REVIEW FROM THE OFFICIAL REVIEWER

to the thesis of Pirmanov Ildar Anuarbekovich
on "Development and research of design methodology for digital training models of helicopter repair processes",
submitted for the degree of Doctor of Philosophy (Ph.D.)
in specialty D105 - Aeronautical Engineering and Technology

Item #	Criteria	Compliance with the criteria (one of the answer options should be checked)	Rationale for the position of the official reviewer
1.	The topic of the thesis (as of the date of its approval) corresponds to the areas of scientific development and/or state programs	1.1 Compliance with the priority directions of science development or state programs: 1) The thesis was carried out within the framework of a project or target program funded from the state budget (specify the name and number of the project or program) 2) The thesis was carried out within the framework of another state program (specify the name of the program) 3) The thesis corresponds to the priority direction of science development, approved by the Higher Scientific-Technical Commission under the Government of the Republic of Kazakhstan (specify direction)	The thesis corresponds to the priority direction of science "Information, telecommunications and space technologies" and research in the field of education and science, approved by the Higher Scientific and Technical Commission under the Government of Kazakhstan. Thesis work on the stated goal and solved tasks within the framework of the study, also corresponds to the areas of implementation of state programs: - MB "Digital Kazakhstan", direction "Digitalization of transport and logistics" (12.12.2017). - Message of the President of the Republic of Kazakhstan "New development opportunities in the context of the Fourth Industrial Revolution" (10.01.2018)
2.	Importance to Science	The work does/does not make a significant contribution to science, and its importance is well-discovered/unrevealed	The work of Pirmanov Ildar, makes a significant contribution to science and practice in the direction of "Aviation equipment and technology. The importance of the thesis research is well and comprehensively disclosed. The proposed new scientific approaches and obtained results in solving complex multiparameter problems are based on the system methodology.
3.	The principle of autonomy	Level of autonomy: 1) High; 2) Medium; 3) Low; 4) No autonomy	The results of scientific research presented in the thesis were obtained by the author at a high level of independence.
4.	The principle of internal unity	4.1 Rationale for the relevance of the thesis: 1) Justified; 2) Partially justified; 3) Not justified;	The relevance of the thesis is fully justified. This is explained by the fact that repair of helicopter equipment is accompanied by a number of problems: obsolescence of technology, low level of automation, high requirements for workplace safety compliance. But the most difficult is the procedure of training organization, because as a result the trainees need to assign practical and quality competences with minimum costs and maximum self-training without discontinuing the production of instructor-mentor, as well as to provide

			control of learning material assimilation taking into account the risk of actions on the repair site.
		4.2 The content of the thesis reflects the topic of the thesis: 1) Reflects; 2) Partially reflects; 3) Does not reflect	The content of the thesis fully reflects the topic of the thesis and the provisions defended. All sections and provisions of the thesis are logically and substantively interconnected.
		4.3 The goal and objectives correspond to the topic of the thesis: 1) correspond; 2) partially correspond; 3) does not correspond	The aim of the work is to develop theoretical and methodological approaches, scientific and practical recommendations on digitalization and improving the quality of theoretical knowledge and practical competencies in training based on advanced 3D-modeling and VR-virtual reality technologies on technological processes of repair of helicopter equipment. Objectives: Study of production cycles of aviation enterprises of the Republic of Kazakhstan, to identify a list of problems of the technological process of aircraft repair, requiring urgent resolution with scientific research. Study and analysis of digital tools to solve production problems to determine the basic requirements for the development of digitalization of aircraft repair enterprises. Research and analysis of computer educational technologies and the formation of a list of requirements for the effective advanced training of specialists in the production of repair of helicopter equipment. Development of the conceptual apparatus of digital modeling, classification and structure of the model, forming realistic objects or processes based on 3D-modeling technologies, VR-virtual reality and artificial intelligence, with the transfer of dynamic influences and reactions of its human perception organs. Development of scientific-applied software necessary for the practical implementation of digital training models (hereinafter - DTC) of helicopter repair. Development of a method and algorithm for calculating the assessment of practical competencies of aviation engineering training courses in VR-virtual reality environment with the level of complexity of the developed scenarios and evaluation of actions. The goal and objectives are consistent with the theme of the thesis.

		4.4 All sections and provisions of the thesis are logically interconnected: 1) fully interconnected; 2) partially interconnected; 3) no interconnection	All sections and provisions of the thesis are logically interconnected and set out in a consistent manner, in accordance with the stated objectives.
		4.5 New solutions (principles, methods) proposed by the author are argued and evaluated in comparison with known solutions: 1) there is a critical analysis; 2) partial analysis; 3) the analysis is not one's own opinions, but quotes from other authors	Research results: scientific provisions, methods and algorithms, experimental data are argued and evaluated in comparison with known solutions based on a critical analysis and analytical review of the subject area.
5.	The principle of scientific novelty	5.1 Are the scientific results and provisions new? 1) completely new; 2) partially new (25 to 75% are new); 3) not new (less than 25% are new)	Scientific results and provisions are completely new, in particular, a theoretical and methodological approach, scientific and practical recommendations on digitalization and improving the quality of theoretical knowledge and practical competencies in training based on advanced 3D-modeling and VR-virtual reality technologies on technological processes of repair of helicopter equipment were developed.
		5.2 Are the conclusions of the thesis new? 1) completely new; 2) partially new (25 to 75% are new); 3) not new (less than 25% are new)	The conclusions of the thesis are completely new. A conceptual apparatus has been developed and the areas of application of educational technologies in the aviation industry, as well as areas of training for the training of installation and repair specialists have been determined. The model and description of helicopter repair technological process operations, stages of VR-virtual reality application development have been developed. As a result of a critical analysis of digitalization tools and computer-based learning technologies offered a new conceptual approach to the classification of digital models and at the conceptual level proposed a new fourth type of model that forms realistic objects or processes based on 3D-modeling technology, VR-virtual reality and artificial intelligence, in which dynamic effects and their responses are transferred to humans through their senses - perception. The structural scheme of application of training digital models of CM-4 in the process of repair of helicopter equipment was developed. The characteristic scientific-theoretical support of the CEM of the helicopter repair process is proposed, which confirms the systematic and methodological approach to the proposed digitalization of production and improving the quality of training with the assignment of practical

			competencies at a high level.
		5.3 Technical, technological, economic or managerial solutions are new and reasonable: 1) completely new; 2) partially new (25 to 75% are new); 3) not new (less than 25% are new)	The totality of technical and technological solutions, as well as experimental results obtained in the work are completely new and justified, they allow to develop a theoretical and methodological approach, scientific and practical recommendations for digitalization and improving the quality of theoretical knowledge and practical competencies in training based on advanced 3D-modeling technology and VR-virtual reality on technological repair processes of helicopter equipment.
6.	The validity of the main conclusions	All major conclusions are/are based on scientifically solid evidence or are reasonably well founded (for qualitative research and arts and humanities degrees)	All conclusions presented in the thesis are well substantiated, which is ensured by an in-depth analysis of literary sources, internal consistency, rigor and correctness of the use of methods of solving problems, a thorough argumentation of the adopted and defended provisions of the study.
7.	The main points of the defense	The following questions must be answered on a provision-by-provision basis: 7.1 Is the provision proven? 1) Proven; 2) rather proven; 3) rather unproven; 4) not proven 7.2 Is it trivial? 1) yes; 2) no 7.3 Is it new? 1) yes; 2) no 7.4 Level for application: 1) narrow; 2) medium; 3) broad 7.5 Is it proven in the article? 1) yes; 2) no	1. All scientific statements are proven. Including methods and results of thesis research, scientific hypotheses, conclusions and conclusions are sufficiently valid and reliable. The first position presents a comprehensive approach to digitalization and improving the quality of theoretical knowledge and practical competencies on the basis of 3D-modeling and VR-virtual reality technologies on technological processes of repair of helicopter equipment. The second position, the design process of CEM in the form of VR-virtual reality application on repair of helicopter equipment with control and evaluation functions and technical regulations, including input data input in digital format, construction and processing of 3D-models of fixed parts and tools. The third provision, a mathematical model of CEM repair of helicopter equipment and design algorithm. Fourth position, scientific-theoretical and applied support of CEM of helicopter equipment repair for their research and design. Fifth position, technology of designing training complexes based on helicopter repair CEM with a database of parts, tools and units based on artificial intelligence technology, 3D modeling and VR-virtual reality to ensure practical competence with high ergonomic indicators: minimum financial costs and time involvement of instructors-mentors, independent learning, control of learning material

			with the risk of actions at the repair site. The sixth provision, the structure of "Helicopter Repair Training Complex" and software and methodological support for the design and operation of interactive training programs based on CEM. Specified provisions in the form of problem statement and its solution are given in the article in the journal, included in the Scopus database. 2. All scientific statements are not trivial. 3. All scientific statements are new. 4. All scientific statements have a broad level of applicability. 5. All scientific statements in the form of statement of the problem and its solution are proved in the articles, including in the journal included in the Scopus database.
8.	Credibility Principle Reliability of sources and information provided	8.1 Choice of methodology is justified or methodology is described in sufficient detail 1) yes; 2) no	The choice of methodology based on a systematic approach is described in sufficient detail and in full. In the text of the thesis the necessary justification is presented in full.
		8.2 The results of the thesis work were obtained using modern methods of scientific research and methods of data processing and interpretation using computer technology: 1) yes; 2) no	The author used modern methods of scientific research modeling: agent-based modeling, software-stochastic modeling, fuzzy algorithms, simulation modeling. Formal models are implemented in software applications and a computer experiment is carried out.
		8.3 Theoretical conclusions, models, identified relationships and regularities are proved and confirmed by experimental research (for the areas of training in the pedagogical sciences the results are proved on the basis of a pedagogical experiment): 1) yes; 2) no	Theoretical assumptions and conclusions, models, identified patterns are proved and confirmed. Experimental data are integrated in a computer experiment, which revealed that the structure of the digital training model and training complex allows you to effectively implement in practice the process of digital 3D-models processing and development of VR - virtual reality applications for further training and application in intelligent methods of information processing.
		8.4 Important statements are supported /partially supported /not supported by references to relevant and reliable scientific literature	Important statements are supported by references to relevant and reliable scientific literature. In particular, computer simulations revealed that consumer and producer risks are system compositions and depend to a greater extent on the ratio of the uncertainty of the measuring instrument to the uncertainty of the controlled parameter.
		8.5 Literature sources used are sufficient/insufficient for the literature review	The literature sources used are sufficient for a literature review, with the dissertator analyzing a large volume of modern scientific literature in the amount of 101 sources.

9	The principle of practical value	9.1 The thesis is of theoretical significance: 1) yes; 2) no	The thesis is of theoretical significance, as the results of the study are methods and algorithms for calculating the assessment of theoretical competencies of the aviation engineering courses in VR - virtual reality environment with the definition of the level of complexity of the developed scenarios and evaluation of the trainee's actions during the simulation.
		9.2 The thesis has practical significance and there is a high probability of application of the results in practice: 1) yes; 2) no	The thesis has practical significance, as it allows to design experimental results of building digital and automatic systems for the aviation industry and to optimize technological processes. Also provide improved workplace safety, formation of databases of repaired parts and units for labor and financial resources forecasting. Digital transformation based on the use of CEM allows you to create a universal computer-based learning technology that can effectively improve the quality of theoretical knowledge and practical competencies. The results of the study allow us to propose new effective technologies for repair of transport equipment of wide profile. Also develop decision support systems for human personnel to reduce error risks and increase attention.
		9.3 Are the suggestions for practice new? 1) completely new; 2) partially new (25 to 75% are new); 3) not new (less than 25% are new)	Suggestions for practice are completely new. Especially the structure of the digital training model of the repair process can be highlighted. Method of creating VR - virtual reality with control and evaluation functions and technical regulations. The method of designing a database of 3D-models of photorealistic quality of parts, tools and assemblies of aircraft equipment, as well as their textures for further use. The need for photorealistic quality is to reduce the influence of the human factor on the risks associated with maintenance and repair. The method of designing a database VR - virtual reality of the repair process of aviation equipment units with control and evaluation functions and technical regulations. Technology of designing and layout of hardware and software complex of interactive training programs based on 3D-modeling technology and VR - virtual reality on technological processes of aircraft repair.

10.	Quality of writing and design	Quality of academic writing: 1) high; 2) average; 3) below average; 4) low.	The quality of academic writing is high.

Comments and suggestions:

The results of the research are undoubtedly of theoretical and practical interest, at the same time there is a recommendation to consider issues of integration with information educational platforms of a higher level.

Conclusion

I believe that the reviewed thesis work of Pirmanov Ildar Anuarbekovich on "Development and research of design methodology for digital training models of helicopter repair processes" fully meets all the requirements for theses for the degree of Doctor of Philosophy (PhD) and its author Pirmanov I.A. deserves a petition to the Committee on Quality Assurance in Education and Science of the MES RK for awarding the degree of Doctor of Philosophy (PhD) in specialty D105 - "Aviation Engineering and Technology".

Official reviewer:
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Signature **Confirmed**

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