

REVIEW
of the dissertation by Sun Yifang
on the topic “Scientific grounds to provide lifetime of regional passenger
airplane wing structural members”
presented for the Doctor of Philosophy degree
in the field of knowledge 13 “Mechanical Engineering
in the specialty 134 “Aviation and Aerospace Technology”

Relevance of the dissertation topic.

The topic of this dissertation (thesis), which focuses on ensuring the durability of structural elements of the wing of a regional passenger aircraft, is very relevant in the field of aviation engineering. This is manifested in several key aspects.

1. Meeting the Needs of the Airline Market.

The global airline market is on an upward trend, which is driving demand for regional aircraft. As these aircraft play an increasingly important role on short- and medium-haul routes, the need for improved safety and reliability becomes paramount. The wing, being a critical load-bearing component, requires careful design and analysis of its structural elements. Research on the fitting joint between the center wing section and the outer wing section of a regional aircraft directly addresses the need for stronger and more reliable wing structures. By increasing the durability and strength of these joints, it ensures that regional aircraft can operate safely and efficiently, thus meeting market demands for improved air transportation services.

2. Overcoming Technical Obstacles in Aircraft Design.

Designing a fastening joint between the center wing section and the outer wing section is a complex and challenging problem. Different docking methods result in different force transfer patterns, which in turn significantly affect the aircraft's service life, assembly process, and overall performance. The wing root joint area, in particular, has strict requirements in terms of structural strength, durability, load transfer efficiency, and assembly coordination. The research in this thesis work to develop new methods to strengthen and extend the life of the fitting joint offers practical solutions to these technical challenges. This helps aircraft designers to optimize wing design, reducing the risk of structural failures and improving the overall quality of the aircraft structure.

3. Advances in Structural Analysis and Aircraft Design

The methods proposed in this thesis work represent a significant advance in the structural analysis and design of aircraft. An innovative approach to joint design and static strength calculation at the modeling stage, based on the calculation of stresses caused by discrete force transfer between elements, provides engineers with a new and more accurate way to evaluate and optimize joint designs. The introduction of an indirect method for calculating the stress-strain state of a fitting joint not only enriches the existing analytical tools, but also increases the efficiency of structural analysis. These methods can be integrated into the aircraft design process, leading to more efficient design iterations and, ultimately, better aircraft performance.

4. Engineering Practice and Education

The results of the study have direct implications for engineering practice. Experimental studies of the effect of extruded arc grooves, extruded ring grooves and anti-fretting paste on the fatigue life of wing panels and double shear joints provide practical recommendations for aircraft manufacturers. These methods can be implemented in the production of regional aircraft to increase the fatigue resistance of wing structures. In addition, the results of the research are used in the educational process of the National Aerospace University “Kharkiv Aviation Institute”, contributing to the training of future aviation engineers. This integration of research into practice and education helps to bridge the gap between academic research and real-world applications, contributing to the development of the aviation industry.

Assessment of the validity, reliability and novelty of the scientific results of the dissertation.

In this thesis work, the author has provided the validity and reliability of the research results on ensuring the service life of wing structural elements of a regional passenger aircraft in many aspects. The study is based on reliable principles of solid mechanics and extensive knowledge of aviation engineering. For example, the method of stress calculation based on the discrete transfer of force between elements in the joint design and strength calculation is theoretically sound, and the analysis of static strength by determining force-related curves and load distribution adds to the theoretical accuracy. A large number of experiments were conducted to verify this. In the study of the effect of extruded arc grooves on the fatigue life of wing panels with functional holes, specimens of the same material as the actual wing panels were used,

several operating conditions were set and several specimens were tested under each condition to reduce errors. The same applies to the study of extruded annular grooves.

Advanced modeling and design technologies such as CATIA and ANSYS were used. The model was given precise parameters to account for the complexity of the actual structure, and the indirect finite element analysis method was used to obtain accurate stress-strain states. The results obtained by different methods were compared. For example, the indirect method of calculating the stress-strain state is compared with the direct method to verify the accuracy of the modeling. In addition, the research results are applied in practical engineering, for example, the use of methods for extending the fatigue life of the wing in the actual design and production of aircraft, as well as in the educational process. The positive feedback from practical applications further confirms the reliability and effectiveness of the research results.

The scientific novelty of the results of the dissertation research is as follows:

1. For the first time, an effective solution for designing and calculating the static strength of a joint is proposed at the modeling stage. The method and its application are presented on the example of preliminary analysis and calculation of the design of a flange joint of a regional airplane wing center section.

2. An indirect method for calculating the stress-strain state of the fitting joint between center wing section and the outer wing section of a regional aircraft is proposed for the first time. The stress-strain state of the fitting joint was obtained by the indirect method through two finite element calculations. The results are compared with those calculated by the direct method.

3. The influence of the depth and angle of the extruded arc groove on the fatigue life of the wing panel is studied in detail by experiment and new finite element modeling methods. The results show that the extruded arc groove can increase the fatigue life of the wing panel, and the optimal depth and angle of the extruded arc groove are obtained.

4. It is proposed for the first time to increase the service life of the wing panel with functional holes by using an extruded annular groove, and it is verified by experiments.

5. For the first time, the method of extruded annular grooves combined with anti-fretting paste is proposed to extend the durability of double shear joint of wing panel. The study shows that the combination of extruded annular grooves and anti-fretting paste can improve the durability of the double shear joint of the wing panel.

Thus, the scientific problem proposed in the dissertation was successfully completed, and the applicant fully mastered the methodology of scientific activity.

Practical importance of results.

The practical value lies in the use of the research results in the educational process of the National Aerospace University “Kharkiv Aviation Institute”.

Methods of extending fatigue life of the wing have been applied in actual engineering with good results. The results obtained in the thesis work have been applied in the educational process of the National Aerospace University "Kharkov Aviation Institute" and in the process of design and production of Chinese aircraft.

Assessment of the content, completeness and compliance with the scientific integrity of the dissertation.

The content of the dissertation of the applicant Sun Yifang fully complies with the standards of higher education in the specialty 134 “Aviation and aerospace technology” for aerospace engineering and the research areas of the aerospace engineering educational program.

The results of the applicant's research indicate a high scientific level and methodological value of the work performed. The results of the author's research answer the questions posed in the article and testify to the theoretical and practical significance of the study.

After reviewing the similarity report based on the results of the dissertation text compliance check, we can conclude that Sun Yifang's dissertation is the result of the applicant's independent research and does not contain falsification, compilation, fabrication, plagiarism, or elements of borrowing. The cited ideas, results, and texts of other authors are duly cited from the relevant sources.

Language and style of presentation of results.

The thesis work is written in English. It is consistent, well-structured, easy to understand and written in technical language using scientific terminology.

The accessibility of the presentation is ensured by the use of explanations in the fragments of the work that relate to mathematical and numerical research methods.

Evaluation of the content of the dissertation.

The text of the thesis work is quite voluminous and illustrated with figures and tables. The thesis work consists of an abstract, introduction, five chapters, general conclusion, bibliography and appendix.

Chapter 1 focuses on the important wing root joint of regional aircraft. It begins by introducing the various typical fitting joint types, including multiple single joints and scalloped profiles. This is followed by an analysis of the respective B777, A320 and B787 joints, highlighting their advantages and disadvantages. Design methods are then presented, covering load transfer, root nerve location, joint order, and flexible expansion joints. The chapter concludes with key conclusions on the impact of root nerves and joint design principles.

In **Chapter 2**, the design of the frame fitting is described in detail using the example of a comb fitting joint. Initial design data such as component dimensions and material properties are defined. A calculation method based on discrete force transmission is proposed, along with specific steps. An example calculation is presented, and the results show the basic rationality of the design and areas for improvement.

Chapter 3 develops an indirect method for calculating the stress-strain state of a fitting joint. It segments and simplifies the 3D model in CATIA and performs two finite element calculations in ANSYS Workbench. Compared to the direct method, the indirect method is found to be feasible with less computational effort and faster speed. The analysis also shows that the fitting joint meets the strength requirements.

In **Chapter 4**, the effect of extruded arc grooves in wing panels with functional holes is investigated to reduce fatigue life. Through experiments and finite element modeling, it was found that these grooves can extend fatigue life. The depth and angle of the grooves have a significant impact on fatigue life, and the optimal values are determined. The findings have practical applications in engineering.

Chapter 5 proposes the use of extruded annular grooves to extend the service life of double shear joints in wing panels. Experimental studies of the effect of these grooves on wing panels with functional holes show an inverted V-shaped relationship between groove depth and durability with a maximum value of 0.26 mm. The grooves and anti-fretting paste were found to improve the durability of the double shear joints.

General Conclusions. This section summarizes the results of the study. It includes the study of joint structures of international regional aircraft, new design and calculation methods, the influence of various factors on the durability of the wing structure, and the practical application of these findings in engineering and education.

The dissertation was prepared in accordance with the Order of the Ministry of Education and Science of Ukraine of January 12, 2017, No. 40 “On Approval of the Requirements for the Dissertation Works”.

Publication of the results of the dissertation work.

At the time of graduation in 2025, Sun Yifang published eight scientific works, including: four articles in Ukrainian specialized scientific journals, three articles in Scopus-indexed journals (Q1-Q3), one technical report presented at a scientific and technical conference. All results presented in the documents were obtained by Sun Yifang independently. The publications reflect his active participation in the research topic and his contribution to the improvement of aerospace structure design methodologies and durability optimization.

The scientific publications of the applicant contain a description of the scientific research conducted within the framework of the dissertation research, the essence of the problem, analysis of research methods and results, and reasonable conclusions. No violations of the principles of academic integrity were found in the applicant's scientific publications, and the conclusions are original.

Thus, the scientific results presented in the dissertation are fully covered in the applicant's scientific publications.

Disadvantages and overall assessment of the dissertation.

1. The simulation results show that the extruded arc groove can improve the fatigue life of the wing panel. Chapter 4 describes the optimization of the angle of the extruded arc groove. However, the optimization problem was not solved in a mathematical sense. Modeling and parameter selection were performed. It would be interesting to still solve the optimization problem, e.g., by methods of nonlinear programming or optimal control, and compare with simulation results.

2. In the thesis, the fatigue life of a wing panel with consideration of a crack is investigated. However, the conditions of crack initiation are not formulated and its further behavior is not analyzed. It is also not specified whether the crack is a single crack or a system of cracks may appear in the structure under realistic operating conditions.

3. Many comparisons of simulation results with experimental data are given in the dissertation. It was necessary to describe the methods of processing the experimental results, as well as how their accuracy was controlled.

Sun Yifang's dissertation is a completed scientific research that makes a significant contribution to the development of aviation technology. The work meets the requirements for awarding the degree of Doctor of Philosophy. The proposed methods are of high scientific value and practical applicability. The comments made do not affect the positive assessment of the dissertation.

Conclusion.

I believe that the dissertation of the candidate for the degree of Doctor of Philosophy Sun Yifang “Scientific grounds to provide lifetime of regional passenger airplane wing structural members” is performed at a high scientific level, does not violate the principles of academic integrity and is a complete scientific research, the set of theoretical and practical results of which solves a scientific problem of significant importance for 13 Mechanical Engineering. The dissertation fully complies with the requirements of the current legislation of Ukraine, as provided for in paragraphs 6, 7, 8 and 9 of the “Procedure for awarding the degree of Doctor of Philosophy and revocation of the decision of a one-time specialized academic council of a higher education institution, scientific institution to award the degree of Doctor of Philosophy”, approved by the Resolution of the Cabinet of Ministers of Ukraine No. 44 of January 12, 2022.

To recognize the dissertation as meeting the requirements, and the applicant Sun Yifang worthy of the degree of Doctor of Philosophy in the field of knowledge 13 “Mechanical Engineering” in the specialty 134 “Aviation and Aerospace Technology”.

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