MATHEMATICAL METHODS OF METROLOGY AND OPTIMIZATION APPLICATION IN THE DESIGN AND MODERNISATION OF TECHNIQUES AND DEVICES FOR THERMOPHYSICAL MEASUREMENTS

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Astract: Three possible approaches to the choice of the optimal regime parameters of the meas-urement methods, conditions of functioning of data processing algorithms and rational construction siz-es of the devices used in the design and optimization of information-measuring and control systems for thermophysical properties measurements and research are discussed.

Key-Wordes: Metrology, optimization methods, design, modernization, information-measuring and control system.

1. Introduction

The article presents the results of research works performed in Tambov State Technical University (TSTU) in 1972-2017. A distinctive feature of these works is the desire (even at the design stage of new and/or upgrade of existing methods and means for thermophysical properties (TPP) measurements) due to the use of metrology mathematical methods *to choose the optimal:*

– *mode parameters of the measuring operations* of developed and modernized methods for experimental determination of substances and materials TPP;

– *conditions and functioning parameters* of algorithms for data processing;

– *basic structural dimensions* of the designed measuring cells and devices.

2. Three approaches to solving the considered optimization problems

Based on the experience of developing methods and devices for TPP measurements it is possible to formulate three main options [1-3] for possible approaches to the choice of the optimal regime parameters of the developed methods, modalities of data processing algorithms and rational structural dimensions of the measuring cells.

1. *A purely theoretical approach* to the mathematical formulation of the optimization problem and its solution by using known methods of solving such problems. Examples of problems formulation and solution of problems for an optimum choice of regime parameters and the rational structural dimensions of the measuring device for TPP measurements considered in [1-3]. The disadvantage of this approach is the inability to take into account all the details and peculiarities of the measurement process and device in the mathematical formulation.

2. *Using a purely experimental approach,* for example, by measuring the TPP of the reference materials and substances (with known TPP) and the subsequent selection of the optimal regime parameters of the used method and the rational structural parameters of applied measuring devices based on the obtained experimental data. In many cases, this approach may seem attractive (especially for researchers who prefer to work without the use of mathematics), because it eliminates the need for the formulation and solution of mathematical optimization problems. For the successful application of this approach it is needed to understand very deeply the physical basis of the method of measurement and intuitively feel which of observed in the experiment parameters must be identified and should be inspected (chosen, controlled) in order to assure the optimal operating parameters of the measuring process. This experimental approach in practice requires a large investment of financial, material, human and time resources, and in many cases does not lead to obtaining answers to questions of optimization.

3. The most proper and successful way to the objective *is both theoretical and experimental approach* involving a combination of the two above-mentioned approaches. In order to achieve the stated goal under this approach one should proceed in the following way:

a) first it is necessary to formulate and solve the optimization problem for the operating parameters of the measurement method and for the structural dimensions of the measuring device while using the application of mathematical tools

of Metrology. It should not be forgotten that the solutions obtained are not quite accurate, because in the formulation of mathematical optimization problems were adopted a number of assumptions, allowing to simplify the formulation of the problem, but does not allow to consider all features of the examined process; as the result (of this initial work) appears indicative values of operating parameters of the method and structural dimensions of the measuring device;

b) in the second phase of the work it is necessary to make a prototype or layout of the measuring device and by conducting experimental measurements of substances and materials with the known TPP, to assess the real errors of measurements and to draw conclusions about the practical possibility of using obtained in the previous step theoretical recommendations on the choice of the optimal regime parameters of the method and rational structural dimensions of the measuring device; it should be noted that the volume of experimental researches (in the case of using the third *both theoretical and experimental approach*) can be considerably reduced in comparison with the case of applying the second purely experimental approach, because it considerably reduces the ranges of the parameters of the experiments (their approximate values are already known from the solution of the mathematical problem of optimization);

c) the following can be recommend at the next phase (depending on what results were obtained during the earlier conducted experiments):

- if the measurement results obtained using the reference materials contain significant systematic errors, it is necessary to develop a methodology for introduction of amendments [4] to these experimentally identified systematic errors and then include this methodology in the software used by information-measuring and control system (IMCS);

- if the results of the TPP experimental measurements of the reference substances and materials demonstrate the need to make a correction in previously defined theoretically optimal regime parameters of the method or structural dimensions of the measuring cell, it's necessary to make these changes in IMCS software, which will apply the developed method and the measuring cell.

During the research process, it became clear that during the design and development of the new and/or during modernization of existing methods and means of TPP measurements, the designer can use the recommendations of the «solving problems methodology», which is a detalization of the famous Deming cycle of quality improvement [1].

3. The main stages of the research.

Historically, some of the first results in the methods and means of TPP measurements optimization in this study were obtained in the 1972-95 years in relation to the so-called method of a laminar mode [1-3]. These results were partially recognized as inventions.

The results on the choice of optimal conditions and functioning parameters of algorithms for experimental data processing had been obtained during the second phase in 1990-99.

A lot of attention was paid to the choice of optimal conditions for the implementation of the methods of TPP measurements with flat and linear "instant" and pulse sources of heat during the next stage in 2000-2017.

4. References:

[1] **Ponomarev, S. V.** Primenenie matematicheskikh osnov metrologii pri optimizacii regimnikh parametrov metodov i osnovnikh konstrukcionnikh razmerov ustroi'stv dlya izmereniya teplofizicheskikh svoi'stv veshchestv: monografiya / S. V. Ponomarev, A. G. Divin, D. A. Lyubimova. – Tambov: Izd-vo Tamb. Gos. Tekhn. Universiteta, 2015. – 160 s. ISBN 978-5-8265-1492-4

[2] **Ponomarev, S. V.** Teoreticheskie i prakticheskie osnovi teplofizicheskikh izmerenii': monografiya / S. V. Ponomarev, S. V. Mishchenko, A. G. Divin, V. A. Verthogradsky, A. A. Churikov; pod nauch. red. S.V. Ponomareva. – Moskva.: FIZMATLIT, 2008. – 408 s. ISBN 978-5-9221-0956-7

[3] **Ponomarev, S.V.** Measurements of Thermophysical Properties by Laminar Flow Methods/ S.V. Ponomarev, S.V. Mishchenko, T.F. Irvine. - New-York: Begell House Inc., 2001. – 278 p. (in English) ISBN 1- 56700-151-3

[4] **Ponomarev S. V.** Rekomendacii po razrabotke metodiki vvedeniya popravok na sistematicheskie pogreshnosti izmereniya teplofizicheskikh svoi'stv veshchestv / S. V. Ponomarev, A. G. Divin, P. V. Balabanov, A. V. Gurov, D. A. Divina, A. E. Postnikova // Metrologiay. – 2013. - No. 10. – P. 38-47. ISSN 0132-4713

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