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IMPACT BEHAVIOUR OF FRPS: EFFECT OF LOW AND HIGH LOADING RATES

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An extensive study of mechanical behaviour of fibre-reinforced polymer (FRP) composite laminates was carried out in order to understand complex mechanisms of damage initiation and propagation under impact loads within a broad range of load rates – from low to high. The cases studied included (i) low load-rate, low-energy impacts on woven carbon- and glass-fibre fabric-reinforced laminates, typical for sports or automotive applications, (ii) ballistic impact on woven-fabric FRP laminates, (iii) blast-related impact on CFRP-based laminates and (iv) hypervelocity impact.

The experimental tests were carried out to assess the damage and deformation in these cases. In the case of low-load-rate impact, large-deflection impact bending tests were performed on un-notched specimens using a Resil impactor to assess their transient response and energy-absorbing capability, in Loughborough University, UK [1]. This was accompanied by X-ray micro computed tomography of damaged and failed specimens that revealed prominent damage modes in dynamically tested laminates – through-thickness matrix cracking, inter-ply and intra-ply delamination such as tow debonding, and fabric fracture. Ballistic impact tests were carried out at IIT Bombay, India using a single-stage gas gun and employing a ballistic limit velocity (V50) as a criterion to assess the energy absorbing capacity of target composite laminates. Damage loci at their front and rear faces were analysed, where fibre breakage and delamination were found to be the dominating failure modes [2]. Blast test studies were conducted at University of Rhode Island, USA using a shock-tube apparatus. A controlled blast load was imparted to CFRP panels, and a digital image-correlation technique was used to measure in-plane strain, out-plane deflection and velocities at their back faces. A post-mortem analysis was also carried out, revealing that fibre breakage was a governing failure mode [3].

All the dynamic loading cases were thoroughly analysed using advanced numerical models developed in a commercial finite-element (FE) code ABAQUS/Explicit. A ply-level FE model was developed, with a ply modelled as a homogeneous orthotropic elastic material with a potential to sustain progressive stiffness degradation due to fibre/matrix cracking, and plastic deformation under shear loading. The model was implemented as a VUMAT user subroutine and was able to distinguish fibre- and matrix-related failure modes. Delamination was modelled using cohesive-zone elements. All FE models were validated with the experimental results and showed a reasonably good agreement.

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