THE HIGH STRAIN RATE TENSION BEHAVIOUR OF PSEUDO-DUCTILE HIGH PERFORMANCE THIN PLY CARBON/GLASS HYBRID COMPOSITES

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ABSTRACT

Nowadays, the use of polymer-matrix composites is increasing very rapidly due to their superior specific structural properties. However, these materials have a sudden brittle failure with a linear elastic response and little warning before failure. This drawback leads to a costly conservative design of composite structures.

Hybridisation of thin plies of different types of fibres has been found to be a promising method to introduce gradual failure and avoid sudden failure in composite materials. Recently, nonlinear pseudo-ductile stress–strain responses were reported for unidirectional (UD) [1–3] and quasi-isotropic (QI) [4-8] hybrids made of different types of thin plies with low strain and high strain fibres, when subjected to quasi-static tensile loading condition. This pseudo-ductility was achieved by suppressing the catastrophic delamination and introducing gradual damage mechanisms of (i) low strain material failure/fragmentation, (ii) stable delamination, and (iii) high strain material failure. Material properties, proportion and absolute thickness of the low strain fibre plies are the design parameters that need to be optimised/selected to achieve pseudo-ductile UD hybrids. The performance of the pseudo-ductile QI layups was influenced not only by the UD laminates' design parameters but also by the stacking sequence of the plies [5, 7].

In industrial applications, the pseudo-ductile laminates will be subjected to high strain rates. Therefore, to design robust and reliable structural components, it is essential to understand the strain rate-dependence of the pseudo-ductile hybrid composites.

In this paper the effect of strain rate on the tensile behaviour of pseudo-ductile low strain / high strain fibre hybrids is reported. A comprehensive set of thin-ply pseudo-ductile UD and QI interlayer hybrid composite materials comprising S-glass/913 epoxy and thin-ply T300-carbon/120˚C epoxy prepregs was designed and subjected to tension at cross head speeds of 2 mm/min, 5 m/s and 10 m/s. The quasi-static tests were conducted on an electro-mechanical universal test machine and the high strain rate tests on a very high speed servo-hydraulic machine. Digital Image Correlation was used to capture the strain fields with the help of high speed cameras. Unique elastic–pseudo-yielding–hardening type stress–strain responses similar to those at low strain rates were achieved at high strain rates through fragmentation and stable pull-out of the carbon layers. The observed failure mechanisms, deduced from high speed videos, confirmed the existence of pseudo-ductile damage mechanisms. The delamination strain, controlled by the mode II interlaminar fracture toughness increased with increasing strain rate. This study demonstrates the potential of thin-ply carbon/glass hybrid laminates to generate high performance composites that show pseudo-ductility in high strain rate tensile loading.

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