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Partial modeling of aircraft fuselage during an emergency crash landing

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Abstract

During an emergency crash landing, the first requirement translates into the ability of an aeronautical structure to ensure a vital space for the occupants during an impact, and then limiting the accelerations on the occupants in terms of intensity and duration.
The aim of this study is about the impact phenomenon, that is generally not addressed to understand if and how the structure is deformed, but if the structures allocate the kinetic energy resulting from the impact and if it is completely able to participate to the absorption of impact, all for the benefit of passive safety occupants. On the basis of this consideration, therefore, it becomes much more significant for the structural designer to try to correlate the paths of energy absorption, and this is obtained studying the composite materials and polymers, and their difference in behavior compared to metallic materials, highlighting the design parameters of the same material as a function of impact behavior.
A finite element model of a typical composite fuselage was developed using the nonlinear, explicit transient dynamic code, LS-Dyna. The numerical simulations aided to evaluate the part of the structure able to absorb the energy during the impact, the results allowed to reproduce the similar scenario but on a "scaled" numerical component.
The focus of this paper is to evaluate the scaling concept and its possible incorporation into the crashworthiness evaluation of fuselage as a potential crashworthiness evaluation tool.

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Keywords: Composites material; aerospace applications; crashworthiness; dynamic loads; impact.

1. Introduction

The research carried out in the field of passive safety (crashworthiness) and the analysis about the aeronautical accidents' dynamic have allowed to develop materials and manufacturing technologies that have led to the definition

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of solutions in which the possibility of occurrence of a structural failure in a collision is reduced. Furthermore the ability of these structures to absorb energy is increased and then their level of passive safety, [1].

The fuselage must meet criteria somewhat restrictive as regards the certification since the collapse of this structure causes, in the case of non fatal impacts, an increase of the risks to the passengers due to both the possibility of collisions with objects that the possibility of being trapped, [6]-[9].

The regulations require that the structure, containing the passengers, be subjected to the drop tests without showing cracks or deformations such as to be harmful or too high, [10]-[12].

An aircraft designed for impact must meet a number of requirements; in particular the passenger area and the safety of themselves must not be compromised and the structural components are able to dissipate the kinetic energy of the aircraft, maintaining the level of deceleration below a tolerable limit. In most aircraft structures designed to support the high loads encountered during the various types of accidents are often designed as thin-walled components of metallic material or composite material, [4].

In the case of conventional metallic materials the plastic collapse of structures subjected to impact phenomena is very important because the two most important forms of collapse, involved in energy dissipation during the impact, are represented by the collapse flexural and axial collapse. In situations of impact loading, in fact, the structure for energy absorption is loaded beyond its capacity of elastic resistance giving rise to the collapse of the same in localized areas with shapes or controlled processes; for example it can dissipate the kinetic energy with remarkable efficiency using the hinges in the joint areas, where, after impact, it has a plastic deformation. On the other hand a structure in composite material, made with carbon fibers immersed in an epoxy matrix, is not characterized by a plastic deformation. Initially, in this case, the stress is transmitted from the point of impact to the whole structure so that the energy can be absorbed with a high total load without permanent damage. Only when the load in the contact zone exceeds the absolute resistance of the laminate, the break in that area becomes total and the laminate tends to crumble progressively. The failure of composites ensures that they do not exceed the yield strength of processes characteristic of ductile metals, but the application of the load will deform elastically up to the point of fracture.

The department is involved in the study of preliminary design of a fuselage section in composite material. The study will be dedicated to design a five 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 will be subjected to the experimental drop test. In this paper the numerical simulation are performed to analyze the partial fuselage (cargo section, stanchions) when it is subjected to a 15 [m/s] vertical drop test to evaluate the impact responses of composite airframe structures, and to evaluate the capabilities of the explicit transient dynamic finite element code, LS-DYNA®, to simulate these responses including damage initiation and progressive failure. The properties of the composite material were represented using both a progressive in-plane damage model (Mat 54) in LS-DYNA, [2]. This paper provides the numerical analysis and the study of the time history responses and the location and type of damage for representative section components, this method is more considered by the tools able to optimize the structure using the certification by analysis approach, [5].

2. Fuselage section model development

The model geometry was developed from technical drawings of the fuselage section. Development of the model was performed using two pre-processing software package, MSC.Patran and LS PrePost. A geometric model of the fuselage section was developed containing the important structural features of the airframe. The geometric model was discretized, and element and material properties were assigned, all parts are modeled by two-dimensional elements. A database of composite materials and metal was implemented, to allow changing in the properties of each part to optimize the absorbing of energy. It is in fact thought to analyse the behaviour of non-homogeneous structures, creating models made entirely of composite material and other mixed composite material and aluminium, in order to highlight the structural solution faster in the event of a crash. All models have in common geometry, initial and boundary conditions.

The complete finite element model of the fuselage section with cargo section and passenger floor is shown in Fig. 1. Components of the model including the outer skin, fuselage frames, floor, longitudinal stringers, cargo and stanchions elements are shown in Fig. 2