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Dynamic tests of composite panels of an aircraft wing

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ABSTRACT

The paper describes the analysis of aerospace composite structures under dynamic loading. Today, it is common to use design procedures based on assumption of static loading only, and dynamic loading is rarely assumed and applied in design and certification of aerospace structures. The paper describes the application of dynamic loading for the design of aircraft structures, and the validation of the procedure on a selected structure. The goal is to verify the possibility of reducing the weight through improved design/modelling processes using dynamic loading instead of static loading. The research activity focuses on the modelling and testing of a composite panel representing a local segment of an aircraft wing section, investigating in particular the buckling behavior under dynamic loading. Finite Elements simulation tools are discussed, as well as the advantages of using a digital optical measurement system for the evaluation of the tests. The comparison of the finite element simulations with the results of the tests is presented.

1. Introduction

The paper summarizes the findings of the research done at Brno University of Technology within the Dynamics Aircraft Engineering Design and Analysis for Light Optimized Structures (DAEDALOS) project funded by the European Commission under Framework Programme 7 [1]. The project focused on the development of innovative design approaches for aircraft structures to investigate the dynamic behavior in the loading process.

Major objective of the work described in this paper was the application and validation of the procedures enabling to design aerospace structures with consideration of dynamic loading. Today's design and certification procedures of aircraft are mainly based on conservative static loading which leads to additional weight and, potentially, to a structurally unsafe aircraft. According to the current design practice, the load envelope to size aircraft structures is applied statically. Since real loads are dynamically changing, there is a significant space to develop more precise design methods and procedures. One of the objectives of the work consisted in developing techniques which can take into account dynamic loads into finite element analyses in order to investigate the structural response to dynamic loads.

The expected outputs were more precise definition of loading imposed on the aircraft structure, and reduction of added weight of structural components due to conservative design.

While several works related to static buckling of composite structures can be found, e.g. Bisagni [2], Bisagni and Cordisco [3], Meyer-Piening et al. [4], Degenhardt et al. [5] and Malis and Urik [6], there is a very limited number of works on dynamic buckling behavior of composite structures for aerospace use, e.g. Simitses [7] or Bisagni [8].

Aircraft are often subjected to abrupt movements of surrounding air in the form of a turbulence or a gust. Such a load is often a decisive factor for the structural sizing of transport aircraft. All major airworthiness codes include two sets of gust criteria based on "discrete gust" and "continuous gust" concepts. Within the presented work, only the discrete gust approach is discussed.

The proposed "DAEDALOS design process" aims to use the dynamic loads to directly define the sizing of an aircraft. A comparison of the most commonly used approach and the new approach can be seen in Fig. 1.

The paper focuses on composite panels representing local segment of an aircraft wing section. The loads used in the work are representative of typical loading imposed on aircraft wing structure during the flights, such as those deriving from discrete gusts and landing. The gust was defined in accordance with the regulation EASA CS-25.341/FAR-25.341 for large airplanes.

Design practices based on static loading represent the current approach for designing and sizing aircraft structures. On the contrary, the new design approach here discussed considers the dynamic nature of the applied loads. Attention was given to the loading speed and its influence on the buckling and load carrying capacity.

The activities described in this paper are part of the DEADALOS project and represent a continuation of Brno University of

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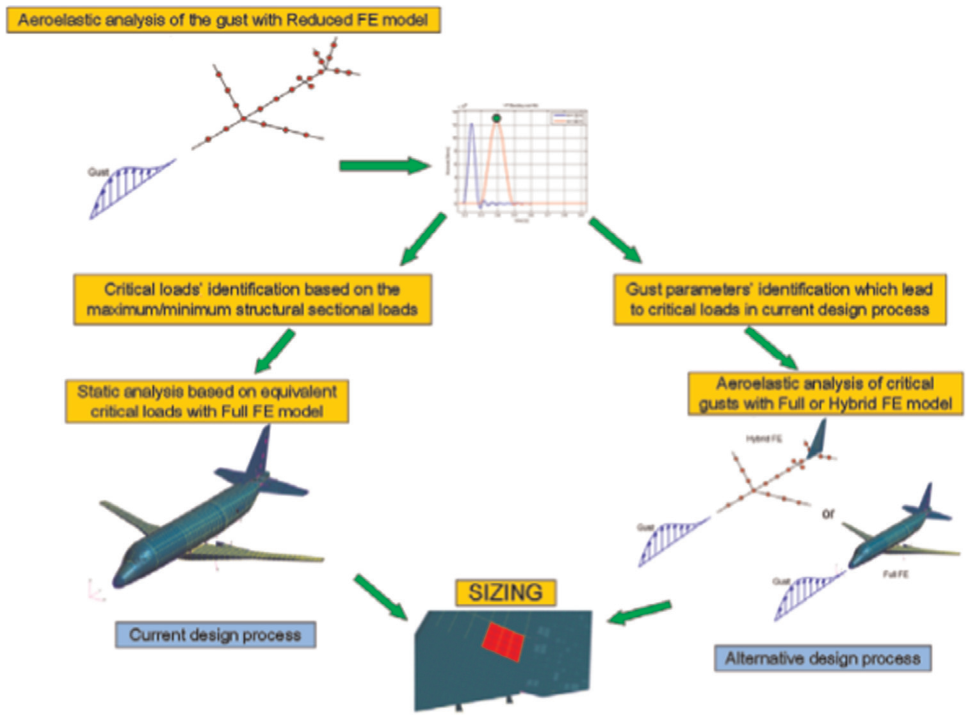

Fig. 1. New design process for gust response loads [9].

Technology (BUT) research in the field of composite aerospace structures, e.g. works of Malis and Urík [6], Symonov et al. [10] and Juracka and Lialiukhina [11].

The composite panels under investigation were manufactured using carbon-fiber composite material. The testing procedure included state-of-the-art monitoring systems, i.e. the 3D optical digital measurements system ARAMIS.

The behavior of the panels under dynamic loading was simulated using the Finite Element (FE) commercial code MSC.Patran/MSC.Dytran, while the behavior under static loading was simulated using MSC.Patran/MSC.Nastran.

The activities were focused on buckling behavior of flat panels. Imperfections were not included in the analysis, as their effect was assumed to be negligible for flat panels. Furthermore, the study was restricted to the initial buckling, while the post-buckling response of the panels was not investigated.

2. Carbon-fiber reinforced composite panel

A total of 7 composite panels were tested under static and dynamic loads at the Brno University of Technology, Institute of Aerospace Engineering. The panels were manufactured by DAEDALOS partners. In particular, AERNNOVA delivered 4 panels and LETOV delivered 3 panels.

The design of the carbon-reinforced composite panel is shown in Fig. 2. The overall dimensions of the panel were $400 \times 550\ \text{mm}^2$. Each panel was manufactured from unidirectional prepreg IM/8552. The panel skin consists of 18 plies with total thickness of 2.25 mm, while the stringers and caps consist of 11 and 13 plies, respectively.

Denoting with LB the symmetric and balanced lay-up sequence [+45/−45/0/90/0/−45/+45], the skin lay-up can be defined as [LB/0/90/90/0/LB]. The thickness of the lay-up LB is equal to 0.875 mm, while the skin has a total thickness of 2.25 mm. The

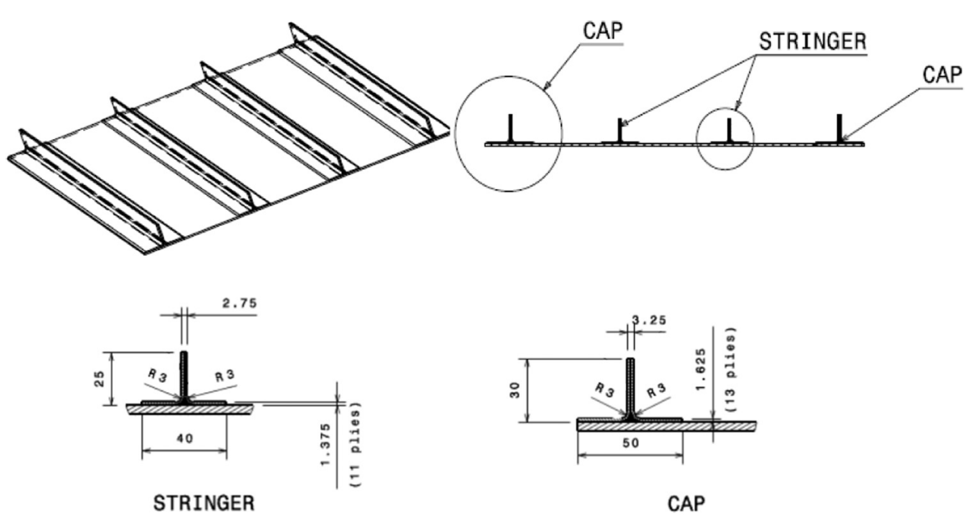

Fig. 2. Flat composite panel [12].