55**(2012) 2069–80

[6] Han Z, Fina A 2011 Thermal conductivity of carbon nanotubes and their polymer nanocomposites: a review *Progress in Polymer Science* **36**(2011) 914–44

[7] Sandrock G, Reilly J, Graetz J, Zhou W-M, Johnson J, Wegrzyn J 2005 Accelerated thermal decomposition of AlH3 for hydrogen-fueled vehicles *Appl. Phys.* **A80** 687–90

[8] Dantzer P 1997 *Metal-Hydride Technology: A Critical Review, in Hydrogen in Metals III. Properties and Applications* (Topics in Applied Physics, Volume 73) // Ed. by H. Wipf. Springer-Verlag Berlin Heidelberg p. 279–340

[9] Dedrick D.E., Kanouff M.P., Replogle B.C., Gross K.J. Thermal properties characterization of sodium alanates // J. Alloys and Compounds. – 2005. –Vol.389. –P. 299–305.

[10] Kim K J, Montoya B, Razani A, Lee K-H 2001 Metal hydride compacts of improved thermal conductivity *Int. J. Hydrogen Energy* **26** 609–13

[11] Rodriguez Sanchez A, Klein H P, Groll M 2003 Expand ed graphite as heat transfer matrix in metal hydrid e beds *Int. J. Hydrogen Energy* **28** 515– 27

[12] Klein H P, Groll M 2004 Heat transfer characteristic s of expanded graphite matrices in metal hydride be ds *Int. J. Hydrogen Energy* **29** 1503–11

[13] Celzard A, Krzesinska M, Begin D, Mareche J F, Puricelli S, Furdina G 2002 Preparation, electrical and elastic properties of new anisotropic expanded graphite-based composites *Carbon* **40** 557–66

[14] Chawla K K 1999 *Composite Materials* Science & Engineering, New York, Springer-Verlag

[15] Evans A, Marchi C S, Mortensen A 2003 *Metal Matrix Composites in Industry* Dordrecht, Kluwer Academic Pub.

[16] Porfiri M, Nguyen N Q, Gupta N 2009 Thermal conductivity o multiphase particulate composite materials *Syntactic and composite foams* **44** 1540–50

[17] Lykov A V 1982 *Heat and Mass Transfer* Moscow: Energiya 560 p.

[18] Matsevityi Yu M 2002 *Inverse heat conduction problems* Kiyev, Naukova dumka *(In Russian)*

[19] Cheng C-Y 2003 Shape Identification by Inverse Heat Transfer Method *J. Heat Transfer* **125**(2) pp. 224–31

[20] Rysbaiuly B 2014 Mathematical properties of the iterative method to calculate the coefficient of thermal conductivity of multilayer ground W*ulfenia Journal*, Austria **20**(12)

[21] Kalmykov S A, Shokin J I, Juldashev Z X 1986 *Mehods of interval analysis* N.: Nauka SO p.224

[22] Zholen L, Kifer M, Didri O, Valter E 2007 *Applied interval analysis* M.: Institute of computer researches p.467

[23] Kabanikhin S I 2011 *Inverse and Ill-Posed Problems. Theory and Applications* De Gruyter, Germany 459 p.