

REVIEW

on the dissertation work of **Denys KATAIEV** on the topic
**"Software and information complex for improving the accuracy of
measurements of geometric parameters of power equipment parts based on a
neural network"**,
submitted for the degree of Doctor of Philosophy
in the field of knowledge 17 "Electronics, automation and electronic
communications"
in speciality 175 "Information and measurement technologies"

Relevance of the research topic, its connection with scientific programmes, plans and topics.

The energy sector is one of the key areas for ensuring the stable functioning of modern society. Insufficient measurement accuracy leads to a decrease in equipment life, increased maintenance costs and, in some cases, to emergency situations.

The use of modern information and measurement systems makes it possible to achieve high accuracy, speed and automation of control processes. However, they have a number of limitations, including insufficient adaptation to the impact of external destabilising factors (vibrations, thermal deformations, inertial effects).

The relevance of Denys KATAIEV's dissertation is due to the need to improve the accuracy of measurements of the geometric parameters of power equipment parts, since the reliability and efficiency of equipment operation under critical operating conditions directly depends on the accuracy of these measurements. The task of compensating for non-kinematic measurement errors caused by external factors, such as temperature changes, vibrations and electromagnetic interference, which cannot be eliminated by standard calibration methods, is particularly relevant. Therefore, the development of a software and information complex using neural networks to compensate for such errors is a timely and important task.

The chosen topic of the dissertation corresponds to the current trends in the development of information and measurement technologies in the energy sector. Denys KATAIEV's dissertation research is related to the following research works: "Development of methods and means for monitoring the state of the environment of energy facilities based on wireless sensor networks" (0123U100127, 2023 - 2027).

Assessment of the scientific level of the dissertation.

The dissertation work of Denys KATAIEV consists of an introduction, 5 chapters, general conclusions, a list of references and 4 appendices. The work is presented on 157 pages, includes 53 figures and 16 tables. The list of references contains 143 items.

In the *first* chapter, the author analyses modern methods of compensating errors in coordinate measuring systems, identifies the shortcomings of existing solutions and justifies the feasibility of using artificial neural networks to compensate for non-kinematic errors. The chapter is theoretical in nature and contains clearly formulated research objectives.

The second section is devoted to the creation and calibration of a kinematic model of a coordinate measuring arm. The combined calibration methodology with three standards proposed by the author allows to effectively eliminate systematic kinematic errors.

The third section covers the design of a software and information complex with an integrated neural network, describing in detail the choice of neural network architecture, activation functions, hyperparameters, and software tools that ensure high adaptability of the system to the measurement conditions.

In the *fourth* section, the author proposes effective methods of data preparation for training neural networks, creating synthetic data sets with consideration of

destabilising factors, as well as algorithms for dividing data into training, validation and test sets.

The fifth chapter contains experimental studies of the developed complex, demonstrating a 6-fold reduction in non-kinematic measurement errors due to the use of neural networks, which confirms the effectiveness of the proposed solution.

The conclusions of Denys KATAIEV's dissertation present the most significant scientific and practical results of the study. The results of the development of a universal method for calibrating a coordinate measuring arm and the implementation of a single-point model for compensating kinematic errors, which significantly improved the accuracy of measurements, are described. The results of experimental studies of the developed software and information complex with an integrated neural network are described, which showed its high efficiency in compensating for non-kinematic errors, providing a sixfold reduction in errors compared to traditional methods.

Novelty of the presented theoretical and/or experimental results of the research conducted by the applicant.

The scientific novelty of the study is the development of new methods and models to improve the accuracy of measurements of geometric parameters of power equipment parts by creating a universal calibration method using three standards, which allows to take into account systematic measurement errors. The proposed method of single-point compensation of kinematic errors of the coordinate measuring system provides a significant reduction in residual errors and allows achieving stability of measurement results under various operating conditions. The developed model of neural network training provides adaptive compensation of non-kinematic errors arising under the influence of external factors, such as temperature changes, vibrations, electromagnetic interference, which allowed to achieve a sixfold reduction in these errors compared to traditional compensation methods.

Scientific validity of the results presented by the applicant.

The developed method of universal calibration of coordinate measuring systems should be used in production conditions to ensure high accuracy of control of geometric parameters of power equipment parts, which directly affects the service life and reliability of the equipment. The proposed method for compensating residual kinematic errors can be recommended for integration into existing measuring systems, which will significantly reduce measurement errors and improve the quality of production control. The methodology of training, education and integration of neural networks into software and information systems can be used to create high-precision adaptive measurement systems capable of operating in difficult production conditions, taking into account a wide range of destabilising factors. This can significantly increase the competitiveness of domestic equipment manufacturers in the modern power engineering market.

Information on compliance with academic integrity.

In the dissertation of Denys KATAIEV, there are no facts of academic plagiarism, fabrication or falsification of the obtained results were not found. The dissertation of Denys KATAIEV fully complies with the requirements of the "Procedure for awarding the degree of Doctor of Philosophy and cancellation of the decision of a one-time specialised academic council of a higher education institution of a scientific institution to award the degree of Doctor of philosophy", approved by the Resolution of the Cabinet of Ministers of Ukraine of 12 January 2022 No. 44.

Shortcomings and comments on the work.

1. In the description of the calibration algorithm (Section 2), the author proposes to use three standards. It would be worthwhile to justify in more detail why this number of standards is optimal and how changing the number of standards can affect the accuracy of the calibration and the complexity of the procedure.

2. In Chapter 3 of the thesis, the author provides a detailed justification for the choice of neural network architecture and presents results for a large number of model variants. However, it would be advisable to indicate in the text of the thesis why these types of neural networks were chosen and why the possibility of using other promising types of networks, such as recurrent (RNN) or convolutional (CNN), which could further improve the accuracy of error compensation, was not considered.

3. Chapter 4 insufficiently covers the analysis of the sensitivity of the neural network to the variation of certain hyperparameters (number of layers, number of neurons, learning rate, etc.). It is recommended to provide a more in-depth analysis of the impact of these parameters on the accuracy and stability of neural network training.

4. In the fifth section, when describing the results of neural network training, it would be advisable to add additional graphical dependencies (training graphs) that would clearly demonstrate the dynamics of changes in network accuracy and the convergence process during training.

5. Chapter 5 presents the results of experimental studies of the effectiveness of the proposed software and information complex only for certain types of activation functions. It requires additional explanation why a more extensive comparative analysis of the effectiveness of using different loss functions and their impact on the final accuracy and training speed of a neural network was not conducted.

6. The paper pays insufficient attention to the performance of the developed complex, in particular, the impact of the neural network processing time on the overall performance of the measurement process, which is important for the practical use of the developed solution in real production conditions.

Despite the presence of a small number of typos, the paper is of a high enough standard in terms of style and language. These remarks are advisory in nature, are insignificant and do not reduce the scientific value and practical significance of the results of the dissertation by Denys KATAIEV.

Conclusions on the thesis.

Denys KATAIEV's dissertation "Software and information complex for improving the accuracy of measurements of geometric parameters of power equipment parts based on a neural network" is a completed scientific work that fully solves the scientific task of compensating for kinematic and non-kinematic errors of coordinate measuring systems using neural networks. The validity and reliability of the scientific positions and conclusions are ensured by a clear statement of tasks, the use of modern methods of analysis, modelling, experimental research and practical testing of the results at Ukrainian enterprises.

Denys KATAIEV's dissertation is an independently conducted research, characterised by a high level of scientific novelty and practical significance. The conclusions and results presented in the thesis were obtained by the author personally. The main scientific results of the dissertation have been fully published in 9 scientific papers, including 6 articles in professional scientific journals of Ukraine, 3 proceedings of international and national conferences.

I believe that Denys KATAIEV is fully proficient in the modern methodology of scientific research and deserves to be awarded the degree of Doctor of Philosophy in the speciality 175 "Information and Measurement Technologies".

Reviewer

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