The influence of complex through-thickness stress states on in-plane fibre tensile strength of CFRP

Kilian Gruebler, Michael Wisnom and Stephen Hallett

This PhD project will investigate the influence and interaction of combinations of through-thickness (primarily compression) and shear stresses on the in-plane tensile strength of fibre reinforced composites. A bespoke test method is being developed to study the material behaviour and based on this a numerical model will be developed and validated. A successfully developed model and test method will give the opportunity to improve the design and the reliability of composite components. Such a model and test method can be applied to applications where composites are subject to complex 3D stress states and the results will give a better understanding on the strength of composites.

State of the art:
K.W. Gan, S.R. Hallett, M.R. Wisnom

Bespoke test methods were developed for testing material properties in the presence of through-thickness stress. It was shown that:

- Fibre direction tensile strength decreases significantly with increasing through-thickness compressive stresses, which can be expressed as:

\[ \sigma_{11}^{\text{reduced}} = \sigma_{11}^{\text{initial}} - \alpha \cdot |\sigma_{33}| \]

This work did not however account for the effect of through-thickness shear on fibre tensile strength. A case that has been observed in industrial applications.

Bespoke test methods:

For longitudinal tensile loading under combined through-thickness compressive and shear stress (\( \sigma_{11} + \sigma_{33} + \tau_{13} \) stress state)

- Bi-axial 4-point bending test with use of stress concentrations
- Bi-axial test with inserted fibre curvature in test specimen

Strain will be measured with digital image correlation technique. Failure stress state will be predicted by numerical models.

Expected results:

3D fibre failure envelope expressible as:

\[ \sigma_{11}^{\text{reduced}} = \sigma_{11}^{\text{initial}} - \alpha \cdot |\sigma_{33}| - \beta \cdot |\tau_{13}| \]

Definition of \( \beta \) will be project outcome

supported by

bristol.ac.uk/composites