EXPERIMENTAL STUDY OF THE PLY THICKNESS EFFECT ON
DELAMINATION RESISTANCE OF UNIDIRECTIONAL CARBON
EPoxy LAMINATES

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A major concern in the utilization of fiber-reinforced polymers arises from the fact that their layered structure is susceptible to separation along the plies’ interfaces, i.e. delamination. In this work, an experimental approach is employed to characterize the ply thickness influence on mode-I interlaminar fracture toughness of unidirectional carbon fiber-reinforced epoxy laminates under monotonic loads.

Laminate made from thin ply prepregs ([0\textdegree 80], 50 gr/m\textsuperscript{2}, T700, North TPT\textsuperscript{TM}, www.thinplytechnology.com), was compared with another unidirectional laminate of the same fiber-resin system but built from thicker prepregs ([0\textdegree 26], 150 gr/m\textsuperscript{2}). Two other laminates with different fiber and resin ([0\textdegree 26], 150 gr/m\textsuperscript{2}, T700 or M40J, ACG\textsuperscript{TM}, www.advanced-composites.co.uk) were also tested as reference materials. Double cantilever beam (DCB) specimens with non-adhesive insert as delamination initiator were tested according to ASTM standard D5528. The energy release rate G during delamination propagation was calculated using the compliance calibration method. After delamination testing (i.e., crack length \textasciitilde 115 mm), selected specimens were cut along a section in the delamination zone at about one centimeter from the crack front. These blocks were embedded in epoxy, polished and examined under an optical microscope to reveal the qualitative extent of fiber bridging.

Delamination resistance curves from DCB tests indicate the same initiation G value of both standard thickness and thin ply laminates with the same fiber-resin system. With delamination growth, a considerably higher delamination resistance of the TPT thicker ply laminate was observed when compared with the thin ply laminate as shown in Figure 1. This suggests more fiber bridging during crack propagation in the former laminate since fiber bridging is assumed as the main toughening mechanism involved in mode I. The results for the two reference laminates are also illustrated in Figure 1.

Comparison of micrographs of thin and thick (or standard) ply laminates (Figures 2) indicates the presence of more fibers in the wake of the delamination of the thicker ply laminate. Moreover, in the finer microstructure plies are rather smooth and well aligned while thicker plies are wrinkled and wavy. Therefore, the different fiber bridging contribution in thick- and thin-ply laminates can be attributed to the different crack propagation pathways.
The same $G$ at initiation is attributed to the presence of a matrix rich zone at the tip of the crack starter. However, the direction of crack propagation in the plates with the wavy microstructure is more irregular as it propagates not only between plies but also in the plies leading to the presence of more fibers (or bundles of fibers) that interconnect the crack faces. In contrast, the crack path in the thin ply laminates with smoother plies is more regular with delamination propagating almost only between plies leading to low extent of fiber bridging. Thus, the latter case is energetically more favorable for delamination propagation.

Figure 1: Delamination resistance curves from the DCB testing.

Figure 2: Transverse sections of thin (a) and standard ply laminates indicating delamination planes (b). Microstructures of thin (c) and standard ply laminates (d).

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