

REPORT OF THE OFFICIAL OPPONENT

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

Relevance of the Research Topic

The topic of Sun Yifang’s dissertation is highly relevant, as enhancing the competitiveness of the aircraft industry in the global aircraft services market requires new scientific developments and the creation of innovative methods for design, engineering, manufacturing, and testing. The research presented in this dissertation is of great significance, and its scientific results are well-substantiated and reliable, this is evident from the perspective of research necessity, industry trends, and the critical importance of wing joints.

Research Necessity: The global air transportation market continues to expand steadily, leading to a sharp increase in demand for regional passenger airplane. To meet the heightened requirements for safety and reliability, it is essential to ensure the long-term performance of aircraft components. As wing structural elements endure complex loading during flight, any potential design or manufacturing deficiencies may pose a serious threat to flight safety. Therefore, in-depth studies on strength methods and the extension of service life for wing structural components are not only necessary but also timely. This research addresses existing knowledge gaps and provides crucial technical support for the development of safer and more reliable regional aircraft.

Industry Trends. The aviation industry is constantly evolving, with increasing attention being paid to the use of advanced materials and innovative design concepts. Composite materials are being used more and more in aircraft structures to reduce weight and improve fuel efficiency. However, these new materials present new challenges in the design of structural joints. Traditional joining methods may not be suitable for composite structures, which require more precise and efficient design approaches. The research presented in this dissertation aligns with these industry trends by exploring new methods for designing wing joints that are compatible with modern materials, ensuring that the advantages of advanced materials in aircraft can be realized without compromising structural integrity.

Importance of Wing Joints: The fitting joint between the wing center section and the outer wing section is a critically important component in aircraft structures. It serves as a main area for load transfer between the wing and the fuselage, and its characteristics directly affect the overall strength, durability, and safety of the aircraft. Different methods of joining these parts result in varying load transfer characteristics, which can significantly influence the aircraft's service life and the assembly process. A well-designed wing joint can efficiently distribute loads, reduce stress concentration, and enhance fatigue resistance. Therefore, research aimed at optimizing wing joint design is fundamental to improving the overall performance of regional aircraft, making it a main aspect of aircraft engineering.

The application of this study's results can lead to a more optimized joint that ensures flight safety, air-frame weight efficiency, and competitiveness of the domestic aviation industry.

Justification and Reliability of Scientific Results, Conclusions, and Recommendations

The analysis of the content of Sun Yifang's dissertation confirms the validity and reliability of the scientific principles and conclusions presented:

- The scientific principles submitted for defense, along with the conclusions and recommendations, are sufficiently substantiated and validated;
- The research is grounded in solid principles of solid mechanics and comprehensive knowledge of aircraft engineering;
- The strength and fatigue life calculations of the fitting joint between the wing center section and the outer wing section are based on classical concepts of strength of materials, elasticity theory, and finite element computer modeling;
- Numerical methods are also applied in the dissertation to analyze flange joint structures for wing panel calculations.

The reliability of the theoretical research results is supported by:

- Results of relevant experimental studies;
- Comparisons of computational models with verified sources;
- A substantial body of information presented in mathematical expressions, figures, and tables, which illustrate and support the dissertation's principles;
- Implementation of the research results in the educational process at the National Aerospace University "Kharkiv Aviation Institute".

For instance, the stress calculation method, based on the discrete transfer of force between elements in the joint structure and strength analysis, is theoretically sound, the static strength analysis through curve definitions related to force and load distribution enhances theoretical accuracy. When studying the effect of extruded arc grooves on the fatigue life of wing panels with functional holes, samples were made from the same material as actual wing panels, multiple working conditions were established, and several samples were tested under each condition to minimize errors. The same approach was applied in the study of extruded arc grooves. Advanced modeling and design technologies such as CATIA and ANSYS were used. Results obtained by different methods were compared - for example, the indirect stress-strain state calculation method was validated against the direct method to ensure modeling accuracy. Furthermore, the research findings are applied in practical engineering, such as in real-world aircraft design and manufacturing, particularly in methods for extending the fatigue life of wings, and in educational programs. The positive feedback from practical applications further confirms the reliability and effectiveness of the study's results.

The following are considered new scientific results of the dissertation:

1. For the first time, an effective solution for the design and static strength calculation of the fitting joint in the modeling stage is proposed. The method and its application are introduced by taking the preliminary analysis and design calculation of the flange connection design of the center wing section of a regional aircraft as an example..
2. For the first time, an indirect method for calculating the stress-strain state of the fitting joint between the center wing section and the outer wing section of a regional aircraft is proposed. The indirect method obtains the stress-strain state of the fitting joint through two finite element calculations. The results are consistent with those calculated by direct method.
3. For the first time, an increase in the service life of a wing panel with functional holes is proposed through the use of an extruded arc groove. The effect of the depth and angle of the extruded arc groove on the fatigue life of the wing panel has been thoroughly investigated both experimentally and through finite element modeling. The results show that a rational choice of the depth of the extruded arc groove can enhance the durability of the wing panel.
4. For the first time, a method of the extruded arc grooves in combination with anti-fretting paste to extend the fatigue life of the double shear joint of the wing panel

is proposed. The study shows that the combination of the extruded arc grooves and anti-fretting paste can improve the fatigue life of the double shear joint of the wing panel.

Thus, the scientific task proposed in the dissertation has been successfully accomplished, and the applicant has fully mastered the methodology of scientific research.

Assessment of the content, completeness, and compliance with academic integrity of the dissertation

The content of the dissertation by the applicant Sun Yifang fully complies with the higher education standards in the field of knowledge 134 Aerospace Engineering and aligns with the research areas of the educational program in aerospace engineering.

The research results demonstrate a high scientific level and methodological value of the work carried out. The findings of the author's study provide answers to the questions posed in the thesis and confirm the theoretical and practical significance of the research.

Upon reviewing the similarity report resulting from the plagiarism check of the dissertation text, it can be concluded that Sun Yifang's dissertation is the result of the applicant's independent research and does not contain falsification, compilation, fabrication, plagiarism, or any elements of unauthorized borrowing. Ideas, results, and texts of other authors are properly cited and referenced from relevant sources.

Language and Style of Presentation of the Results

The dissertation is written in English. It is coherent, well-structured, easy to understand, and presented in a technical style using appropriate scientific terminology. The text of the dissertation is sufficiently voluminous and is supplemented with illustrations and tables. The dissertation consists of an abstract, an introduction, five chapters, a general conclusion, a list of references, and an appendix.

Chapter 1: This chapter focuses on the critical root joint of regional aircraft wings. It begins with an overview of various typical types of fitting joints, including multiple single joints and comb-type profiles. The chapter presents an analysis of relevant joints in the B777, A320, and B787, highlighting their advantages and disadvantages. Design methods are introduced, covering load transfer, root rib placement, joint sequence, and flexible compensators. The chapter concludes with main findings on the influence of root ribs and principles of joint design.

Chapter 2: Using a comb-type fitting joint of the frame as an example, this chapter details the structural design of the fitting joint. Initial calculation data such as component dimensions and material properties are specified. A calculation method based on the discrete force transfer principle is proposed, along with concrete steps. A sample calculation is presented, and the results demonstrate the fundamental rationality of the design and areas for improvement.

Chapter 3: This chapter develops an indirect method for calculating the stress-strain state of the fitting joint. A segmented and simplified 3D model is created in CATIA, followed by finite element analysis in ANSYS. Compared to the direct method, the indirect method proves feasible, requiring less computational effort and delivering faster results. The analysis also shows that the fitting joint meets strength requirements.

Chapter 4: Dedicated to the issue of fatigue life reduction in wing panels with functional holes, this chapter investigates the effect of extruded arc grooves. Experimental and finite element modeling revealed that these grooves can extend fatigue life. The depth and angle of the grooves significantly affect fatigue life, and optimal values are identified. The findings have practical applications in engineering.

Chapter 5: This chapter proposes the use of extruded arc grooves to extend the service life of double-shear joints in wing panels. Experimental researchers on the effect of these grooves on panels with functional holes show an inverted V-shaped relationship between groove depth and fatigue life, with a maximum at 0.26 mm. It is established that both the grooves and anti-fretting paste enhance the durability of double-shear joints.

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

The dissertation has been prepared in accordance with the Order of the Ministry of Education and Science of Ukraine dated January 12, 2017, No. 40 "On Approval of Requirements for the Preparation of Dissertations."

Completeness of the Presentation of Research Results in Published Works

By the time of graduation in 2025, Sun Yifang had published 8 scientific works, including: 4 articles in Ukrainian specialized scientific journals, 3 articles in Scopus - indexed journals (Q1–Q3), and 1 technical report presented at a scientific and technical conference. All the results presented in these publications were obtained by

Sun Yifang independently. These publications reflect his active involvement in the research topic and his contribution to the advancement of aerospace structural design methodologies and durability optimization.

The applicant's scientific publications include a description of the research conducted within the framework of the dissertation, the essence of the problem, analysis of the methods and results, and well-founded conclusions. No violations of academic integrity have been identified in the applicant's scientific publications, and the conclusions presented are original.

Therefore, the scientific results outlined in the dissertation are fully represented in the applicant's published works.

Remarks on the Dissertation

1. The subheadings in Chapters 2 and 4 are very brief and do not adequately reflect the content described in these chapters.

2. In Chapter 3 of the dissertation, simplified indirect and direct methods for calculating the stress-strain state of the fitting joint are proposed, and their results are shown to be in good agreement. However, there is no quantitative assessment of the reduction in computation volume or acceleration achieved through the use of the indirect method.

3. In Figure 4.19 (page 129), graphs show the relationship between fatigue life and the given groove extrusion depth. It would be helpful to have an explanation of why, as the maximum load σ_{\max} increases, the dependency of fatigue life on groove depth decreases, and why this relationship becomes almost linear at $\sigma_{\max} = 150$ MPa?

In my opinion, the comments provided are not critical and do not diminish the overall scientific novelty or practical significance of the results, and they do not affect the positive assessment of the dissertation work.

General Conclusion

I consider that the dissertation of the applicant for the Doctor of Philosophy degree, Sun Yifang, titled "Scientific Grounds to Provide Lifetime of Regional Passenger Airplane Wing Structural Members", has been completed at a high scientific level, does not violate the principles of academic integrity, and represents a comprehensive scientific study, the set of theoretical and practical results of which solves a scientific problem of significant importance for the field of 13 Mechanical Engineering. The dissertation, in terms of its relevance, practical value, and scientific novelty, fully meets the requirements of the current legislation of Ukraine, as stipulated by paragraphs 6–9 of the "Procedure for Awarding the Doctor of

Philosophy Degree and Revoking the Decision of a One-Time Specialized Academic Council of a Higher Education Institution or Scientific Institution on the Awarding of the Doctor of Philosophy Degree”, approved by Resolution No. 44 of the Cabinet of Ministers of Ukraine dated January 12, 2022.

The applicant, Sun Yifang, deserves to be awarded the Doctor of Philosophy degree in the field of knowledge 13 Mechanical Engineering, specialty 134 Aviation and aerospace technology.

Official Opponent:

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