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Failure Mechanisms and Damage Evolution of Laminated Composites under Compression After Impact (CAI): Experimental and Numerical Study

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Abstract

The damage tolerance of Carbon Fibre Reinforced Polymer (CFRP) to Barely Visible Impact Damage (BVID) is a critical design limiter for composite structures. This study investigated the key driving mechanisms and damage evolution of the compressive failure of laminated composites containing BVID using compression after impact and indentation (CAI) tests. Experiments were carried out on two similar quasi-isotropic laminates: $[45_2/90_2/0_2/\text{-}45_2]_{2S}$ and $[45/90/0/\text{-}45]_{4S}$. Matrix cracking and delaminations were introduced by either low-velocity impact or quasi-static indentation tests prior to the CAI tests. The full-field displacement during CAI as well as the moment of rupture were captured by 3D Digital Image Correlation (DIC). The effect of ply-blocking and influence of factors, such as impact energy, delamination area and surface indentation, on compressive failure was studied. Previously validated high-fidelity finite element (FE) numerical models for the indentation and impact events were then used to investigate the damage evolution during CAI failure.

Keywords: Compression after impact; Numerical modelling; Cohesive interface; Digital image correlation

1 Introduction

Carbon Fibre Reinforced Polymers (CFRP) have become increasingly popular and are gradually replacing traditional metals for applications such as primary structure components in contemporary and future aircrafts. CFRP exhibits superior properties over aluminium alloy like specific stiffness, strength, formability, resistance to fatigue and corrosion performance [1]. Because laminated CFRPs lack reinforcement in the through thickness direction, one of their limiting factors is their resistance to out-of-plane loading such as low-velocity impact and quasi-static indentation. Low-velocity impact, which may occur during manufacture or in service, can result in substantial internal damage without leaving a clear visible trace at the composite surface. This damage is normally called Barely Visible Impact Damage (BVID) [2], which is difficult to detect and easy to be overlooked during general inspection. Hence, there

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