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Dynamic Damage in FRP Composites

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In many applications including automotive, aerospace, naval, defence, energy and sport, the use of fibre-reinforced polymer (FRP) composites has increased considerably over the last few decades. Dynamic loading is often an unavoidable part of in-service conditions for these applications, and can result in complex deformation regimes that may lead to visible and hidden damage [1]. Typical examples include low- and high-velocity impacts (from 1 to 1000 m/s), ranging from flight at Mach 1-2 (300-600 m/s) of fighter jets or intercontinental ballistic missiles through clouds of debris or hailstones, to lower-velocity impacts caused by debris on runways, railway lines, auto race tracks etc., as well as blast loads as a result of close-proximity to explosions or sudden pressure increases.

Apparently, the range of possible dynamic loading conditions is vast, making specific case studies rather unique depending on their methodology, parameters and materials involved. As a result, developing a full understanding of these different types of dynamic loading conditions and their effect on the response of FRP composites is very important. For each, the distribution of stresses and strains can be very different, leading, in turn, to varying deformation and, more importantly, the initiation and evolution of visible and hidden damage. The previous research was mostly focused on the resulting deformation and damage caused by solid projectiles (typically steel), but direct comparisons against other loading conditions are few and far between. When considering the methodology employed, usually in the past the assessment of resultant damage was limited either to a visual inspection of external surfaces or invasive schemes. More modern techniques include investigating internal (i.e invisible) damage with non-invasive X-ray tomography, in which full in-depth volumetric damage analysis can be conducted.

This study presents complementing experimental case studies, in which a 2x2 twill weave T300 carbon fibre/epoxy composite was subjected to ballistic loading with both steel and ice projectiles (95 – 865 J at 70-90 m/s and 300-500 m/s, respectively), and air blast / shockwave loading (with incident pressures of 0.4 MPa, 0.6 MPa and 0.8 MPa, and wave speeds between 650 m/s and 950 m/s). These case studies allow fundamental comparisons of the resultant spatio-temporal deformation and damage observed using non-invasive techniques including digital image correlation and x-ray tomography.

A strategy for numerical simulations of initiation and evolution of dynamic damage in FRP composites is also discussed.

Reference

[1]. V.V. Silberschmidt (ed.), Dynamic Deformation, Damage and Fracture in Composite Materials and Structures. Elsevier, Amsterdam e.a., 2016, 616 pp.