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A Numerical Study on the impact behaviour of an all-Composite Wing-box

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Abstract

In this work a numerical study on the impact behavior of an all composite wing-box is presented. The numerical analyses have been performed by means of advanced numerical models implemented in Abaqus/Explicit. The aim was to estimate the intra-laminar and inter-laminar damage behaviour in a localized area, and, by a Global-local approach, to investigate the impact influence on the overall structural behaviour. The numerical investigation of complex composite structures under several impact conditions in terms of impact position and energy can complement the experimental results potentially leading to a reduction of the experimental tests to be performed with considerable time and cost saving.

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Keywords: impact behaviour ; carbon fibre laminates ; delamination ; wing-box.

1. Introduction

The highly specific mechanical properties of composite laminates have allowed their increased usage in a number of engineering fields such as the aeronautical, railway, automotive and marine ones by replacing metal alloy structural elements. Composites application requires a deep knowledge of the response of composite components and structures to a wide range of loading conditions, some of which may be severe causing internal damages that could lead to the structural collapse [1]. In aerospace industry, in particular, impact damage in laminated composite materials continues to be of major concern. Typically both low and high velocity impacts can start complex damage mechanisms (such as delaminations and intra-laminar damages) in composites depending on the thickness of the component. Delaminations can occur for low velocity impacts, while fragmentation or perforation are likely to occur in case of high velocity impacts. The damage induced by low velocity impacts is of major concern being able to drastically reduce the loading carrying capability of the impacted structure without being clearly detectable form the surface of the laminate.

Several examples of numerical and experimental investigations on the impact induced damages on composite material specimen can be found in literature [2-12]. The experimental test is often simulated by finite element models to get additional information on the damage formation and propagation at ply level. Usually the intra-

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laminar failure is simulated by an appropriate damage criterion such as Hashin, Tsai-Wu, etc. while the delamination is modeled by means of numerical techniques such as the VCCT (Virtual Crack Closure Technique) [13-15] or the cohesive zone approach (cohesive elements or cohesive surfaces) [16-20]. In this study the inter-laminar and intra-laminar damage behavior in a limited area of a full composite wing-box have been investigated simulating a realistic impact scenario and assessing the influence of impact threat on the wing-box structural response. Delamination and fiber/matrix ruptures have been simulated through Continuum Damage Mechanics [21-24] and using a global-local approach [3-5] available in Abaqus/Explicit [24].

2. Model description

The wing-box is composed by two flat panels, two spars and four ribs. The ribs are equally spaced and present mouse-holes in order to let the pass-through of the stringers. Stringers' webs are 30 mm high while stringer foots are fully integrated within the stacking sequence of skin. The stringers, moreover, are tapered at the wing tip. The model has been created by surfaces linked by means of Multi-Point Constraints. At the wing-box root, the upper and lower skins have been reinforced with tapered doublers bonded to the skins in order to give more stiffness to the wing-box root shifting the pick of strains far from constrained extremity. The thickness variation of the doublers has been simulated splitting the geometry in five regions at which a different number of plies has been associated. In Figure 1 the distribution of shell thickness at wing-box root is schematically shown.

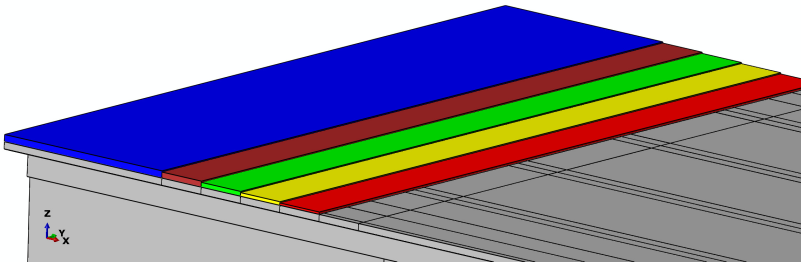

Fig. 1: Doublers thickness.

As already mentioned. the stringers have been designed as fully integrated in the skin leading to the not symmetric lay-up for each bay, presented in table 1 and Figure 2. The doublers at root location have been made of Cytec HTA fabric material system and laid-up according to the stacking sequence of $[(+45,-45,\ 0,\ 90)_3]_S$. The tapering of this component has been obtained dropping the inner plies until the design thickness was reached. The rest of wing-box has been manufactured with the Cramer carbon fabric material system and the stacking sequences used for the different components of the wing-box have been reported in Table 1 and Figure 2.

Table 1. Stacking sequence of wing-box components

skin (layup A)	[+45,-45, 0, 0,-45,+45, 90,+45, 0, 90,-45, 90,90,-45,90,0,+45,90,+45,-45,0,0,-45,+45]
skin (layup B)	[+45,-45, 0, 0,-45,+45, 90,+45, 0, 90,-45, 90,90,-45,90,0,+45,90,-45,+45,0,0,+45,-45]
stringer (layup AB)	[+45,-45, 0, 0,-45,+45, 0, 0, 0, 0, +45,-45, 0, 0,-45,+45]
stringer (layup BA)	[+45,-45, 0, 0,-45,+45, 0, 0, 0, 0, -45,+45, 0, 0,+45,-45]
spar	$[(+45,-45, 0,90)_2]_S$
rib	$[+45,-45,90, 0,90]_S$
L-shaped flange	$[+45,-45,+45,-45]_S$