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SAMPLING OF AN OPTIMAL INITIAL CONDITION FOR THE MATHEMATICAL MODELS DESCRIBING PHYSICAL PROCESSES APPLYING INVERSE PROBLEMS

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Аннотация:Данная статья представляет обзор предложенного алгоритма для выбора оптимальных начальных условий для математической модели описывающих физические процессы. В основе представленных в статье гипотез лежит широкий класс математических задач из области прикладной математики, именуемой теорией обратных задач. Наряду с теоретическими выкладками, статья даёт описание результатов, полученных в результате проведенного вычислительного эксперимента, также предлагается направление для проведения дальнейших исследований по данной тематике.

Ключевые слова: прямая задача, обратная задача, математическая модель, тепломассообмен, начальные условия, многослойная область, вспомогательная задача, итерационная формула, метод баланса.

Annotation: This paper represents an overview of the suggested algorithm for sampling an optimal initial condition for the mathematical model describing real world physical processes. Proposed hypothesis suggests an implementation of the broad range of the theory of applied mathematics, videlicet the theory of inverse problems. As well as the theoretical basis, this paper gives a brief description of the analyses for the results obtained through the numerical experiment and purposely gives a direction for the further investigation for research on this topic.

Keywords: direct problem, inverse problem, initial conditions, heat transfer, multi - layered area, conjugate problem, iterative formula, balance method.

Аннотация: Бұл мақалада физикалық процестерді сипаттайтын математикалық модель үшін оңтайлы бастапқы шарттарды таңдаудың ұсынылған алгоритміне шолу жасалады. Мақалада келтірілген гипотезалар кері есептер теориясы деп аталатын қолданбалы математика саласындағы көптеген математикалық есептерге негізделген. Теориялық есептеулермен қатар, мақалада есептеу тәжірибесі нәтижесінде алынған нәтижелер сипатталған және осы тақырып бойынша әрі қарай зерттеуге бағыт ұсынылған.

Түйін сөздер: тура есеп, кері есеп, математикалық модель, жылу мен масса алмасу, бастапқы жағдайлар, көп қабатты аймақ, көмекші есеп, итеративті формула, баланс әдісі.

Setting up the mathematical model that accurately describes the physical process of specific interest is a key feature of a good design for developing or optimization of various engineering systems. There are a challenging set of tasks and problems in front of the modernity international society of engineers and mathematicians in today's fast developing and constantly changing world. With the help of the symbiosis of an advanced theoretical base of the broad theory of applied mathematics and the lavish opportunities provided by the innovative field of the computational technologies, modern international community of engineers and mathematicians push the frontier of the tremendous potential of the human race.

Mathematical modeling allows us to obtain an information that is necessary to get in order to accomplish design or development of innovative technologies in any enterprises, allowing to escape unpleasant casualties or a high production cost. It is easier and, what is more important, much more safely to simulate different conditions acquired from the real world restrictions on proposed numerical and computer models rather than in real life.

A broad branch of applied mathematics, which is called as the theory of inverse problem has found a wide application in everyday practice of designers and engineers all over the world. When speaking about the inverse problems, we refer to the process of calculating from a set of observation the causal factor that produced them: initial data or the governing parameters of the considering process.

Despite the fact, that we already have a broad set of the models, describing basic physical processes, there is a fundamental lack of well-stated models that would reflect accurately the real world conditions. Beside the necessity of reflecting a key features of the considered physical process, a good model should also take into account the possibility of numerical technologies applied for the design of a system, as well as the accuracy of description of the process. One of the most important factor is to be able to sample an optimal initial condition for the proposed model. An initial condition usually represents the state of the process at initial time, i.e. before the considered process acquire any excitation. Sometimes, it is difficult or even not possible to get the measurements of an initial state of the process due to some technological peculiar properties of investigated system. Most usual practice for engineers is guessing for such conditions that leads to not accurate description of the process and even obtaining of the solution that is weakly describing the features of the developing system in general.

This article is dedicated to the description of the key ideas of the proposed algorithm for sampling an optimal initial condition for the mathematical model, describing physical process. In order to accomplish such sampling, we propose a set of mathematical operations that require only the possession of the special mathematical apparatus referred to as the theory of inverse problems. We call it as the inverse problem, since it starts with the results and then calculates the causes, in our case the initial condition. This is the inverse of a forward or the

direct problem, which starts with the causes and then calculates the results. Inverse problems are one of the most important class of mathematical problems in science and applied engineering, since this apparatus may give us the required information about the parameters that we cannot directly observe or measure. In this sense, it appears to be the valuable tool for sampling the set of preliminary data needed for the model design. Such data may be represented by the boundary and initial conditions as well as the coefficients of the governing equation of the proposed model. An implementation of the preliminary part for mathematical and computer modelling such as the construction of accurately reflecting real world set of parameters should be an everyday practice for each engineer around the world, since it is a matter of great responsibility to rely on modern technologies, that people deal with in their everyday life.

As an example, we will consider a one-dimensional model, describing the heat transfer in a multi-layered non-homogeneous wall. The construction market includes several primary stages that may be split into three main parts for simplicity. They are the stage of the design of the building project, the process of the construction and the monitoring of the further exploitation of an artificial structure. When it is a subject of the building industry, there comes a great responsibility on an engineer, since it is a matter of human lives safety.

Any material undergoes aging processes, caused by the effects of the physical world affection. Those effects may vary from the thermal aging of the structure, due to the natural factors such as the temperature, pressure or the moisture drops, up to the deformation of the structural elements of the construction due to exploitation peculiarities. In this situation, it is a matter of great importance to be able to obtain not visible information about the state of the structure without intermittence to the exploitation process with the help of the methodology of non-destructive control tools. The mathematical and computer modeling as well as the implementation the theory of inverse problems comes out to be a valuable tool for such operations. It is necessary to set a well describing mathematical model that reflects accurately real world conditions in order to obtain such valuable numerical data for analyses and being able to make an assumptions and conclusions about the state of an artificial structure and weather it is safe for further exploitation or not.

In this article, we will demonstrate one of the tool of mathematical apparatus called an inverse problem theory for sampling fitted initial condition. More precisely, we will demonstrate an applied mathematics tools, such as the functional and regression analyses, including numerical methods, used for calculation experiments. We will also discuss the differences, comparing the results obtained through the numerical experiments with and without adjusted initial conditions, pointing out the routes for further investigations in research for sphere of science.

In order to find the proper initial condition, we will use one of the variation calculus tool, videlicet the functional analyses elements. We propose the following algorithm: 1. We construct the auxiliary problem, which is defined as a difference of the direct problem model at current and next iteration; 2. with the help of the balance method, we derive the conjugate problem from an auxiliary one; 3. constructing the functional, that includes the solution of the direct problem and the measured temperature, we want to find its minimum, by checking the

condition pf monotonously decreasing, and from that functional we may derive the recurrent formulas for unknown coefficients of initial condition.

According to the National Annex of The Republic of Kazakhstan (NTP RK 01-01-5.1-2013) “General Loads. Temperature Effects”, the problem of determination of the deformation of construction resulting from the thermal effects, should be solved with the help of choosing the most rational model that properly describes characteristic distribution of the thermal loads and temperature field. Temperature effects on buildings caused by climatic and operational changes in temperature should be taken into account when determining the design parameters of a building if there is a possibility of exceeding the limiting states in terms of bearing capacity and usability due to temperature movements and / or stresses.

However, with the help of the theory of inverse problems, we may obtain unknown data by solving direct and conjugate problems and by performing elements of the functional analyses. An inverse problem in science is the process of calculating from a set of observations the causal factors that produced them: for example, calculating an image in X-ray computed tomography, source reconstruction in acoustics, or calculating the density of the Earth from measurements of its gravity field.

It is called an inverse problem because it starts with the results and then calculates the causes. This is the inverse of a forward problem, which starts with the causes and then calculates the results. Inverse problems are some of the most important mathematical problems in science and mathematics because they tell us about parameters that we cannot directly observe

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