

ANNOTATION

to the dissertation of Ildar Anuarbekovich Pirmanov on the topic "Digital twin of organizational and technical maintenance of helicopter engines and units on a neural network platform" for the degree of Doctor of Philosophy (PhD) in the educational program 8D07101 - "Aviation Engineering and Technology"

Relevance of the topic:

The exponential increase in the complexity of newly created artificial systems, and as a consequence of management and technological tasks, makes, in all sectors without exception, further effective competitive development of the economy impossible without the involvement of new achievements in science and technology. One of the most realistic mechanisms for solving the challenges that have arisen is the widespread introduction of information technologies based on digital principles, which are rapidly penetrating not only all spheres of human activity, but are also an integrating factor, systematically uniting the economy, education, healthcare, production, law, politics, playing a decisive role in increasing state security. Information technology is becoming a "hub of human knowledge," especially with the advent of the Internet, turning into a "networked mind." The existing concept of "digitalization" is functionally and organizationally transformed into an integrated phenomenon of "Digital Transformation". The Republic of Kazakhstan was one of the first to give this concept a legal form in state documents (State Program "Digital Kazakhstan"/Resolution of the Government of the Republic of Kazakhstan dated December 12, 2017 No. 827) [1]. From the information available in the literature, it follows that the concept of "digital transformation" is very multifaceted and can be interpreted extremely broadly.

The aviation industry is a leader in this environment, not only in the design and production of aircraft, but also in terms of modernizing the aircraft operation system. Aircraft are one of the most complex technical systems created and used by man. But like any technical product, aircraft have the ability to fail, that is, to interrupt the functioning process, and this reduces flight safety.

It is possible to eliminate a failure or malfunction, but without identifying and eliminating the cause that causes it, the reliability and operability of the aircraft cannot be guaranteed. To ensure the operational reliability of the aircraft, digital diagnostic technologies, including those based on artificial intelligence, are being developed and implemented based on new achievements of science and technology.

One of such technologies is a digital copy of an object called a "Digital Twin", which reflects the state of the object in its working dynamics. Digital twins are one of the practice-oriented areas of modern digital transformation. The concept of a "digital twin" is interpreted as "a computer representation of a specific physical product or some system and business process. Digital twins integrate precedents that are built on historical information accumulated in Big Data. Recently, neural approaches have been widely used in digital twins, opening up

new possibilities in systems for ensuring the operational reliability of complex objects, which include aircraft engines.

From these positions, the issues of theory and practice of managing the reliability of helicopter engines in operating conditions with the use of digital technologies in the area of maintenance and repair are relevant and are of undoubted scientific interest.

The aim of the study is to improve the quality of maintenance and repair of aircraft equipment.

Research objectives .

1. Development of a neural model for express diagnostics of helicopter gas turbine engines.

2. Development of a neural network model for in-depth diagnostics of gas turbine helicopter engines.

3. Organizational and methodological model of practice-oriented training of personnel for aircraft repair enterprises on the “Digital Twin” platform.

4. Model for forecasting the time costs for repair of helicopter units using Digital Twin technology.

5. Experimental and statistical studies of the certification system of students using digital twins

6. Regression model for assessing the results of certification of mechanics and electronics specialists in an aircraft repair enterprise.

Research methods. The work uses complex studies, including systems analysis, neural network models, precedent approaches, technical and technological monitoring, methods of mathematical statistics, principles of algorithmization, systematicity, complexity and mutual coordination of specific approaches with general systemic patterns.

The main scientific provisions submitted for defense:

1. Neural model of express diagnostics of helicopter gas turbine engines.

2. Neural network model for in-depth diagnostics of gas turbine helicopter engines.

3. Model for forecasting the time costs for repair of helicopter units in the “Digital Twin” technological environment.

4. Regression model for assessing the results of certification of mechanics and electronics specialists in an aircraft repair enterprise.

Results of the study:

1. As a result of the conducted research of literary materials and statistical state reporting data, it was established that the digital transformation of the Republic of Kazakhstan should be based on the phased implementation of new technologies: artificial intelligence, on the systemic restructuring of the country's economy, where special attention is paid to education. Education is based on a practice-oriented approach with close integration of training processes and real production. For the "Academy of Civil Aviation" such enterprises are aircraft repair enterprises.

2. Analysis of the production activities of aviation enterprises of the Republic of Kazakhstan showed that the decrease in managerial and economic

performance in this business environment is largely determined by the lag in the pace of implementation of the latest digital technologies. Among such technologies, the following should be highlighted first of all: - "Neurotechnology and artificial intelligence"; "Technologists Digital twin"; "Technologies of virtual and augmented reality"; "Laser technologies"; "Technical SMART diagnostics".

3. The general shortcomings and problems in the existing management systems have been identified, regardless of the industry affiliation and form of ownership, which can be reduced to the following: low control efficiency, lack of consistency and integration in management and decision-making. For various tasks, especially in the diagnostics of the technical condition of the engine, there is no integrated approach and criterion for assessing the technical condition of the object. There is no methodology for quantitatively assessing the quality of control and control risks, since control errors affect flight safety.

4. It has been proven that improving the quality of control systems and reducing the risks of decision-making in the conditions of parametric uncertainty of system agents and data fuzzy leads to the need for extensive reliance on formal methodologies, convergent approaches in the analysis and synthesis of complex integrated multiparametric systems, the introduction of SMART and neural technologies, the use of remote control methods and the implementation of non-contact remote technological operations.

5. Big Data was used as system mechanisms and tools to ensure the operational reliability of the helicopter fleet, and in particular, helicopter engines. In accordance with the scientific and practical principles adopted in Industry 4.0, this digital ideology is based on the following system areas: infrastructure and products; processes and tools; data; models; personnel; culture. The scope of this scientific and practical work considers a narrower subject matter problem, which is limited to three areas: processes, models, personnel.

6. The work examined the maintenance and repair (M&R) of helicopter engines as processes, relying on modern neural network support. The processes were considered as virtual precedent agents with a statistical nature and history. The quality of the helicopter engine maintenance system was considered as a business process and is supported by the ISO 2015 standard, which regulates the mandatory quantitative assessment of control risks and decision-making.

7. The following models were developed: a neural model of express diagnostics of helicopter gas turbine engines (section 2.3); a neural network model of in-depth diagnostics of helicopter gas turbine engines (section 2.4); structural and functional model of the digital twin of the helicopter engine diagnostics process.

8. It was found that the process of supporting the operational reliability of the GTE is recommended to be built in the form of a horizontally and vertically integrated diagnostics system. The process of organizational and technological integration is presented in two forms and levels of diagnostics: express diagnostics and in-depth diagnostics. The horizontal level provides for a quantitative increase in diagnostic information in each diagnostic feature by processing historical control results accumulated in the Big Data system. The vertical level is

implemented by expanding the number of diagnostic features based on different physical laws and methods - vibroacoustic and pyrometric.

9. The dissertation researched the educational and production efficiency of the "Digital Twin" technological platform in the practice-oriented training of students of JSC "Academy of Civil Aviation at the Enterprise" JSC Aircraft Repair Plant No. 405. It has been established that when designing the components of the CD, it is most rational to carry out not only in the laboratory conditions of the university, but also in production conditions.

10. The practical training experience on the CD platform in this example consisted of students acquiring skills in repairing (assembling) units of varying complexity using a wide range of working tools and devices in a real production process. At the end of the practical training, the goal was to assess the level of training of undergraduate students in the educational program "Aviation Engineering and Technology" at JSC "Academy of Civil Aviation" in the conditions of the current CD system. This work was carried out at the educational and research experimental site of JSC Aircraft Repair Plant No. 405. The studies were conducted using the example of assembly processes on 13 units of varying complexity. Two groups of students, 50 of whom were trained as mechanics and electronics specialists, were tested.

11. Digital twin technology operates with quantitative indicators of the functioning of the observed object or process. Therefore, when implementing the CD, the first stage is the need to identify and justify the optimal set of the most informative technological target indicators. In this precedent, an experimental-statistical approach was used. Experimental-statistical studies were conducted on the example of certification of two sample professional training groups: mechanics specialists and electronics specialists. The study was conducted using the example of the educational program "Aviation Engineering and Technology". The calculated level of preparedness of the aviation specialist based on the time indicator in the form of the difference between the standard assembly time of the unit and the actual assembly time was used as the output integrated criterion for assessing the overall level of preparedness of the aviation specialist. During the experiment, it was revealed that all technological operations significantly depend on the complexity of the unit, therefore, a coefficient of the weight of operations according to the time criterion was introduced into the structure of the evaluation formula.

12. As a result of the experiment, it was revealed that the basic mathematical model of the CD in the algorithm and software implementation should be differentiated from five structural time parameters: the time of general preparatory work for the assembly of each unit and is subject to control in the mode of continuous monitoring throughout the life cycle of this unit, which has its own technical passport in the local database (DB); the time of installation of each part in the unit; local time for preparing parts for assembly in each unit and in total for all units; time of work with the tool in the unit and in total for all units; adjustment time of all units.

13. As a result of the analysis of the results of experimental studies using the method of certification of trainees based on digital twins during the assembly of aircraft units, it was established that in the production area of an aircraft repair enterprise, it is effective to use training at the first stage using digital twins, and at the second stage using real objects. Based on the analysis of experimental data, regression models were obtained for the relationship between the number of trainings at the second stage and the relative coefficient of training time for successful certification of mechanics and electronics engineers.

Scientific novelty.

1. Neural model of express diagnostics of helicopter gas turbine engines.
2. Neural network model for in-depth diagnostics of gas turbine helicopter engines.
3. Organizational and methodological model of practice-oriented training of personnel for aircraft repair enterprises on the “Digital Twin” platform.
4. Model for forecasting the time costs for repair of helicopter units in the “Digital Twin” technological environment.
5. Regression model for assessing the results of certification of mechanics and electronics specialists in an aircraft repair enterprise.

The object of the study is the process of maintenance and repair of helicopter engines.

The subject of the research is to increase the reliability of the control process in the maintenance system of helicopter engines based on digital twins and neural technologies.

Scientific novelty.

1. Neural model of express diagnostics of helicopter gas turbine engines.
2. Neural network model for in-depth diagnostics of gas turbine helicopter engines.
3. Organizational and methodological model of practice-oriented training of personnel for aircraft repair enterprises on the “Digital Twin” platform.
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5. Regression model for assessing the results of certification of mechanics and electronics specialists in an aircraft repair enterprise.

The practical value of the work lies in the fact that the conclusions and recommendations can be widely used in aircraft repair enterprises.

Testing the work. The materials of the dissertation were presented and discussed at scientific seminars. All the results of the research and experiments were reflected in the articles of the publication, the list of which was approved by the Control and Control Commission of the Ministry of Health of the Republic of Kazakhstan and were tested and reviewed in the Scopus databases.

Personal contribution of the author.

1. Development of a Neural network approach for risk management in helicopter technical condition diagnostic / Eastern-European Journal of Enterprise Technologies, 2024, 6(3(132)). DOI:

0.15587/1729-4061.2024.312345 pp. 25-36. / Koshekov K., Pirmanov I., Kenbeilova S., Togambayev R., Toiganbayev B.

The formulation of this problem, the formulation of the main tasks, the search for ways to solve this problem, the development of mathematical methods and models, the main scientific and practical results presented in the dissertation, their analysis, and the formation of conclusions were carried out personally by the author of the dissertation.

2. Digital twins technology in the educational process of the aviation equipment repair / Indonesian Journal of Electrical Engineering and Computer Science Vol. 32, No. 2, November 2023, pp. 752~762 ISSN: 2502-4752, DOI: 10.11591/ijeecs.v32.i2.pp. 752-762 / Koshekov K., Pirmanov I., Alibekkyzy K., Belginova S., Karymsakova I., Karmenova M., Baidildina A.

The formulation of this problem, the formulation of the main tasks, the search for ways to solve this problem, the development of mathematical methods and models, the main scientific and practical results presented in the dissertation, their analysis, and the formation of conclusions were carried out personally by the author of the dissertation.

3. The experience of introducing Digital Twins into the educational process on the example of training in the repair of aircraft equipment units / Journal of Theoretical and Applied Information Technology 30th June 2023. Vol.101. No 12, pp. 5123~5134 ISSN: 1992-8645 E-ISSN: 1817-3195 / Ainakulov Zh., Koshekov K., Astapenko N., Pirmanov I., Koshekov A.

The formulation of this problem, the formulation of the main tasks, the search for ways to solve this problem, the development of mathematical methods and models, the main scientific and practical results presented in the dissertation, their analysis, and the formation of conclusions were carried out personally by the author of the dissertation.

4. Neural model of express diagnostics quality control helicopter engines / Bulletin of the National Engineering Academy of the Republic of Kazakhstan 2024. No. 4 (94), <https://doi.org/10.47533/2024.1606-146X.013> / I. A. Pirmanov, Yu.N. Tanovitsky, K. T. Koshekov, Ya. M. Kurbanov, R.K. Togam

The doctoral student conducted the preparation and scientific research of express diagnostic tools in the technical condition monitoring system of a helicopter engine. Participated in the development of a neural model. All stages of the work - from defining problems and setting tasks to interpreting the results - were carried out under scientific supervision, with the active personal participation of the doctoral student, which testifies to her high research independence and qualifications in the field of digital twins of organizational and

technical maintenance of helicopter engines and units on a neural network platform. .

5. Implementation of Digital Twin technology in the educational process using the example of training in repairing aircraft units / Bulletin of Toraigyrov University. ISSN 2710-3420. Energy series, No. 1. 2024 MRNTI 50.05, 50.41 <https://doi.org/48081/VQFC9074> pp. 219-232 / I. A. Pirmanov, K. T. Koshekov, A. T. Baidildina, Zh. TO. Azamatova, A. T. Nurgalieva

The doctoral student conducted preparation and scientific research of practice-oriented training of personnel for aircraft repair enterprises on the “Digital Twin” technological platform . Participated in the development of Digital Twin technology and its implementation in the educational process using the example of training in the repair of aircraft units. All stages of the work - from defining problems and setting tasks to interpreting the results - were carried out under the scientific supervision, with the active personal participation of the doctoral student, which testifies to her high research independence and qualifications in the field of digital twins of organizational and technical maintenance of helicopter engines and units on a neural network platform.

6. Model of analytical platform with Digital Twins technology / student of Toraigyrov University. ISSN 2710-3420. Energy series, No. 40. 2023 MRNTI 50.05, 50.41 pp. 310-324 / I. A. Pirmanov, K. T. Koshekov, B.K. Seidakhmetov, Ya. M. Kurbanov, K. Ascaduly.

The doctoral student prepared and conducted scientific research on the structural and functional model of the first, second hidden and third neural layers, neural network modeling of in-depth diagnostics processes of gas turbine engines. Participated in the development of an analytical platform model using Digital Twins technology. All stages of the work - from defining problems and setting tasks to interpreting the results - were carried out under the scientific supervision, with the active personal participation of the doctoral student, which testifies to her high research independence and qualifications in the field of digital twins of organizational and technical maintenance of helicopter engines and units on a neural network platform.

7. Application of digital twins in the production process of aircraft repair / No. 3 (2023): "Bulletin of D. Serikbayev VKTU" automation and control DOI 10.51885/1561-4212_2023_3_145 MRNTI 50.01.85 pp. 145-153 / I.A. Pirmanov, E.E. Kuanov, K. Alibekkyzy, V.K. Tulayev, Zh.K. Azamatova, A.T. Baidildina

The doctoral student carried out preparation and implementation of experimental-stochastic modeling of helicopter unit repair processes in Digital Twin technology , and the results of a study of digital twin technology at an

aircraft repair plant were also obtained. Applied the results in the production process of aircraft repair. All stages of the work - from setting tasks to the use of digital twins in the production process of repair of aircraft equipment - were carried out under the scientific supervision, with the active personal participation of the doctoral student, which indicates her high research independence and qualifications in the field of digital twins of organizational and technical maintenance of helicopter engines and units on a neural network platform.

8. Certificate of entry of information into the state register of rights to objects protected by copyright / Methods of using digital twins in the production process of repair of aircraft equipment No. 39895 dated October 26, 2023 / Pirmanov Ildar Anuarbekovich

All stages of the work - from defining problems and setting tasks to interpreting the results - were carried out under scientific supervision, with the active personal participation of the doctoral student, which testifies to her high research independence and qualifications in the field of digital twins of organizational and technical maintenance of helicopter engines and units on a neural network platform.

Publications. On the topic of the dissertation, 8 scientific papers have been published, including 5 articles in publications, the list of which was approved by the Committee for Control and Control of Educational Institutions of the Ministry of Education and Science of the Republic of Kazakhstan for the publication of the main results of doctoral dissertations, as well as 2 articles in a journal indexed in the Scopus database with a percentile of more than 25 [2,3], a certificate of entry of information into the state register of rights to objects protected by copyright.

The structure and volume of the dissertation. The dissertation consists of an introduction, four sections, a conclusion, presented on 131 pages of computer text, includes 12 tables, 47 figures, 2 appendices, a list of references from 117 titles.

The work was carried out within the framework of the project of the Ministry of Science and Higher Education of the Republic of Kazakhstan for grant funding for 2023-2025. IRN AP19680080 "Development of a simulator complex with an engineering support system for the technical operation of military and special aviation transport equipment".