dr hab. inż. Ireneusz Wróbel, prof. UBB

Katedra Podstaw Budowy Maszyn

Wydział Budowy Maszyn i Informatyki

Uniwersytet Bielsko-Bialski

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REVIEW

dissertation M.Sc. Ramesha Kumpati

Optimization method for ultralight aerial composite structures

thesis supervisor: dr hab. inż. Wojciech Skarka, prof. PŚ

The review was prepared based on the order of the Chairperson of the Board of the Scientific Discipline of Mechanical Engineering at the Silesian University of Technology, Prof. Dr. Alicja Piasecka-Belkhayat, dated 23-10-2024.

1. Introduction, formal presentation of the dissertation

The dissertation is written on 173 A4 typewritten pages and consists of eight chapters, bibliography, list of figures and tables, list of abbreviations and designations. The topic of the thesis concerns the design of unmanned aerial vehicles and, in particular, the subject of the development of laminated composite structures considering different design criteria for each composite layer. Traditional design methods, often based on heuristic approaches, do not always lead to optimal solutions. This dissertation proposes advanced analysis and design methods to automate and optimize the process, while ensuring continuous improvement to effectively meet operational requirements.

During the course of the work, optimisation methods based on classical laminate theory were used to determine the most efficient lay-up sequence. This allowed better performance of the structure while significantly reducing its weight. This weight reduction plays a key role in improving the endurance of UAVs and reducing fuel consumption, as lighter structures require less energy during flight.

The first chapter provides an introduction to the scientific issues addressed in the dissertation, presents the current state of knowledge in the field and discusses the author's publications that served as the basis for the dissertation.

Chapter two is devoted to a literature review, discussing the current state of knowledge related to the topic of the dissertation. It includes a description of the fundamentals of buckling analysis, a review of the literature on biocomposites and classical laminate theory.

Chapter three focuses on the optimisation methodology for composite structures, a key element of the dissertation. The optimisation methods and procedures used during the thesis are presented in detail.

Chapter four focuses on the analysis of two cases of composite T-joints and the optimisation of their layered core.

Chapter five presents a case study that describes the design and analysis of the wing plating of the BS17 unmanned aircraft. The chapter compares different wing skin configurations. In addition, a homogenisation approach is presented to predict the mechanical properties of the composites.

The content of chapter six is the process of manufacturing and validating biocomposites in different layering systems. Experimental validation was carried out under laboratory conditions. The results obtained can be applied to the design of unmanned aerial vehicles.

The content of chapter seven is the results of the analyses obtained during the dissertation, including: the results of the T-joint optimisation, the optimisation of the core of the composite sandwich structure, the optimisation strategy of the BS17 UAV wing skin, the buckling analysis, the fibre orientation, the layering sequence and the structural optimisation carried out using genetic algorithms.

The content of chapter seven is the results of the analyses obtained during the dissertation, including: the results of the T-joint optimisation, the optimisation of the core of the composite sandwich structure, the optimisation strategy of the BS17 UAV wing skin, the buckling analysis, the fibre orientation, the layering sequence and the structural optimisation carried out using genetic algorithms.

2. Substantive evaluation of the work

The dissertation of Mr Ramesh Kumpati, M.Sc., deals with the optimal design of composite structures in aeronautical applications, particularly in the construction of unmanned aerial vehicles. The topics are highly relevant and timely because:

- allows the weight of the structure to be reduced, which directly leads to lower fuel consumption and operating costs, and is responsible for a lower environmental impact,
- improves aircraft performance such as speed, range and payload,
- increases the strength and reliability of the structure by enhancing its mechanical performance,
- allows the development of adaptive structural structures with variable mechanical parameters.

The aim of the study was to optimise composite structures in terms of increasing load carrying capacity and stability, with a particular focus on applications in the construction of unmanned aerial vehicles. The research focused on developing a methodology for the construction of an optimization task that maximises the efficiency of natural composite materials, while reducing the weight of the structure.

The thesis was defined as the development of an innovative optimization approach for natural composite structures that will improve strength performance and reduce weight making them suitable for use in unmanned aircraft design. I believe that the definition of the thesis is vague and unclear. It should directly define the essence of the research conducted, indicate the issues to be verified and present the conclusions to be confirmed. Consideration should have been given to posing appropriate research questions, and answers to these questions should have been included in the dissertation.

The main achievements and strengths of the dissertation include:

- the apt choice of research topic, which is a direct realisation of the demand of UAV companies,
- the suitability of the developed optimisation methodology for determining the ultralight structure for the construction of lightweight forms of unmanned aircraft was confirmed,

- a multidisciplinary approach to the problem under consideration, taking into account knowledge of mechanical engineering and materials engineering,
- the development of a methodology for optimizing the structure of the composites, which took into account the form of the layer configuration, the order in which the layers were laid and the thickness of the resulting composite,
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- specimens of composite laminates and sandwich structures were made in order to determine and evaluate their mechanical parameters from different types of resins and reinforcement materials; the respective tensile, compression and three-point bending tests of the specimens were performed; the results obtained were presented and compared,
- optimization of the layered structures was performed, changing the relevant structural parameters of the layered structure; in addition, different geometrical configurations of the layered structure core itself were investigated in three-point bending FEM analysis, evaluating the stresses and strains of the models.

3. Editorial comments

In terms of editing, the dissertation has been prepared with due care. Nevertheless, in the content of the chapters one can notice minor editorial shortcomings that do not significantly affect the substantive value of the dissertation. Several figures with illegible descriptions can be pointed out, i.e.: Fig. 10, 15,19, 20, 46, 47, 48, 55, 56, 57, 58, 59, 60. In the text, incorrect references to figures were also noted:

- on page 134, there is a reference to Figure 3 and there should be a reference to Figure 73,

- page 135 refers to figure 73 as the results of the deformation, while the indicated figure shows something completely different.

4. Critical comments

The content and substance of the doctoral thesis prompts several questions and comments of a debatable nature:

- The dissertation topics are concerned with the development of laminated composite structures considering different design criteria for each composite layer. Advanced analysis and design methods have been proposed, which are based on classical laminate theory. The classical theory of laminates, despite its very broad utility, has significant limitations and drawbacks that may make its application insufficient in some cases. Have the limitations and drawbacks of this theory been analysed as part of your dissertation? Would the use of other more advanced theories not have been more useful in the execution of the dissertation? Has the phenomenon of delamination been taken into account?
- The paper presents a number of FEM computational models prepared to perform various static-strength tests. However, the boundary conditions, i.e. how the model is supported and loaded, are not described in detail.
- The conditions and the assumptions made for the optimisation tasks carried out in the dissertation are not described in a sufficiently clear and readable manner, which makes it very difficult to understand the results obtained.
- When specimens are manually made from composites, a non-uniform structure can result due to the lack of repeatability of process parameters, differences in the precision of layering, the degree of resin saturation and the lack of a quality control system. Composites produced in this way may exhibit variability in mechanical properties. Have any measures been taken as part of the ongoing research to eliminate or at least reduce this variability?
- When specimens are manually made from composites, a non-uniform structure can result due to the lack of repeatability of process parameters, differences in the precision of layering, the degree of resin saturation and the lack of a quality control system. Composites produced in this way may exhibit variability in mechanical properties. Have any measures been taken as part of the ongoing research to eliminate or at least reduce this variability?

5. Final conclusions

M.Sc. Ramesh Kumpati's dissertation deals with the topic of composite structures for unmanned aerial vehicles considering different design criteria for each composite layer.

Following a thorough analysis of the dissertation, I find that it offers a novel approach to a significant scientific issue. The candidate demonstrates a solid theoretical foundation in mechanical engineering and exhibits the capacity to conduct rigorous scientific research. Furthermore, the PhD candidate shows a commendable understanding of the relevant literature and has effectively applied CAX systems to address the research problem.

The reviewed dissertation satisfies the statutory requirements for a doctoral thesis in technical sciences at a satisfactory level. Considering the aforementioned conclusions, I recommend that MA Ramesh Kumpati be permitted to proceed with the public defense of the dissertation.

Prof. I. Wróbel

/podpis odręczny/

*wyłączenie jawności w zakresie danych osobowych oraz ochrony prywatności osoby fizycznej na podstawie art. 5 ust. 2 ustawy z dnia 6 września 2001 r. o dostępie do informacji publicznej (tj. Dz.U. z 2016 r., poz. 1764)