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Delamination Fracture Toughness Benefits of Inter-Woven Plies in Composite Laminates Produced through Automated Fibre Placement

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Abstract : An automated fibre placement method has been developed to build through-thickness reinforcement into carbon fibre reinforced plastic laminates during their production, with the goal of increasing delamination fracture toughness while circumventing the additional costs and defects imposed by post-layup stitching and z-pinning. Termed ‘inter-weaving’, the method uses custom placement sequences of thermoset prepreg tows to distribute regular fibre link regions in traditionally clean ply interfaces. Inter-weaving’s impact on mode I delamination fracture toughness was evaluated experimentally through double cantilever beam tests (ASTM standard D5528-13) on [±15°]9 laminates made from Park Electrochemical Corp. E-752-LT 1/4” carbon fibre prepreg tape. Unwoven and inter-woven automated fibre placement samples were compared to those of traditional laminates produced from standard uni-directional plies of the same material system. Unwoven automated fibre placement laminates were found to suffer a mostly constant 3.5% decrease in mode I delamination fracture toughness compared to flat uni-directional plies. Inter-weaving caused significant local fracture toughness increases (up to 50%), though these were offset by a matching overall reduction. These positive and negative behaviours of inter-woven laminates were respectively found to be caused by fibre breakage and matrix deformation at inter-weave sites, and the 3D layering of inter-woven ply interfaces providing numerous paths of least resistance for crack propagation.

Keywords : AFP, automated fibre placement, delamination, fracture toughness, inter-weaving
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