Deformation and Damage in Fabric-reinforced Composites Under Bending

H. ULLAH, A. R. HARLAND and V. V. SILBERSCHMIDT

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Fabric-reinforced polymer composites used in sports products can be exposed to different in-service conditions such as large bending deformations caused by quasi-static and dynamic loading. Composite materials subjected to such bending loads can demonstrate various damage modes - matrix cracking, delamination and, ultimately, fabric fracture [1-4]. Damage evolution in composites affects both their in-service properties and performance that can deteriorate with time. Such damage modes need adequate means of analysis and investigation, the major approaches being experimental characterisation and numerical simulations. This work deals with a deformation behaviour and damage in carbon fabric-reinforced polymer (CFRP) laminates caused by quasi-static and dynamic bending. Experimental tests are carried out to characterise the behaviour of a CFRP material under large-deflection bending, first in quasi-static conditions and then in dynamic ones, employing a pendulum-type Impactor in Izod impact tests. X-ray micro computed tomography (Micro CT) is used to analyse internal material damage modes such as matrix cracking, delamination, tow debonding and fabric fracture.

These mechanical tests and microstructural studies are accompanied by advanced numerical simulations. Two- and three-dimensional finite element models are developed in a commercial code Abaqus to study the deformation behaviour and damage in CFRP for tested conditions of bending. In these models, multiple layers of bilinear cohesive-zone elements are placed at the damage locations identified in the Micro CT study. Initiation and progression of inter-laminar delamination and intra-laminar ply fracture are studied by employing cohesive elements. Stress-based criteria are used for damage initiation while fracture-mechanics techniques are employed to capture its progression in composite laminates. The developed numerical models are capable to simulate the studied damage mechanisms as well as their subsequent interaction observed in our tests and with Micro CT scanning. The obtained simulation results showed a good agreement when compared to data obtained experimentally for the studied composites.

* Wolfson School of Mechanical and Manufacturing Engineering, Loughborough University, Leicestershire, LE11 3TU, UK
e-mail: V.Silberschmidt@lboro.ac.uk; web page: http://www.lboro.ac.uk/departments/mechman/staff/vadim-silberschmidt.html

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