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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"

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

The modern development of power equipment requires constant monitoring and accurate measurements of geometric parameters that directly affect the reliability and service life of power plants. This problem is especially acute in the production of parts operating under high loads, where even minor errors can lead to serious accidents and financial losses.

The relevance of Denys KATAIEV's work is driven by the need to improve the measurement accuracy of coordinate measuring systems that are exposed to external destabilising factors. Modern calibration methods can effectively compensate for kinematic errors, but are insufficient for nonkinematic influences that are complex, nonlinear and dynamic. In response to these challenges, the author proposes the implementation of a software and information complex with an integrated neural network to compensate for residual nonkinetic errors.

The topic of Denys KATAIEV's dissertation, which is devoted to the development of modern methods for compensating for kinematic and nonkinematic errors in measurements of geometric parameters in coordinate measuring systems based on artificial neural networks, is relevant and fully complies with the research programmes of the Institute of General Energy of the National Academy of Sciences of

Ukraine, namely the programme "Development of methods and means of 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 of Denys KATAIEV is set out on 157 pages of typewritten text, contains an introduction, five chapters, general conclusions, a list of references (143 items) and 4 appendices. The work is accompanied by a large amount of illustrative material: 53 figures and 16 tables, which demonstrate the thorough nature of the study.

In the *first* chapter, the author carried out an in-depth analysis of the problem of accuracy of measurements of geometric parameters and substantiated the feasibility of using artificial neural networks as an effective means of compensating for measurement errors.

In the *second* section, the author first proposed a method for calibrating the coordinate measuring arm using the Denavit-Hartenberg parameters and three reference objects, which ensures increased measurement accuracy.

The third section of the paper is devoted to the development of the architecture of the software and information complex with an integrated neural network, and provides a detailed description of software solutions and error compensation algorithms.

Section 4 describes the methodology for collecting, processing and preparing data for training a neural network, including methods for generating and normalising data that ensure high accuracy and stability of the results.

The fifth section presents the results of experimental studies that confirm a significant reduction in measurement error - up to 6 times compared to traditional methods of compensating for non-kinetic errors.

The *conclusions* present the most significant scientific and practical results of the study. The author describes the results of the development and implementation of a universal method of calibration of coordinate measuring systems using three reference objects, which allows to effectively compensate for systematic kinematic errors. The

results of modelling the compensation of non-kinematic measurement errors using a neural network are presented, which made it possible to significantly (6 times compared to traditional methods) reduce the impact of non-kinematic errors. Practical results of the implementation of the developed software and information complex at Ukrainian industrial enterprises are also presented, which indicates its effectiveness and prospects for widespread use in the field of quality control of power equipment parts.

Scientific novelty of the presented results.

The scientific novelty of Denys KATAIEV's dissertation is the development of calibration methods and models for compensating measurement errors of geometric parameters of parts using neural networks. The author has proposed a method of single-point compensation of kinematic errors and a universal calibration method using three standards, which allows for a comprehensive consideration of systematic measurement errors. Also, the introduction of a neural network model was proposed, which provided significant compensation for non-kinematic errors.

Scientific validity of the results presented by the applicant.

The scientific provisions, conclusions and recommendations of the dissertation are reasonable and reliable. This is achieved through the use of modern methods of mathematical modelling, artificial neural networks, numerous experimental studies and testing of results at production enterprises.

Information on compliance with academic integrity.

No facts of academic plagiarism, falsification or manipulation of research results were found in Denys KATAIEV's dissertation. The work fully meets the requirements for academic integrity.

Shortcomings and comments on the work.

Despite the high level of performance of Denys KATAIEV's dissertation research, there are certain points that deserve attention and additional clarification:

1. In the *second* chapter of the thesis, the author describes the development of a kinematic model using the Denavit-Hartenberg parameters. It would be advisable to provide a more detailed justification for the choice of this particular model, taking into account modern alternative methods of kinematic modelling (e.g., models based on the finite element method or alternative kinematic models with fewer parameters). It is also advisable to analyse the advantages and disadvantages of the proposed method in comparison with other approaches.

2. In the *third* section, the author presents in detail the structure and algorithms of the developed software and information complex. At the same time, the issue of integration of this complex with the existing industrial systems of automated quality control of parts requires additional explanation. It would be advisable to highlight the main technical and software requirements for such integration, in particular, the issue of compatibility of data transfer protocols.

3. *Chapter 4 of* the thesis discusses the methodology of data preparation for training neural networks. The author does not pay enough attention to the rationale for choosing specific methods of normalisation and generation of synthetic data. It would be necessary to indicate more clearly how these approaches affect the overall training efficiency and accuracy of the results obtained, as well as to conduct a comparative analysis of different data preprocessing techniques.

4. The influence of external conditions (temperature fluctuations, vibrations, electromagnetic interference, etc.) on the accuracy of measurements after neural network compensation is not sufficiently covered in the thesis. It would be advisable to provide additional experimental data on the behaviour of the proposed software system under conditions of significant environmental changes, which is an important factor in assessing the stability of measurements in production conditions.

5. Although the thesis contains a significant amount of illustrative material, certain results of experimental studies are presented mainly in the form of tables. It would also be advisable to provide a graphical comparison of the accuracy of the

proposed complex with existing analogues or traditional methods of error compensation, which would allow a more visual assessment of the advantages of the proposed approach.

The above shortcomings of Denys KATAIEV's dissertation are insignificant and do not diminish its scientific value and the significance of the results obtained.

Conclusions on the dissertation.

The dissertation work of Denys KATAIEV is a completed, independent scientific research, which fulfilled the scientific task - developed a software and information complex to improve the accuracy of measurements of geometric parameters of power equipment parts.

The author has fully mastered the methodology of scientific research. The main results have been published in 9 scientific papers, including 6 articles in professional journals of Ukraine, which confirms the proper testing of the results.

I believe that the dissertation of Denys KATAIEV meets all the requirements for dissertations for the degree of Doctor of Philosophy, and its author deserves to be awarded the degree of Doctor of Philosophy in the speciality 175 "Information and Measurement Technologies".

Reviewer

Doctor of Technical Sciences, Professor,

Leading Researcher

of the Department of Monitoring and Diagnostics of Energy Facilities

of the Institute of General Energy

National Academy of Sciences of Ukraine _____ Yurii Kuts