COMPOSITE SKIN-STIFFENER VIRTUAL TESTING

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1 Introduction

The application of composites in basic structural components (main structures of aircrafts, for instance) is still limited because of the difficulty in predicting their lifetime under service. In fact, while military aircrafts are mainly built with composite materials; civil aircrafts are still produced with metals. As the understanding of their behaviour improves; the use of composite materials in aeronautics is increasing. However, the usual methodology for the determination of reliability, which implies a large number of tests in real-size structural components, is only suitable in sectors with a large added value, -such as aeronautics- that can afford its cost. Moreover, experimental tests are not able to reproduce all the possible circumstances that a structural element will encounter during his service life (environment conditions, cyclic loads, load combination, etc.). Because of this, to increase the reliability and to decrease the development costs of complete and efficient new components, design tools are needed. These tools, once strictly verified against experimental tests, will be able to predict the behaviour of a component under service.

2 Skin-stiffener virtual testing

Design of components in the aeronautic industry relies on a 'building-block' approach, where a large number of experimental tests are performed throughout the product development process. Analyses are carried out in different geometric complexity levels. At each level, a validation of the design must be made before proceeding to a higher level. The analyses cover the range from material to actual substructures (see Fig. 1). All of these steps need a large number of tests, which significantly increase the design cost.

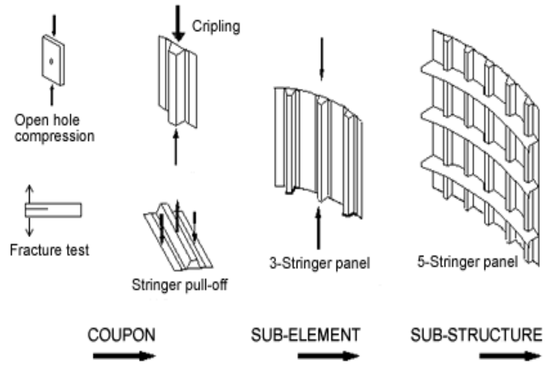

Fig. 1. Building Blocks design procedure.

Carbon fiber reinforced skin-stringer configurations are a very common structural solution used in spaceships and aircrafts. Therefore, they are the perfect element for validating the development of computational tools and structural supervision techniques.

Normally, the research ways are based on the analysis of specimens those don't represent physically real structural elements. Future acceptance of the methodology by industry and certification authorities however, requires the successful demonstration of the methodology on structural level. For this purpose a panel is selected that is reinforced with three stringers [1]. This panel is modeled and simulated in finite element software with capabilities for non-linear implicit analysis (ABAQUS). All simulations are carried out using shell elements. Using shell elements allow to reduce the computational costs counter to use solid elements [2].

The principal goal of this report is to verify the prediction capacities of the skin-stiffener panel model when different damage mechanisms are present and interact. These damage mechanisms are debonding of the stiffener, compressive failure, global instability of the element (buckling) and matrix cracking. Certainly, the models will have been parameterized to get versatility to study the skin-stiffener behaviour. Basically, the development component will be virtually tested under unidirectional compression (in the plane of the panel and according to the direction of the stiffeners).

The intralaminar damage is introduced using a user material. This damage model is based on continuum solid mechanics and fracture theory that allows to represents the intralaminar damage and its propagation [3]. On the other hand, the interlaminar damage is introduced using a user element. These elements have been developed using a damage model thermodynamically consistently based on Fracture Mechanics evolution laws. This model has produced satisfactory results for static or quasi-static loads, both for single modes (mode I, II or mixed-mode I-II) and for variable mixed mode [4]. Presently, cohesive finite elements are the best option for the numeric modeling of the delamination failure mechanism in skin stiffener joint.

Finally, after verification of the predictive capabilities of the virtual test, this will be used for the optimization of the geometry of the structural element (stiffener's width, distance between stiffeners, etc.) and laminate configuration. The objective is to avoid an unnecessary over dimensioning (overweight of the structure, excessive cost) as well as to assure a correct response of the element to the previewed loading situations. Thus, the element will be optimized according to weight, damage resistance, and damage tolerance requirements.

References

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