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IDENTIFICATION OF THE STRAIN RATE DEPENDENCE OF THE ELASTIC PROPERTIES OF CFRP USING DIGITAL IMAGE CORRELATION

Marco L. Longana[1], Janice M. Dulieu-Barton[2] and Fabrice Pierron[2]

[1]ACCIS (Advanced Composites Centre for Innovation & Science)
University of Bristol, Queen's Building, University Walk, BS8 1TR, Bristol, UK
Email: m.l.longana@bristol.ac.uk, web page: http://www.bristol.ac.uk/composites/

[1]Faculty of Engineering and the Environment, Engineering Sciences
University of Southampton, Highfield, Southampton, SO17 1BJ
Email: janice@soton.ac.uk, web page: http://www.soton.ac.uk

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ABSTRACT

A methodology for the full-field study of the strain rate dependent constitutive behaviour of FRP materials with the aid of Digital Image Correlation has been devised, applied and validated. In this work, a high-speed servo-hydraulic tensile test machine is used to impart an intermediate strain rate loading. A methodology that identifies the Young's moduli, E_{11} and E_{22}, and the Poisson's ratio at strain rates up to 100 s^{-1} using high-speed imaging and full-field strain measurement techniques has been presented in [1]. An example of the evolution of the strain and strain rate maps, obtained from a unidirectional lay-up of glass reinforced epoxy specimen at nominal strain rate of 80 s^{-1}, for the identification of E_{11} and ν_{12} is shown in Figure 1. It is clear from the strain rate plots that there is a region where a constant strain rate can be obtained from which the elastic properties can be derived. However, an additional specimen configuration is required to determine the shear modulus, G_{12}.

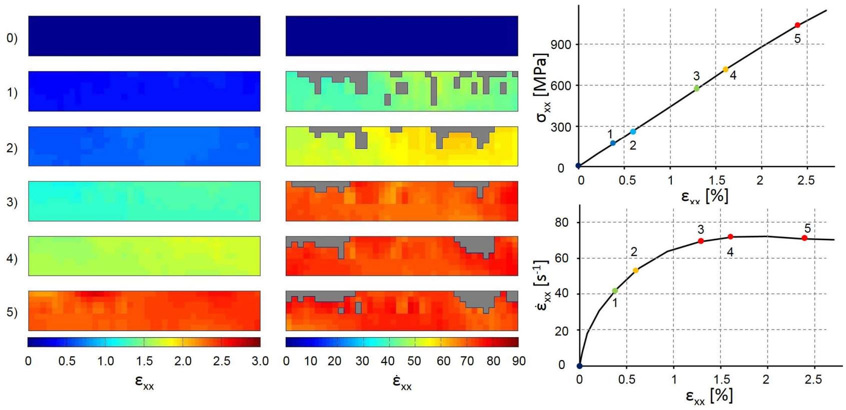

Figure 1: Strain and strain rate maps for material characterization

There are various techniques available to identify the shear modulus (G_{12}) at quasi-static strain rates, such as rail shear test, Iosipescu double V-notched beam test and the thin tube subject to torsion. However these specimens would prove extremely difficult to set up in a high speed servo-hydraulic test machine, as to minimise inertial effects the actuator has to accelerate to a 'constant' velocity prior to clamping the specimen. Therefore, to obtain G_{12} the off-axis tensile test on specimens manufactured from unidirectional material is used [2], as this allows the use of the same specimen geometry and experimental set-up as used in [1]. The specimens incorporate oblique end-tab to mitigate the effect of stress concentration in the proximity of the end-tabs [3]. Furthermore, the specimen geometry enables a large area to be imaged to perform DIC with sufficient images to characterise the material. Figure 2 shows the test specimen geometry and nomenclature.

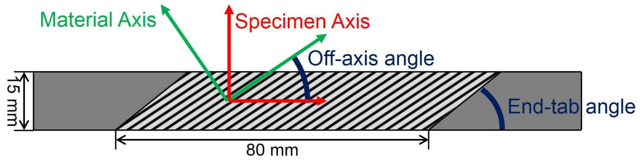

Figure 2: Specimen geometry and nomenclature

The methodology used here to achieve a precise material characterisation involves initial tensile tests on specimens with 0° fibre orientation to identify E_{11} and ν_{12} and 90° fibre orientation to identify E_{22}, as well as an off-axis test with square end-tabs to estimate G_{12}. The preliminary results are used to define the end-tab and the optimal off-axis angle to identify G_{12}. The benefits of oblique end-tabs, i.e. parallel displacement contours and reduction of stress concentration at the specimen ends, are shown in Figure 3.

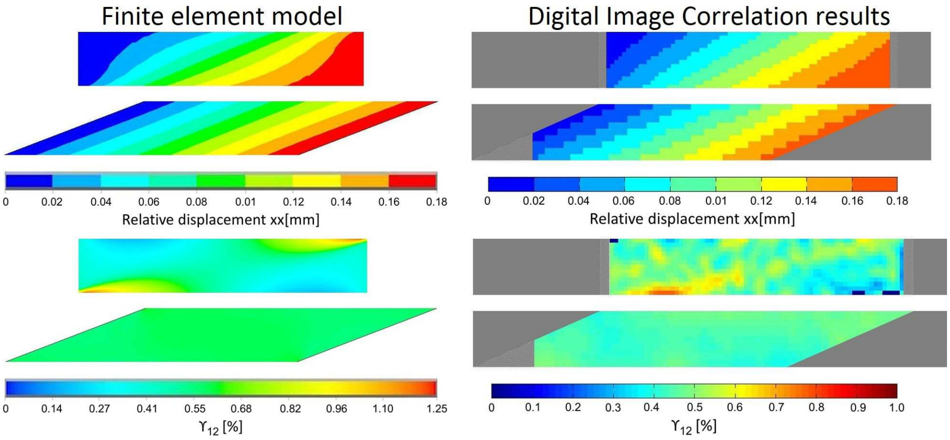

Figure 3: Displacement and strain maps for square and oblique end-tabs, FE and experimental results

This methodology has been used to characterise a CFRP material, MTM58FRB/HS(24K)-450-38%RW, and to inform a model of the stiffness-strain rate dependency, as shown in Figure 4.

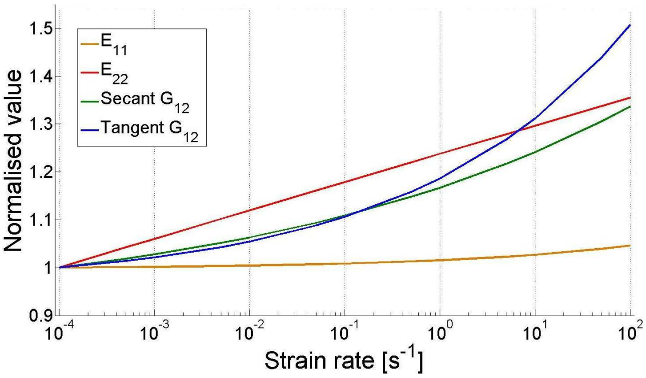

Figure 4: Normalised moduli as function of the strain rates

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