MECHANICAL PROPERTIES OF DELAMINATED COMPOSITE PLATES

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Low-velocity impact loadings can condsiderably reduce the mechanical properties of composite laminates. The changes in the compressive strength of aircraft skin-stringer panels may reach more than 50%. Three major damage types may be recognized in the damaged regions of polymer matrix composites, namely, matrix cracking, de-lamination between layers and fibre breakage.

In the present work, a theoretical characterization of micro-damage in the quasi-isotropic carbon fibre/epoxy matrix laminates is performed. An impact damaged area in a composite plate is considered to be in the form of a cylinder consisting of sublaminates separated from one another (i.e., delaminated). The elastic properties of each sublaminate may be degraded (so-called "soft sublaminate"). Such damaged area reduce the elastic constants of the lamina. The size and properties of each sublaminate control the micro-stress distribution in the damaged area and thereby the residual strength of the lamina. The sublaminates may be unbalanced and nonsymmetric, which means that the out-of-plane elastic properties of each sublaminate plays a role in the local stress redistribution during loading.

Numerical calculations using a finite element (FE) code were performed.

With the goal of comparing the numerical simulation results with experiment, a tensile and compressive testing program was realized. All the laminates observed were manufactured from a Hexcel HTA/6376C carbon/epoxy prepreg. After curing, the laminates were C-scanned to check the fabrication defects. Two different lay-ups of quasi-isotropic plates (180mmx180mm) were studied: "thin" $[(0,+45,-45,90)_s/(90,-45,+45,0)_s]$ and "thick" $[(0,+45,-45,90)_s/90,-45,+45,0)_s]_3$.

The low-velocity impact tests were conducted using a drop-weight rig. The impact energy was equal to 8 J ($M = 1.63$ kg) for the "thin" and 30 J ($M = 6.12$ kg) for the "thick" laminates. The tip radius of the steel impactor was 7.5 mm. The edges of the plates were clamped and the span to thickness ratio was 61 for thin and 20 for thick laminates. The impact damage was examined using the ultrasonic C-scanning and optical microscopy. Averaging the results, a maximal diameter of the cylinders modeling the damaged area was obtained. This parameter was used in the numerical calculations. Thereafter, the plates were cut into strips (specimens) each of 8-10mm wide. The specimens from different plates were cut in three different directions. Specimens of all orientations were cut at different distances from the impact application point. Specimen edges were carefully polished for optical observation of damage as a function of the distance from the impact point. All specimens were tested in a screw-driven Instron 1272 testing machine in tension and compression. The crosshead speed was 0.5 mm/min.

Thereafter, the specimens which had crossed the damaged area were polished changing their thickness, ply after ply, with simultaneous measuring the elastic properties. In such a way a through-the-thickness distribution was obtained. The experimental results were compared with the numerical simulation, and good agreement was obtained.