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Fuselage crashworthiness lower lobe dynamic test

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Abstract

The focus of this paper is to demonstrate the energy absorption capability of the lower lobe section of the aircraft, and to provide test data in support of validation of the LS-DYNA numerical model.
Following a national research program, a full scale drop test, of an airliner composite sub cargo floor fuselage, has been performed by the Italian Aerospace Research Center (CIRA) at their LISA (Laboratory for Impact testing of Structures in Aerospace field) facility.
The ultimate aims of research are design, size and evaluation of the crash behaviour of a specific concept of composite aircraft fuselage section linked to the full scale tests.
The results are based on pre-test simulations performed on coupon including representative elements devoted to the absorbption of the crash energy, and finally with the final drop test results and the corresponding post-test simulations.
Test provides validation of LS-DYNA analysis, and using the simulation tools it is possible to quantify different parameters as energy distribution, accelerations, dynamic structural efficiency, and structural deformations throughout the crash event, but above all the importance to define the real conditions of the constraints and loads in the attempt to reproduce the behaviour of the full scale aircraft fuselage, or section of it, during an emergency landing condition, partially reduced to the full scale subfloor. Then the simulation allows to develop geometries and size of the structures with stanchions and other structural elements in order to reduce the energy absorbing capabilities of the cargo subfloor.
Test data indicates the cargo subfloor can absorb an impact velocity of 22 feet/sec with typical payload, and the certification requirements about the emergency landing as satisfied. Finally, the decelerations and deformations are restricted in a survivable space for the passenger compartment.

Keywords: emergency landing; crashworthiness; drop test; fusolage lower lobe; aircraft certification.

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1. Introduction

The paper describes the research activities which are of interest to the scientific community, with specific reference to an industrial application, for the research of new configurations and materials that can be adapted on the lower lobe of an aircraft fuselage in accordance with the certification requirements. Among the sizing requirements and as a result of certification program a critical point is the emergency landing, ref. [1] and [2].

These activities are dedicated to the design, sizing and crash behaviour evaluation of a specific concept of composite aircraft fuselage demonstrator with the objective to validate FE code on a subfloor cargo composite fuselage section drop tested by CIRA.

The goal of the research program is to develop some of the technologies required to enable the introduction of composite materials into aircraft primary structures. Actually, the use of composite material in airframe component manufacturing is becoming widespread and the trend will continue. The understanding of how composite materials behave as load-carrying material is being developed continuously.

The major difficulties are derived from the introduction of the composite materials in a field where the survivability has been and will continue to be the main theme in aircraft safety, considering that the certification specifications adopted from the authorities to certify an aircraft are not ready to define a complete transfer from metallic to composite materials.

The Federal Aviation Administration, FAA, is a national aviation authority in the United States, One of FAA's major function is to define the standards regulating civil aviation. Composites are non-standard technology with limited shared databases, methods and guidelines. In past, FAA introduced the advisory circulars that present recommendations for showing compliance with specific requirements associated with composite materials, ref. [3] and [4]. These circulars are considered essential in the certification process for composite aircraft components as well as for establishing quality control provisions for material manufacturing and implementation.

This work presents the crashworthiness capabilities that a new concept of regional A/C must show under foreseeable survivable impact events, and the regulatory requirements imposed by EASA and FAA require to demonstrate the compliance to these rules by dynamic tests or analysis comparable to that achieved on previously certificated A/C of similar size, [6] and [7].

So one possibility is to examine the crashworthiness of composite structures and to develop a guidance certification analysis and test protocol for composite fuselage crashworthiness certification in order to increase the confidence and level of safety of composite components, [8]and [9].

In order to enable further implementation of composite structures in future crashworthy designs, a good way of modelling composite materials needs to be defined. Many composites exhibit energy absorption capability even during crushing, which is advantageous during a crash event, since this leads to a constant deceleration of an impacting object. This is what makes composite materials interesting in crashworthy structures, apart from the fact that composites exhibit a high stiffness-to-weight ratio. Damage in fiber reinforced polymers can occur with a combination of many failure mechanisms, such as delamination, fiber kinking, fiber pullouts and matrix crack propagation. During crushing of composites, most of these modes can be observed. There are many software using different techniques and material models for fiber reinforced polymers, consequently, the various methods need to be evaluated.

The study will be dedicated to design a three bay long section and in particular to design the cargo section and how to increase the ability of this structure to absorb energy and the level of passive safety. Finally, a preliminary prototype was designed, manufactured and tested at the experimental drop test. In this paper the numerical simulations are performed to analyze the partial fuselage (cargo section, stanchions) when it is subjected to a low velocity impact so to evaluate the impact responses of composite airframe structures, and to extend these responses up to the real condition obtained during an emergency landing. This paper provides the correlation between the experimental test at low velocity impact and the numerical analysis that are the final step of an extensive campaign of test performed on the coupon level and on model in small scale. The aim of this correlation offers multiple advantages:

- Improving the energy absorbing qualities in the event of an impact;
- Evaluation of the energy absorbing supports to distribute the contact force over a larger part of the body, so not only the lower lobe's structural elements are involved in the energy absorbing process.