Damage characterisation in open hole composites using finite element and complementary NDE techniques

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Despite advancements in the design and manufacture of high-performance composite materials, a lack of confidence in their long-term performance remains a challenge. This can result in over-engineered design, laborious inspection, and premature replacement of components. The layered nature of composites can facilitate the permanent integration of sensors capable of diagnosing the health state of a structure. The use of such sensors to detect and monitor the presence and growth of defects and damage could lead to a reduction in downtime for inspection and increase the accuracy of lifetime predictions delivered by simulation techniques.

In the present work, carbon fibre/epoxy laminates, constructed from IM7/8552 with several different lay-ups were investigated: quasi-isotropic, cross-ply, and angle-ply containing 0° and ±45° plies. Rectangular specimens with a central 4 mm diameter hole were subjected to quasi-static tensile loading using an electro-mechanical Instron testing machine. Four Mistras Pico sensors, bonded to the back surface of each specimen, were used to detect acoustic emissions (AE) produced by changes in the microstructure during loading – such as from the onset and growth of cracks in the matrix, separation of layers (delamination), or fibre fracture. Analysis of the signals and their features can enable identification of different damage mechanisms in composites as well as estimation of the damage locations [1], [2]. The delta-T mapping technique [3] is applied to the recorded data to locate damage events. Partially loaded specimens – loaded to between 80 and 95% of the breaking load – were then scanned at TWI Technology Centre Wales using X-ray computed tomography (CT). Figure 1 shows the lay-up and a virtual CT slice of accumulated damage in the surface 0° plies in three angle-ply blocked laminate specimens: (i) untested specimen with drilled hole, (ii) specimen loaded to 29 kN, and (iii) specimen loaded to 33 kN. The recorded AE and X-ray CT data were used to better understand failure progression in open-hole specimens, as well as to asses a finite element-based progressive damage model run in Abaqus [4].

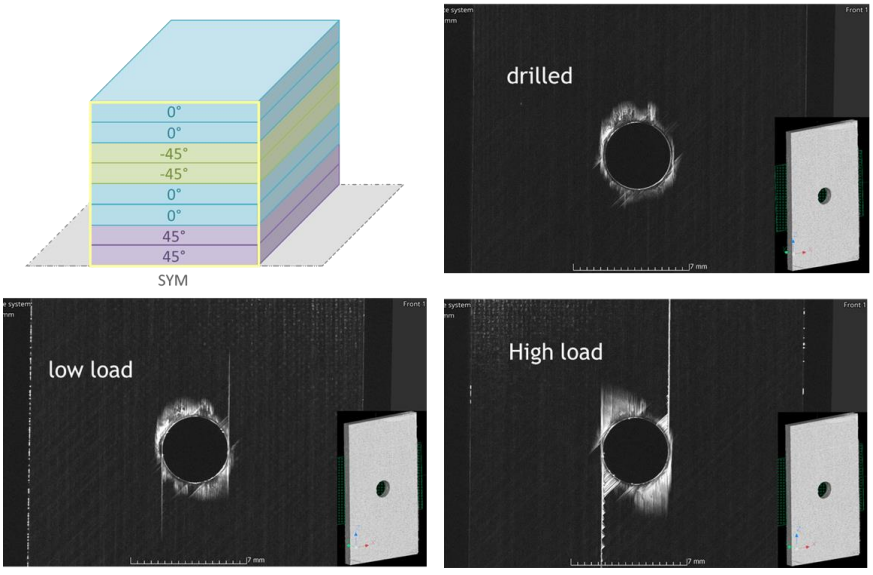

Figure 1: Schematic (top-left) and X-ray CT of angle-ply blocked specimens: standard deviations taken from a "thick slice" of the volume showing the two surface 0° plies of three specimens: drilled/untested (top-right), low load (bottom-left), and high load (bottom-right).

References

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