IDENTIFICATION OF DAMAGE INITIATION AND PROGRESSION IN OPEN HOLE COMPOSITES USING ACOUSTIC EMISSION AND DIGITAL IMAGE CORRELATION

Neha Chandarana[1,2], Rafael Ruiz Iglesias[1], Oliver Helps[2,3], Emmanuel Ramasso[4], and Philip J. Withers[2]

[1]Bristol Composites Institute, Faculty of Engineering, University of Bristol, Bristol BS8 1TR, UK
Email: neha.chandarana@bristol.ac.uk, rafael.ruiziglesias@bristol.ac.uk
web page: http://www.bristol.ac.uk/composites/

[2] Henry Royce Institute, The University of Manchester, Oxford Road, Manchester M13 9PL, UK
Email: p.j.withers@manchester.ac.uk, oliver.helps@postgrad.manchester.ac.uk
web page: https://www.royce.ac.uk/

[3] TWI Technology Centre Wales, Harbourside Road, Port Talbot SA13 1SB, UK

[4] Institut FEMTO-ST, Université Bourgogne Franche-Comté, 25000, Besançon, France
Email: emmanuel.ramasso@femto-st.fr, web page: https://www.femto-st.fr/en

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ABSTRACT

The progression of damage in multidirectional open hole composite specimens subjected to tensile loading is dependent on the properties of the constituent materials as well as the laminate lay-up (fibre orientations, ply thickness). The use of permanently integrated sensors to obtain structural health information from composites is promising, but it is necessary to validate the ability of such systems to distinguish between different damage mechanisms that occur in composites. Acoustic emissions (AE) are produced by changes in the microstructure during loading, such as the onset and growth of matrix cracks, separation of fibre plies (delamination), or fibre fracture. AE signal and feature analysis can enable damage mechanism identification as well as estimation of the damage locations [1,2].

In the present work, carbon fibre/epoxy laminates (IM7/8552, 134 gm^{-1} fibres, 0.125 mm ply thickness) were provided by Hexcel Composites with an 'angle-ply blocked' lay-up, having the stacking sequence $[0_2/-45_2/0_2/+45_2]_S$. Rectangular specimens with a central 4 mm diameter hole were subjected to quasi-static tensile loading using an electro-mechanical Instron testing machine. Four Mistras 'Pico' sensors, bonded to the back surface of each specimen, were used to detect AE, while a LaVision stereo digital image correlation (DIC) system was used to capture full-field deformation of the specimens to obtain displacements and strains. A time-dependent unsupervised clustering algorithm, based on the Gustafson Kessel [3] algorithm was applied to the AE data generated during loading. Full details are given in [4,5]. Several specimens were loaded until failure, generating AE and full-field DIC data only, while a few were only partially loaded to between 85-97% of the mean open-hole-tensile strength. These specimens were assessed with non-destructive techniques including x-ray computed tomography (with and without contrast agent), edge-illuminated phase contrast x-ray radiography, and ultrasonic c-scan to characterise the extent and type of damage.

Figure 1 shows the results from a specimen loaded to failure (35.2 kN). The AE data is separated into eight clusters (d) whose initiation and growth corresponds to the onset of significant delamination captured by out-of-plane displacement measurements [6] from the DIC data (a and b). The cumulated AE signal energy corresponds to the growth of longitudinal cracking in the surface 0° plies, as seen in the white light image (c) captured shortly before final failure. These results confirm the potential for damage classification in composites using AE, validated by full-field surface measurement using DIC and x-ray CT for internal damage characterisation. Next steps in this work will involve the assessment of AE monitoring to distinguish damage sequences in laminates with different stacking sequences.

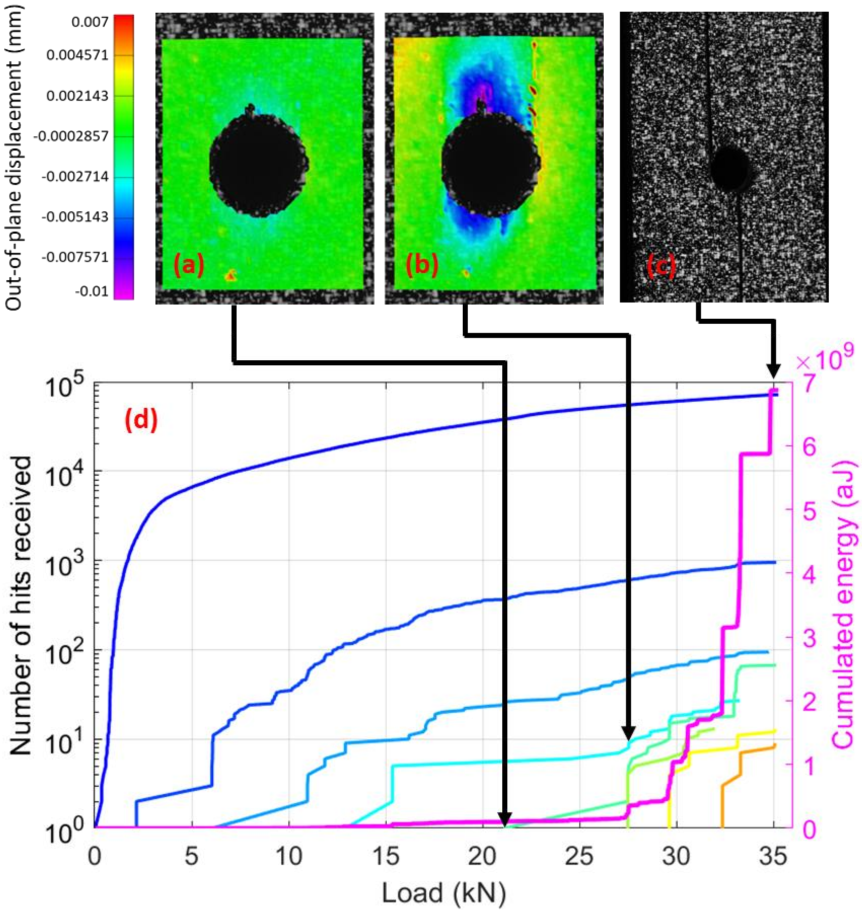

Figure 1: Progression of damage in an angle-ply blocked open-hole tensile coupon during loading, showing out-of-plane displacements captured by DIC at (a) 21 kN and (b) 27 kN; (c) white-light image captured at 35 kN; (d) evolution of AE data clusters and cumulated energy of AE signals.

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