

REVIEW

on the dissertation paper of Mr. Sun Yifang with following topic:
“SCIENTIFIC GROUNDS TO PROVIDE LIFETIME OF REGIONAL
PASSENGER AIRPLANE WING STRUCTURAL MEMBERS”,

which is applied for the Doctor of Philosophy degree in the field of knowledge 13
Mechanical engineering and in the specialty 134 Aerospace Engineering

Relevance of the Dissertation Topic.

The global air transport market shows a steady growth trend, which leads to an increase in the demand for regional aircraft. Ukraine is one of the few countries in the world that has industrial and scientific and technological potential and a complete production cycle for the creation and manufacture of modern aviation equipment. The fitting joint design of the center wing section and the outer wing section is one of the important links in aircraft design. Different docking methods have different force transmission methods, which will have a significant impact on the service life and assembly process of the aircraft. Foreign countries have accumulated a lot of experience in aircraft design. By analyzing the docking forms and structural characteristics between the center wing section and the outer wing section of foreign aircraft, it has important reference significance for my country's aircraft design research. In addition, the wing root connection area of regional aircraft is a key part of the load exchange balance between the wing and the fuselage. Thus, the relevance of the dissertation topic “Scientific grounds to provide lifetime of regional passenger airplane wing structural members”, is no doubt.

Evaluation of the Validity of Scientific Results of the Dissertation, their Reliability and Novelty.

The scientific novelty of the dissertation research results are following:

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. 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 experimental and new finite element simulation methods. The results show that the extruded arc groove can improve the fatigue life of the wing panel and the optimal extruded arc groove depth and angle are obtained.

4. For the first time, the extruded annular groove is proposed to extend the fatigue life of the wing panel with functional holes, and it is verified by experiments.

5. For the first time, a method of the extruded annular 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 annular grooves and anti-fretting paste can improve the fatigue life of the double shear joint of the wing panel.

All the main results that constitute the essence of the dissertation work were obtained by the author himself. Together with the scientific supervisor, the tasks were formulated, the main results were analyzed and interpreted, and the scientific conclusions were formulated. In the co-authored report, the applicant proposed to develop a new method to ensure the specific resource characteristics of structural elements and study its effectiveness, considering the consideration of fretting coatings on the contact surface to reduce or eliminate the influence of fretting corrosion. In the co-authored articles, the applicant used the CAD/CAM/CAE system to create an assembly joint model and used the ANSYS system to analyze the characteristics of its stress-strain state using the finite element method. The author's personal contribution was to create a three-dimensional model of the fitting joint and perform finite element analysis. According to the results of the stress-strain state analysis, the force distribution of the four rows of bolts was obtained by calculating the average stress of the cross section between the bolts. In the co-authored article, the applicant studied in detail the effect of the extruded arc groove on the fatigue life of the wing wall panel with functional holes. The author's personal contribution was to calculate the optimal depth and angle of the extruded arc groove through finite element

simulation. In the co-authored article, the applicant proposed an effective method to solve the design, quality and static strength calculation of the joint in the modelling stage. The author's personal contribution is to simplify the connection joint by segments. In the personal article, the influence of interference on the mechanical properties of the bolted wing bolt connection structure can significantly improve the stress distribution of the hole edge structure and reduce stress concentration. In the co-authored article, the applicant verified the effect of extruded annular groove on the fatigue life of the perforated wing panel through experiments. The author's personal contribution is to develop the test plan and implement the test. In the co-authored article, the applicant studied the performance of z-pin and rivet reinforced composite T-joints through experiments and finite element simulations, and compared the reinforcement effects of z-pin and rivets.

The subject of the dissertation work is directly related to the implementation of the state budget subject No. DR 0113U001047 “Methods of creating advanced aircraft designs for 20 local airlines using information technologies” and No. DR 0118U004041 “Methods of integrated design, construction and modeling of efficient aviation equipment using modern CAD\CAM\CAE systems”, which are agreed upon in accordance with the Order of the Cabinet of Ministers of Ukraine of December 27, 2008 No. 1656-p “On approval of the development strategy” and implementation of the strategy for the development of the domestic aviation industry until 2024. This dissertation work is supported by the National Scholarship Council of China (No. 201908360296).

The main contents and results of the thesis work are carried out at the seminar of the Department of Aircraft and Helicopter Design of the Aerospace University "Kharkov Aviation Institute" (2019 – 2025).

Thus, the **goal** of this research subject is to develop a method for strength design and fatigue life extension of the fitting joint between the center wing section and the outer wing section of a regional aircraft to increase the service life of new domestic regional aircraft.

This purpose has been fully accomplished, and the candidate has extensively acquired the methodology of scientific research throughout the dissertation work.

Evaluation of the Practical Significance of the Research Results of the Dissertation.

The practical significance of the research results of the dissertation are the following:

1. The design type, method and principle of the fitting joint between the center wing section and the outer wing section of international regional aircraft are investigated, the difficulty analysis of the root connection design of the regional aircraft wing, the load transfer characteristics analysis, the root rib arrangement method and its characteristics analysis, and the comparative analysis of different root fitting joint design schemes are given, and a flexible compensation design method for alleviating structural assembly stress is proposed, and the feasibility of the relevant flexible compensation design method is verified by experimental results.

2. For the first time, an effective solution for joint design, quality and static strength calculation method in the modelling stage are 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. The method is based on the calculation of stress caused by the discreteness of force transmission between units. The calculation method obtains a simplified hyperstatic joint model based on the geometric characteristics and force transmission characteristics of the cross section at each node in the flange connection design. During the calculation process, the following are determined: the curves of bending moment and axial force obtained by the force method, and the force load distribution of each part of the model, in order to further analyze the static strength reserve. The calculation results obtained are compared with the requirements of the airworthiness standards to determine whether they meet the design requirements. For components with large static strength or that do not meet the requirements, it is recommended to change the design parameters additionally to ensure the effective design of the connection between the center plane and the aircraft wing and subsequent recalculation. The calculation method has practical value as a preliminary engineering analysis.

3. 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 is proposed. This indirect method obtains the stress-strain state of the fitting joint through two finite element

calculations. In order to prove the validity of the calculation results, the stress-strain state results calculated by the indirect method are compared with those calculated by the direct method. The results show that the calculation results of the indirect method are consistent with those of the direct method. Therefore, the indirect method is a very feasible method for obtaining the stress-strain state of the fitting joint. Compared with the direct method, the indirect method has the advantages of small calculation amount and fast calculation speed.

4. The influence of the depth and angle of the extruded arc groove on the fatigue life of the wing panel with functional holes is studied by experimental and finite element simulation methods. The study shows that for wing panel with functional holes, the extruded arc groove can extend their fatigue life. This is because the residual stress generated after the extrusion process offsets the effect of part of the load to reduce the characteristic stress. The fatigue life of the wing panel with functional holes is affected by the depth of the extruded arc groove. When the depth is 0~0.15 mm, the fatigue life is not extended much; when the depth is 0.15~0.3 mm, the fatigue life is greatly extended; when the depth is greater than 0.3 mm, the fatigue life is extended slowly. The fatigue life of the wing panel with functional holes is also affected by the angle of the extruded arc groove. The fatigue life increases with the increase of the angle until the optimal angle is 120 °. The use of the optimal extended arc groove can extend the fatigue life of the studied wing panel by more than 2.34 times.

5. The effect of extruded annular groove on the fatigue life of the wing panel with functional holes is studied by experimental methods. The study shows that for aircraft wing panels with functional holes, the extruded annular grooves around the functional holes can extend the fatigue life of the wing panels with functional holes. The depth of the extruded annular groove has an effect on the fatigue life of the aircraft wing panel with functional holes. With the increase of the depth of the extruded annular groove, the fatigue life of the wing panel changes in an inverted "V" shape. When the groove depth is 0.26 mm, the fatigue life of the aircraft wing panel with functional holes is the longest, which can be increased by 2.35~32.9 times.

6. The effect of extruded annular groove and anti-fretting paste on the fatigue life of the double shear joint of the wing panel is studied by experimental methods. The study

shows that the extruded annular groove can increase the fatigue life of the double shear joint. The fatigue life of the double shear joint with the extruded annular groove is about 2.28 times that of the double shear joint without the extruded annular groove. Anti-fretting paste can increase the fatigue life of the double shear joint. The fatigue life of the double shear joint coated with anti-fretting paste is about 1.28 times that of the double shear joint without anti-fretting paste.

The extruded arc grooves, the extruded annular grooves, application of anti-fretting paste, these 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.

Evaluation of the Dissertation Content, Its Completeness, and Adherence to the Principles of Academic Integrity.

The dissertation consists of an abstract, a list of abbreviations, an introduction, 5 chapters, conclusions and appendices. The total volume of the dissertation is 182 pages, of which 137 pages are the main text. The dissertation contains 106 figures, 14 tables, references to 71 references and three appendices.

In the **first** chapter the problems of structural analysis of fitting joint between the center wing section and the outer wing section of a regional aircraft was formulated and review of existing papers was analyzed.

In the **second** chapter the method of fitting joint structure designing accounting for strength and fatigue life requirements was suggested and implemented to airplane structure.

In the **third** chapter the finite element analysis method for stress-strain state of developed fitting joint was realized for verification of suggested design procedure.

In the **fourth** chapter the method for fatigue life extension of wing panels with functional extruded arc grooves was implemented. Results of experimental fatigue life test were considered and compared with theoretically predicted.

In the **fifth** chapter the method for extending fatigue life of double shear joint in wing was suggested and implemented for airplane structure.

The author's personal contribution to the research directions is to create a three-

dimensional model of the fitting joint and perform finite element analysis, calculate the optimal depth and angle of the extruded arc groove through finite element simulation, simplify the connection joint by segments, develop the test plan and implement the test and is no doubt. According to the report on the originality of the dissertation paper, the level of plagiarism in this paper according to UNICHECK software is 6.6%, moreover, this index includes references to articles published by the author of the dissertation paper. Thus, based on the report, it can be concluded that Sun Yifang's dissertation is the result of independent research and does not contain elements of falsification, compilation, fabrication, plagiarism or borrowing. The ideas, results and texts of other authors presented in the dissertation work have appropriate links to sources.

Undoubtedly, the dissertation paper of candidate Sun Yifang fully complies with the Standard of Higher Education in specialty 134 Aerospace Engineering and corresponds to the areas of scientific research in accordance with the relevant educational program. The presented dissertation work was completed at a high scientific level and is a fully completed scientific work.

Language and Style of Presenting the Results.

The dissertation paper was written in English and presented consistently, in a scientific style, using generally accepted terminology. The dissertation material, description and mathematical calculations are laid out consistently, logically and in an accessible form. For all abbreviations that are not generally accepted or little-known, transcriptions are provided at the first mention in the text.

The dissertation adheres to the requirements outlined in the order of the Ministry of Education and Science of Ukraine dated January 12, 2017, No. 40, “On Approval of the Requirements for the Dissertation Formatting”.

Approbation and Publication of Dissertation Results.

The candidate has covered the results of his research in 8 scientific papers.

A part of the scientific provisions and results of the dissertation were reported and discussed at international and national scientific conferences: “Problems of creation and ensuring of aviation objects lifetime”: materials of International Scientific and Engineering conference (Kharkiv, Ukraine, 2020).

The author has published a total of 7 scientific articles and 1 theses of the conferences, including: 2 – in publications belonging to the Science Citation Index Q1–Q2 (the Scopus database); 1 – in publications belonging to the international scientometric database, Scopus (Q3 the Scopus database); 4 – in publications belonging to the scientific professional publications of Ukraine (Ukraine category B); 1 publication – in the materials of international conferences (Indexed by Copernicus, WorldCat, Ulrich's Periodicals Directory and Google Scholar).

Disadvantages and Suggestions to the Dissertation Paper.

Among the disadvantages and suggestions, the following should be noted:

1. Efficient design methods are needed to consider the influence of both mechanical loading and the thermal field. Unfortunately, the influence of the thermal field was not considered.
2. The influence of fasteners diameter on fatigue life of lap joints is also interesting. Only one diameter of fasteners was considered. It is recommended to study it in future research.
3. In the fourth chapter it is claimed the research of a panel joint, but only representative strip joint is analyzed. The influence of neighboring rows is not considered.

Conclusion on the Dissertation Paper.

The dissertation paper of the candidate for the scientific degree of Doctor of Philosophy Sun Yifang on the topic “SCIENTIFIC GROUNDS TO PROVIDE LIFETIME OF REGIONAL PASSENGER AIRPLANE WING STRUCTURAL MEMBERS” is a fully completed work at a high scientific level. The candidate adhered to the principles of academic integrity. The presented dissertation work is a comprehensive scientific study that solves a research problem that is important for the field of Knowledge 13 Mechanical Engineering. The dissertation work is relevance, practical value, and scientific novelty, fully meeting the requirements of the current legislation of Ukraine as outlined in paragraphs 6-9 of the “Procedure for awarding the degree of Doctor of Philosophy and revoking the decision of a one-time specialized academic council of a higher education institution, research institution, on awarding the degree of Doctor of Philosophy”, approved by the Resolution of the Cabinet of Ministers

of Ukraine on January 12, 2022, No. 44.

The candidate Sun Yifang deserves to be awarded the degree of Doctor of Philosophy in the field of Knowledge 13 Mechanical Engineering, in the specialty 134 Aerospace Engineering.

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