Multi-axial Failure Envelopes for Laminated Composites

Bassam El Said* **and Stephen R. Hallett**

Bristol Composite Institute (ACCIS), University of Bristol
BS8 1TR, Bristol, United Kingdom.
e-mail: bassam.elsaid@bristol.ac.uk, web page: http://www.bristol.ac.uk/composites

ABSTRACT

Laminated composites exhibit complex inter-ply and intra-ply damage patterns. These damage modes can take the form of matrix cracks, delamination and fibre rupture. Traditionally, composite damage models are defined on the scale of a single ply where the failure criteria are defined based on the local stress/strain state. However, in practical applications uni-directional composites are seldom used. It is almost always the case, that in order to achieve the required stiffness/strength performance, a multi-directional composite laminate is needed. Since the failure criteria use the local stress/strain state on a single ply or on the interface between two plies, they cannot be applied to a complete laminate with multiple ply orientations and a varying stress state through the laminate thickness. For a design activity, a homogenised failure criterion defined using the global stress state is necessary. In this work, a novel homogenised failure criterion which also considers the change in fibre orientation across a laminate's thickness will be presented.

The foundation of the proposed approach is a set of meso-scale (ply-by-ply scale) Repeating Volume Element (RVE) models for a given layup. These models are used to predict the laminate failure under a range of loading conditions. The global failure stresses for this layup are then calculated using periodic homogenisation. Next, the proposed approach employs a parametric representation of composite layups based on lamination parameters [1]. In this approach, the stiffness response of a composite layup is divided into a set of material invariants and a set of fibre orientation dependant parameters, which are known as the lamination parameters. In conjunction with the lamination parameters, a topological representation of the failure envelopes of composite layups under multi-axial loading is created. This topological representation facilitates the development of homotopic relations [2] between failure envelopes of various composite layups. This procedure allows for the topological failure envelopes associated with a composite layup with known performance to be morphed into the failure envelopes of a layup with as yet unknown performance. This is achieved by using the lamination parameters and the knowledge of the laminate design space. Overall, the proposed approach provides an homogenised failure indicator for any multi-axial laminated composite under general macro-scale multi-axial loading, from a reduced number of meso-scale models, built using only ply and interface material properties.

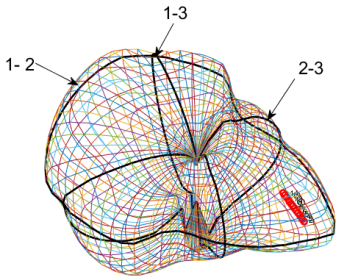

Figure 1 A tri-axial failure surface for a Quasi-Isotropic layup under [1,2,3] loading directions. The surface is calculated from the multiscale frame work here. Red circles show the meso-scale RVE results.

REFERENCES

[1] El Said, Bassam, and Stephen R. Hallett. "Multiscale Surrogate Modelling of the Elastic Response of Thick Composite Structures with embedded defects and features." Composite Structures (2018).

[2] Lee, John. Introduction to topological manifolds. Vol. 202. Springer Science & Business Media, 2010.