ANNOTATION

dissertation work of Mukaddas Turganovna Arshidinova on the topic: “Development and research of computational algorithms and programs for assessing and modeling thermophysical processes in rods of variable cross-section”, submitted for the degree of Doctor of Philosophy (PhD) in the specialty: 6D070400 – “Computer technology and software”.

Relevance of the dissertation work. In modern conditions of the country's economic development, the most important task is to modernize existing and create new highly efficient, reliable, safe systems and production facilities. This is evidenced by the address of the President of the Republic of Kazakhstan Kassym-Jomart Tokayev at the XI Forum of Mechanical Engineers of Kazakhstan, which says “Domestic mechanical engineering, being the locomotive of industry, shows production growth of 9.4%, and according to the results of the first quarter of 2023, 36%. We need to achieve accelerated growth in mechanical engineering based on innovation and advanced technologies."

Further development of power engineering and, above all, engine building is associated with a significant increase in specific indicators. Increasing the reliability and durability of engine structural elements operating under conditions of complex cyclic thermomechanical and thermophysical loading is one of the highest priority tasks of modern engine building. The assessment of reliability and durability is preceded by an analysis of the temperature and stress-strain states of the structural elements under study. Currently, one of the most promising areas for studying temperature and stress-strain states is the development of effective computational algorithms.

Due to the increasing frequency of emergency failures of supporting structures of technological equipment, casings and transport tunnels of underground city communications, multifunctional high-rise buildings and other engineering structures similar to the above in emergency modes, reliable prediction of their failure becomes relevant. This forecast is necessary for the development of additional measures to reduce damage from man-made accidents by increasing the reliability of supporting structures in extreme exposure modes. There are practically no statistics on the destruction of the above-mentioned objects, and it is not possible to conduct full-scale experiments on many special structures.

The high dynamics of modern development of computing tools has led to the emergence of powerful computer systems. This opens up new, broader opportunities for the effective use of computational algorithms for complex thermophysical and physical-mechanical processes. At the same time, the quality of computational algorithms largely depends on the reliability at the theoretical level of the adopted mathematical models.

The most important result of using mathematical modeling is checking the accuracy and depth of understanding of the studied thermophysical and physical-mechanical processes by comparing numerical and available experimental data. At the same time, it is very useful to jointly coordinate experimental and numerical

studies and, as a result, to build and replenish information databases about simulated physical processes that have a broad prospect of technical implementation in the created samples of the latest technology.

It is relevant to study the qualitative and quantitative influence of the parameters of the heat source and the geometric characteristics of the rod on the temperature field. This is due to the fact that the reliable operation of technological lines of processing enterprises, elements of nuclear and thermal power plants, jet engines and internal combustion engines depends on the thermophysical state of these elements when exposed to heterogeneous heat sources.

The problem of creating new effective algorithms and, on their basis, modern application software for solving problems of computational thermal conductivity is also relevant.

Purpose of the thesis work. Development of computational algorithms and a software package for the study of thermophysical characteristics of thermally insulated and non-thermally insulated rod of variable cross-section.

Research objectives.

According to the set goal, the following tasks are solved in this work:

– investigation of the thermomechanical state using the variational approach for a rod of variable cross-section;

– development of numerical method and algorithms on the basis of the proposed variational approach for estimation of thermophysical processes in rods of variable cross-section;

– creation of a software complex on the basis of the developed algorithms.

– development of algorithm and software for solving the problem of heat conduction in a non-thermally insulated cylinder using cylindrical coordinate system.

Object of the research. Thermophysical processes in a rod of variable cross-section.

Subject of the research. Numerical methods and algorithms for solving problems of determining the thermomechanical state of a rod of variable cross-section based on the variational approach.

Research methods. To solve the problems set in the work are used: variational method, analytical method, methods of finite differences and finite elements, Galerkin method.

The information base of scientific work is materials of periodicals on researches in the field of thermodynamics, monographs, Internet resources, materials of scientific-practical conferences.

The ASIR software package was developed to conduct numerical experiments.

Scientific novelty. Scientific Novelty. The presented study has the following significant results that give it scientific novelty:

– a model has been developed to investigate the thermophysical characteristics of a rod of variable cross-section using a variational approach;

– ethods of forming a system of linear equations to determine the law of temperature distribution for a thermally insulated and non-thermally insulated rod of

variable cross-section have been developed, which significantly reduces the number of machine operations;

– developed computational algorithms for automatic formation of functional and determination of thermophysical characteristics;

– developed algorithms and software for solving the problem of heat conduction in a non-thermally insulated cylinder using a cylindrical coordinate system.

Provisions submitted for defense.

Methods and algorithms for studying the thermophysical characteristics of a rod in the form of a truncated cone, operated under various types of thermal influence, satisfying the requirements of the specified conditions of operation.

These results considerably enrich the field of research in numerical modelling of heat conduction and expand the application of such models in various fields of science and technology. The developed method, algorithms and software package can be useful in engineering calculations, as well as in other applied areas where it is important to analyse thermophysical processes in structures with variable characteristics and multiple heat sources.

The practical significance of the work is as follows:

ASIR software allows engineers to optimise the geometry and materials of cores to achieve desired thermal performance, which can lead to reduced weight, cost and improved efficiency. Understanding thermophysical processes is important for assessing the service life and reliability of structural components, which contributes to improved safety. Analysing the effects of thermal processes on materials can help in the development of new materials with improved performance. The resulting algorithms and programmes can be used academically for teaching students and conducting scientific experiments. Analysis of modelling results can support engineering and management decisions. The algorithms can be adapted and used in various fields where understanding of thermal processes is important, such as biomedicine, aerospace, and mechanical engineering. The developed methods and tools can find wide practical applications and become a significant contribution to the development of relevant technological and scientific fields.

Thus, the thesis is of high practical relevance as it provides tools and solutions for real engineering and industrial problems and has been successfully validated in an industrial context.

Personal contribution of the researcher. The researcher conducted personal problem solving related to the thesis work, which emphasises his active participation in the research and development process. The following types of research were carried out as part of the work:

-analytical research: the researcher analysed previous work and developed an algorithm to estimate the thermophysical characteristics of a variable cross-section rod. This analysis helped in formulating mathematical models and approaches to solve the problem.

-Numerical study: based on the developed mathematical models and algorithms, the researcher carried out numerical calculations to evaluate the

thermophysical processes in a variable cross-section rod. These calculations provided quantitative results and analyses under different conditions.

-Software development: the researcher has developed an architecture and software package ASIR , which allows the evaluation of the thermophysical characteristics of a variable cross section rod. This software package can be used to solve practical problems in engineering and science.

All these steps allowed the researcher to develop a comprehensive approach to solving the problem and present a new method and software package for evaluating the thermophysical characteristics of a rod of variable cross-section of limited length.

Reasons for performing the work. The dissertation work was carried out under project No. AR05131093, with grant funding from the Ministry of Education and Science of the Republic of Kazakhstan, the project leader is Doctor of Physical and Mathematical Sciences, Professor A.K. Kudaikulov, Chief Researcher of the RSE at the PVC "Institute of Information and Computing Technologies" of the Scientific Research Institute of Education and Science of the Republic of Kazakhstan.

Approbation of work. The main provisions and results of the research were discussed at the Department of Informatics of the Kazakh National University. Al-Farabi, at seminars at the RSE at the Institute of Information and Computing Technologies of the National Science Ministry of Education and Science of the Republic of Kazakhstan, at the Department of Mechanical Engineering of the Faculty of Engineering of Kocaeli University (Izmit, Turkey), speeches at international scientific and practical conferences.

The reliability of the obtained numerical results is confirmed by comparison with the data of other authors, with the results of analytical solutions and experimental studies.

Publications. The main scientific results of the dissertation are presented in 17 publications, including: 2 monographs, 4 - in scientific publications recommended by the Committee of Science and higher education of the Republic of Kazakhstan, 2 - in international scientific publications included in the Scopus database, 9 - in materials of international scientific and practical conferences, of which:

– 2 articles in international scientific journals indexed in Web of Science with impact factor Q3: (Eastern-European Journal of Enterprise Technologies, International journal of mechanics)

– 4 articles in journals from the list recommended by the Committee for Control in the Sphere of Science and Higher Education of the Ministry of Education and Science of the Republic of Kazakhstan (COCSEHE): (Bulletin of KazNITU, Izvestiya NAS RK. Series of physics and mathematics, Bulletin of KazATK, Bulletin of KazUTB).

– 9 publications in the materials of international and republican conferences and reports at scientific seminars:

– at the III International Scientific and Practical Conference, Ukraine, Pereyaslav-Khmelnitsky, April 2018;

– at the 16th International Conference Information Technologies and Management / 16th International Conference Information technologies and Management, 2018, Information Systems Management Institute, Riga, Latvia;

– at the 5th International Conference on Information Science and Control Engineering / 2018 5th International Conference on Information Science and Control Engineering (ICISCE 2018), Zhengzhou, China Jule,2018;

– at the 2nd International Conference on Advances in Civil, Energy Resources and Environmental Engineering, 2020, Nanning, China. IOP Conference Series: Earth and Environmental Sciences / 2nd International Conference on Advances in Civil Engineering, Energy Resources and Environmental Engineering, 2020, Nanning, China. IOP Conference Series: Earth and Environmental Science;

– in a paper at the 1st and 2nd International Conference on sustainable on science and technology, 2018, Antalya-Turkey/ 1st International Conference on sustainable on science and technology, 2018, Antalya-Turkey- 2nd International Conference on Sustainable Science and Technology , 2019, Istanbul- Turkey;

– in a paper at the 22nd ULIBTK‘19 Congress of Thermal Sciences and Technology, 2019, Kocaeli - Turkey/ ULIBTK’19 22nd Congress of Thermal Sciences and Technology, 2019, Kocaeli - Turkey;

– in a presentation at the 7th Asian Mechanisms and Machine Science Conference (ASIAN MMS 2024);

The developed software complex ASIR for the study of thermophysical processes in the rod have been implemented and tested in TeploSnab LLP (Astana) and Ontustik Zharyk Transit LLP (Shymkent), which is confirmed by certificates of production tests, № 148 from 12.09.2023 and № 776 from 17.10.2023, respectively.