Study of the Experimental Low Velocity Impact Phenomenon on Carbon Composites to Support Numerical Simulations

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Summary: *Low velocity impact tests were carried out on carbon fibre reinforced plastic laminates at complete penetration at different energy levels at the aim to investigate about the damage initiation and propagation. Some of the specimens were destined to CAI tests and the residual strength was evaluated. The laminates were fabricated by a new vacuum assisted technology labelled as "pulse infusion". All the experimental results, after analysing, were used to assist the numerical simulation. By the comparison, good agreements were found.*

1 INTRODUCTION

Composites materials, due to their non-homogeneous and anisotropic nature, when impacted, can fail in a wide variety of modes and can severely reduce the integrity of the structural components even if the visual damage is not so evident.

The different impact damages can be collected in: a) external damages, indentations with different depths and b) internal damages, like inter-laminar fractures (delaminations) caused by inter-laminar stresses, fibres cracks (in-tension fibre breakage and in-compression fibre buckling) and matrix cracks. Moreover, the interaction between failure modes assumes a primary role in understanding damage modes, initiation and propagation [1]. It is, so, very crucial but very difficult, to have a clear understanding of the impact phenomenon. A lot of efforts were done for many years [2] at the aim to investigate about the influence of the large number of parameters involved in dynamic phenomena and the very complex interaction mechanisms between the different modes of failure. A large number of experimental tests were carried out and the results widely studied but, due to the very complex response of composites to impacts, a lot of questions remain unanswered yet. Moreover, the complex interaction between the failure modes, since influenced by a variety of parameters can be hardly predicted by analytical and numerical tools [3]. The same holds for residual compression strength after impact.

Validated finite element (FE) models could be, however, an essential tool to reduce testing time and costs in the development phase, especially for impact tests on large structures which are becoming too expensive to be carried out in the development stage.

In this work, a large experimental campaign of low velocity impact tests has been carried out on composite laminates with the aim to supply useful information to develop an impact oriented design methodology. The laminates made by carbon fibres in

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polymeric matrix RTM6 have been manufactured by a new vacuum-assisted technology called pulse infusion. It is based on the use of a proper designed pressure distributor, that allows to control the pressure of the vacuum bag on the dry fiber reinforcement and induces a pulsed transverse action to promote the through thickness resin flow. Moreover, thanks to the use of a reusable pressure distributor, it is characterized by a reduction of production costs and a significant waste decrease. Unidirectional layer of dry fibres were overlapped following the stacking sequence $[(0)/(90)/(+45)/(-45)]_s$, resulting in a laminate nominal thicknesses of 2.5 mm.

The experimental tests have been carried out on a Ceast Fractovis MK4 drop machine, allowing to vary the impact energy by changing the impactor mass and the drop height. Impact tests were carried out up to the complete penetration of the coupons. The instrumented impactor was cylindrical shaped hemispherical nose, 19.8 mm in diameter. The rectangular specimens, 100x150 mm, were clamped using a clamping device suggested by the EN6038 standard. The force-time and force-displacement curves obtained by the complete penetration tests were recorded by the DAS4000 acquisition program and successively studied to evaluate the penetration energy and the variable energy values for the indentation tests. The latter allowed the study of the damage initiation and propagation. The variable energies were measured in correspondence of characteristic points of the load curves like load drops or deep changing clearly evidencing changing in material behaviour like possible damages.

The load curves recorded in all the test conditions were used to evaluate the main impact parameters involved in the phenomenon like penetration energies and maximum forces, so as the correspondent displacements. Penetration and absorbed energy, first failure and maximum force have been measured. Compression after impact tests (CAI) were carried out on some of the damaged specimens and the residual strength was evaluated.

The indentation depth was measured by bifocal microscopy whereas the internal damages was evaluated by the well known US technique allowing to have information about delamination layer by layer. Semiempirical models were validated to test the efficiency of the new infusion technology.

Results from numerical explicit FE simulations of the impact phenomena under experimental test boundary conditions have been considered in order to set some test parameters. The numerical analyses have been developed by using commercial finite element codes (ABAQUS/Expl.) and a global/local approach has been followed. Numerical results concerning impact damages are in good agreement with the experimental ones.

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