Multiscale modelling the effect of voids on short beam shear strength of composites

Fen Huang, Bassam El Said, Luiz F. Kawashita, Iryna Tretiak and Stephen R. Hallett

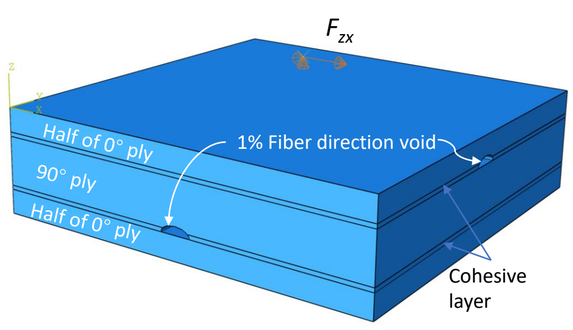
Bristol Composites Institute, Department of Aerospace Engineering, University of Bristol, Bristol, UK

Introduction

Voids are one of the most common manufacturing defects in composites. They can promote damage initiation at the micro-scale or meso-scale and affect the failure response of composite structures. Predicting the effects of voids on composite damage has long been sought for certification by analysis. Since full-scale models containing microscopic or mesoscopic void details are computationally prohibitive, the presented work focuses instead on employing multi-scale modelling approaches to investigate the effect of voids on the Short Beam Shear (SBS) strength of laminates.

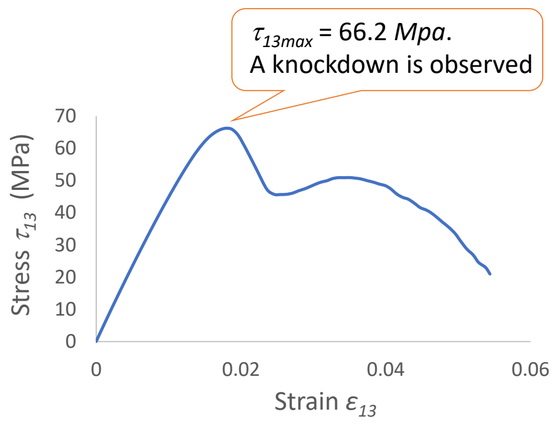
Meso-scale RVE models → Response under shearing → Computational homogenization → Equivalent material properties → Macro-scale SBS model → 3-point bending → Shear strength prediction

Meso-scale RVE model

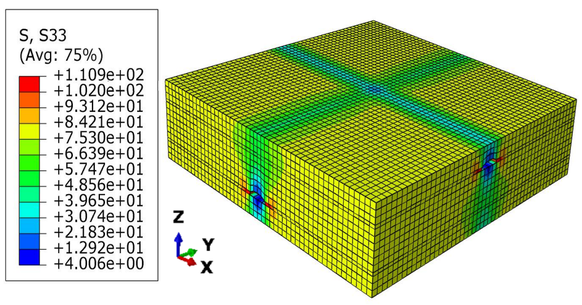


Simulation steps under periodic boundary conditions:

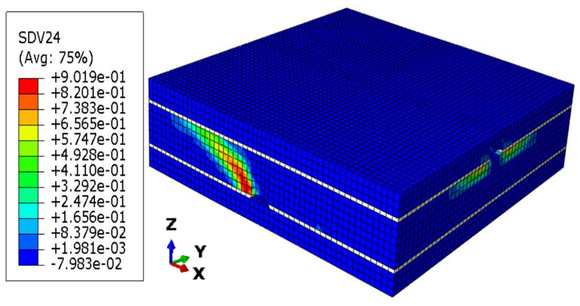
- Step 1- Temperature drop for curing.
- Step 2- In-plane shear.



Homogenized stress-strain behaviour.



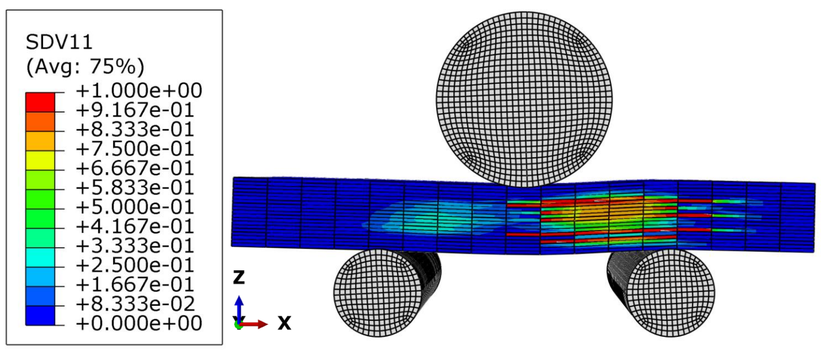
High local residual stresses around voids at the end of thermal step.



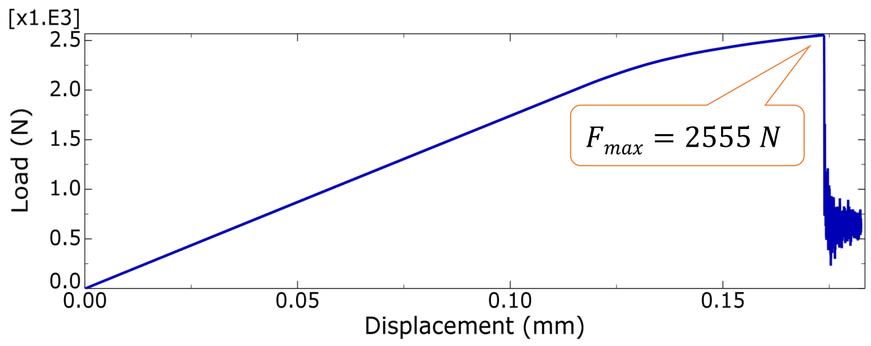
Matrix-dominated damage is seen to initiate around voids in the 90° ply.

Macro-scale SBS model

- A 3D orthotropic material model is employed.
- Shear response is informed by the homogenized RVE model.
- Full 3D model of 3-point bending SBS setup.

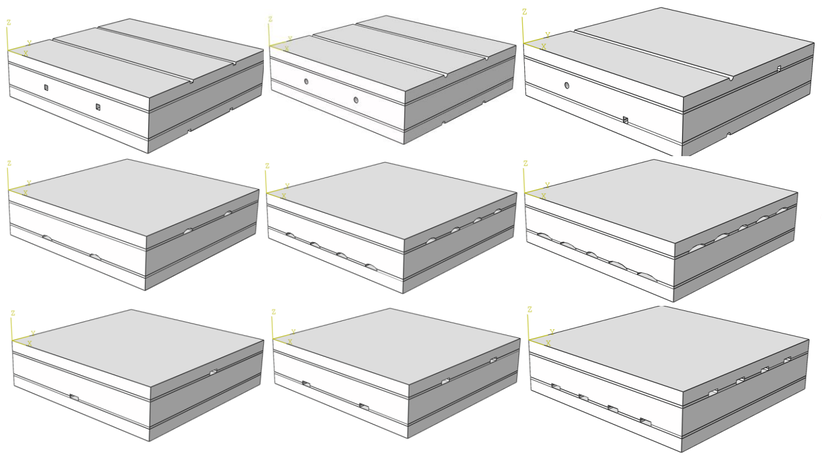


Damage contours showing failure between rollers on the SBS model

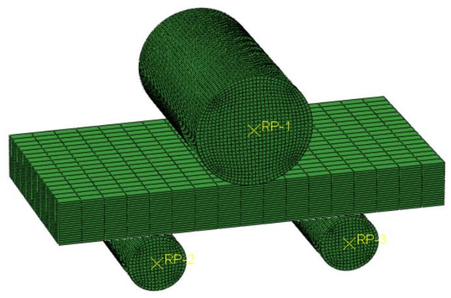


Equivalent SBS strength $s_{13} = 80\ MPa$

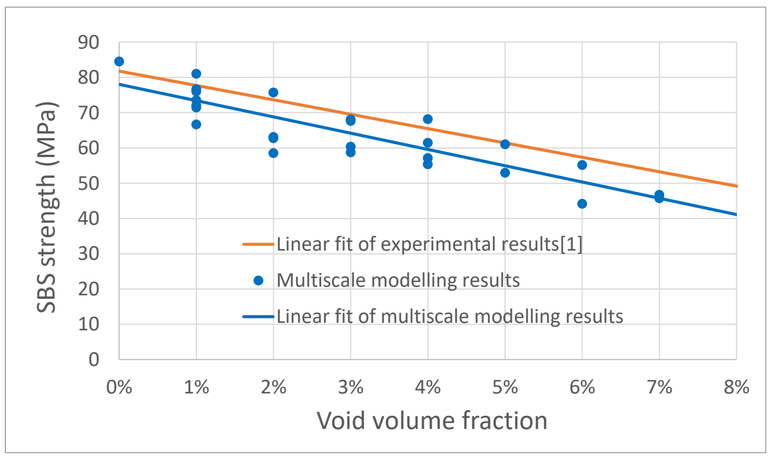
Exploration



RVE models containing 1%-7% void volume fraction to take into account more void morphologies.



Macro-scale SBS models to represent meso-scale material behaviours. Effects of different combinations of void morphologies on the SBS strength of laminates are investigated.



Predicted SBS strengths and their correlation with existing experimental results[1]. Good agreement is shown between the linear fits.

[1] I. Tretiak, 'Effect of voids on the interlaminar failure of carbon/epoxy composites', Ph.D thesis, Department of Aerospace Engineering, University of Bristol, 2019. [Online]. Available: http://researchinformation.bristol.ac.uk

bristol.ac.uk/composites