NUMERICAL MODELING OF WOVEN CFRP PARTIALLY FLUID FILLED TUBES SUBJECTED TO HIGH VELOCITY IMPACT


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Summary. In this work, a numerical analysis of partially fluid-filled CFRP woven tubes impacted by a steel sphere at high velocity is made; simulations have been validated with experimental tests.

1. INTRODUCTION

Nowadays, composite materials are increasingly used in aerospace structure, due to its high strength-density ratio, which give the possibility of producing lighter aircraft structures with less fuel consumption. A critical issue in the design of composite aerospace structure is vulnerability against high-velocity impact loads [1]. Bird strikes [2] or hailstones [3] are examples of impact situations that are considered due to the high probability of occurrence and disastrous consequences. When the impact takes place in the wings, the projectile may penetrate into the fuel tank, producing the phenomenon known as Hydrodynamic Ram (HRAM). In HRAM, momentum and kinetic projectile’s energy is transferred through the fluid to the surrounding structure, increasing the risk of catastrophic failure and excessive structural damage. HRAM is particularly dangerous for aircraft with lightweight designs because the structural resistance of their integral fuel tanks cannot be improved by strengthening the airframe, since would counteract the requirements of a lightweight design. Usually, HRAM phenomenon is analyzed considering completely filled tanks; but in a real flight situation, it is more likely that the impact could happen when the tank is partially filled [4].

In this work, numerical simulations of partially fluid-filled carbon/epoxy woven laminates square tubes (150x150x750mm³) impacted by steel spherical projectile (12.5mm diameter) at different velocities (600m/s and 900m/s) and different filling levels (60% and 75%) are shown. The simulations are performed with the commercial finite element code Abaqus/Explicit using a Coupled Eulerian Lagrangian approach to reproduce the fluid-structure interaction. Woven
CFRP material model is implemented by an user subroutine VUMAT accounting fiber failure, in-plane shear failure, matrix crushing and delamination [5]. Experimental tests providing the pressure in different points of the fluid, failure of the walls and cavity evolution for different impact velocities and filling levels [6] are compared with the numerical results in order to assess the validity and accuracy of the model to reproduce such a complex phenomenon. Finally, HRAM effects of partially filled impacts will be compared with completely filled ones to analyze the effect of the layer of fluid which impacts in the upper wall of the tube, figure 1 (b). In figure 1 (a), it can be seen how this layer of fluid is raised by the projectile as it travels through the tank [4].

Figure 1. Impact at 900 m/s at 60% of filling level. Contour plot of stresses in fiber direction ($\sigma_{11}$) at (a) 50μs and (b) 600μs after the impact.

References


