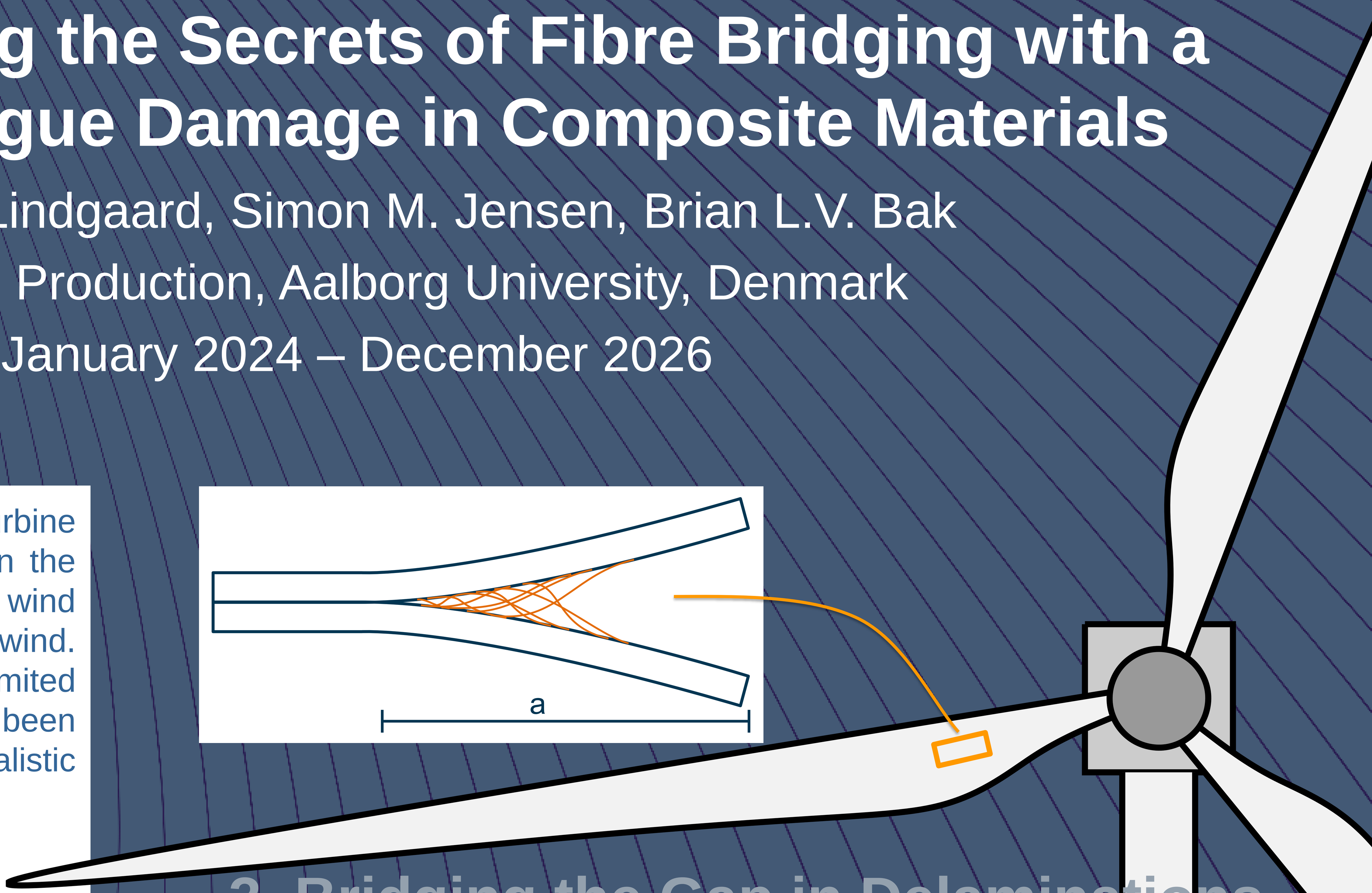
Bridging the Gap: Uncovering the Secrets of Fibre Bridging with a Multiscale Approach to Fatigue Damage in Composite Materials

Stagsted, Niklas Kristian Kronborg; Lindgaard, Esben; Mosbjerg Jensen, Simon; Bak, Brian Lau Verndal

Publication date:
2024

Document Version
Publisher's PDF, also known as Version of record

CraCS Research Group



Bridging the Gap: Uncovering the Secrets of Fibre Bridging with a Multiscale Approach to Fatigue Damage in Composite Materials

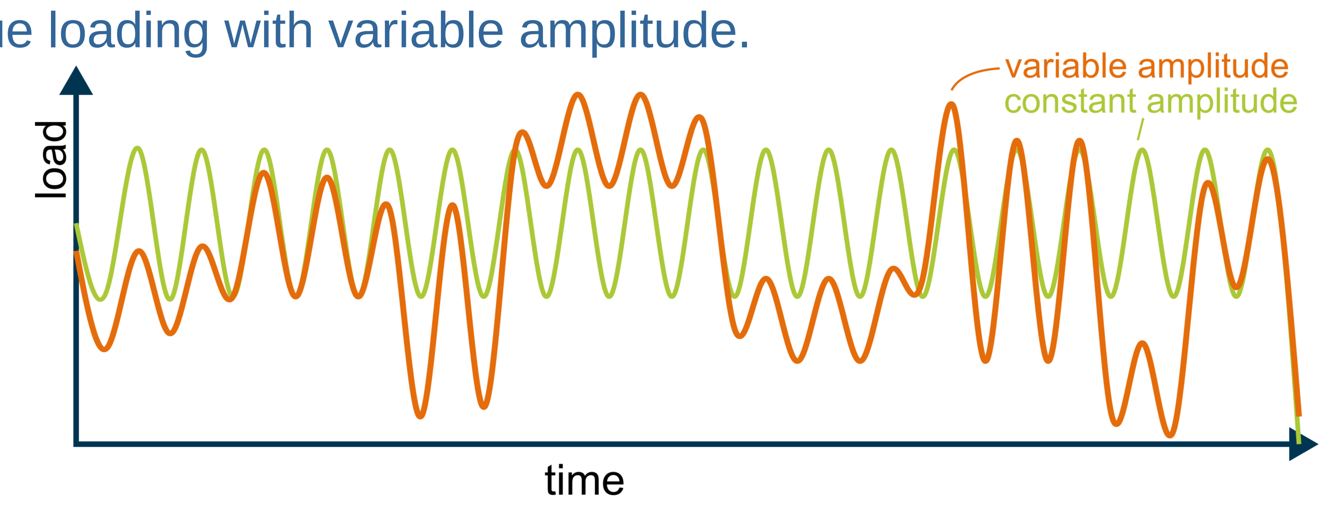
Niklas K.K. Stagsted*, Esben Lindgaard, Simon M. Jensen, Brian L.V. Bak

Department of Materials and Production, Aalborg University, Denmark

*nkks@mp.aau.dk, January 2024 – December 2026

1. Introduction

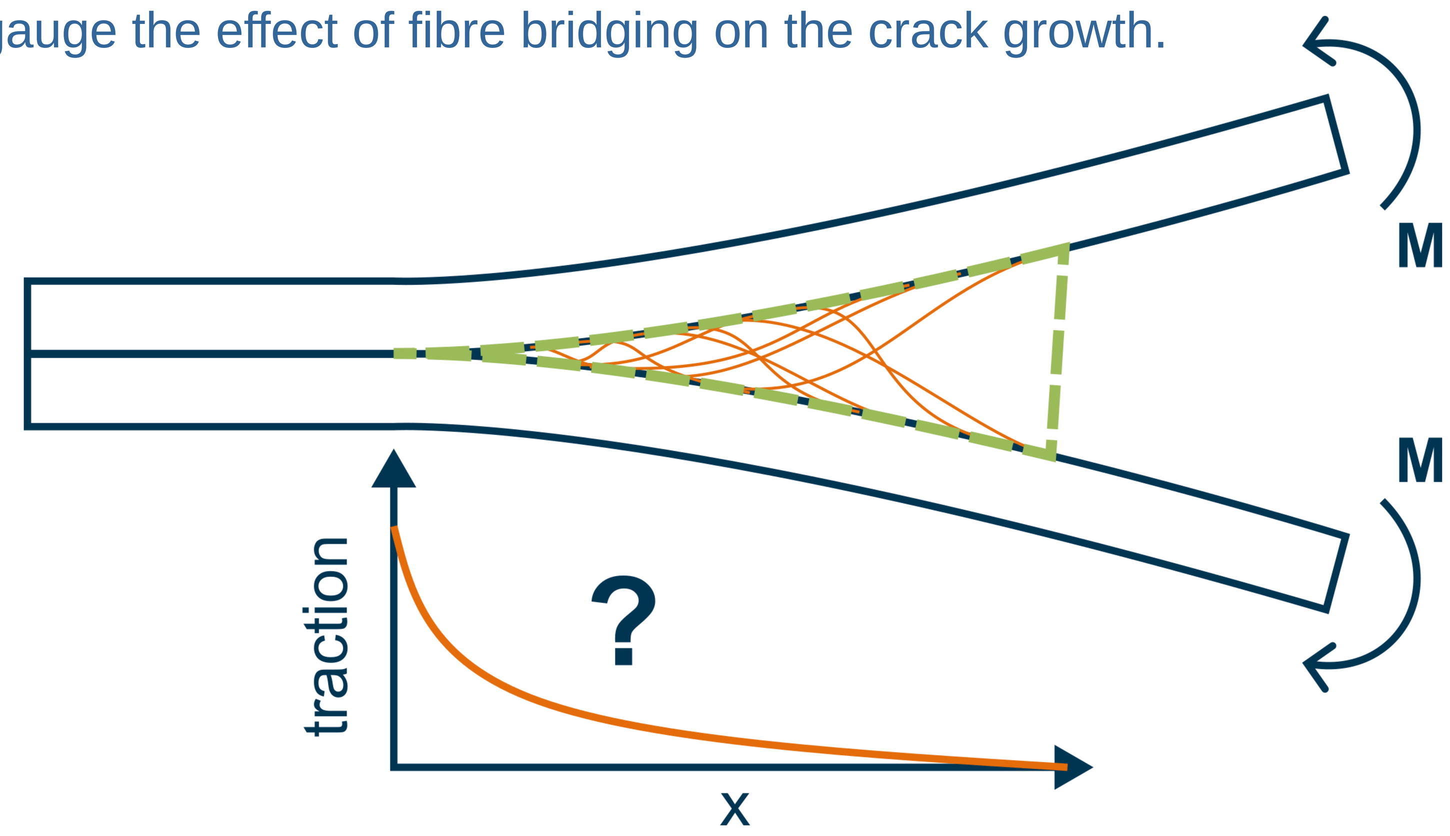
The primary failure mode in laminated composites such as wind turbine blades, is delaminations. Delamination is the growth of cracks in the interface between layers of a laminate. During their lifetime, wind turbine blades are exposed to highly varying loads from the wind. However, current understanding of delamination crack growth is limited to simple cyclic fatigue loading with constant amplitude, which has been shown to be inadequate in describing crack growth under more realistic fatigue loading with variable amplitude.



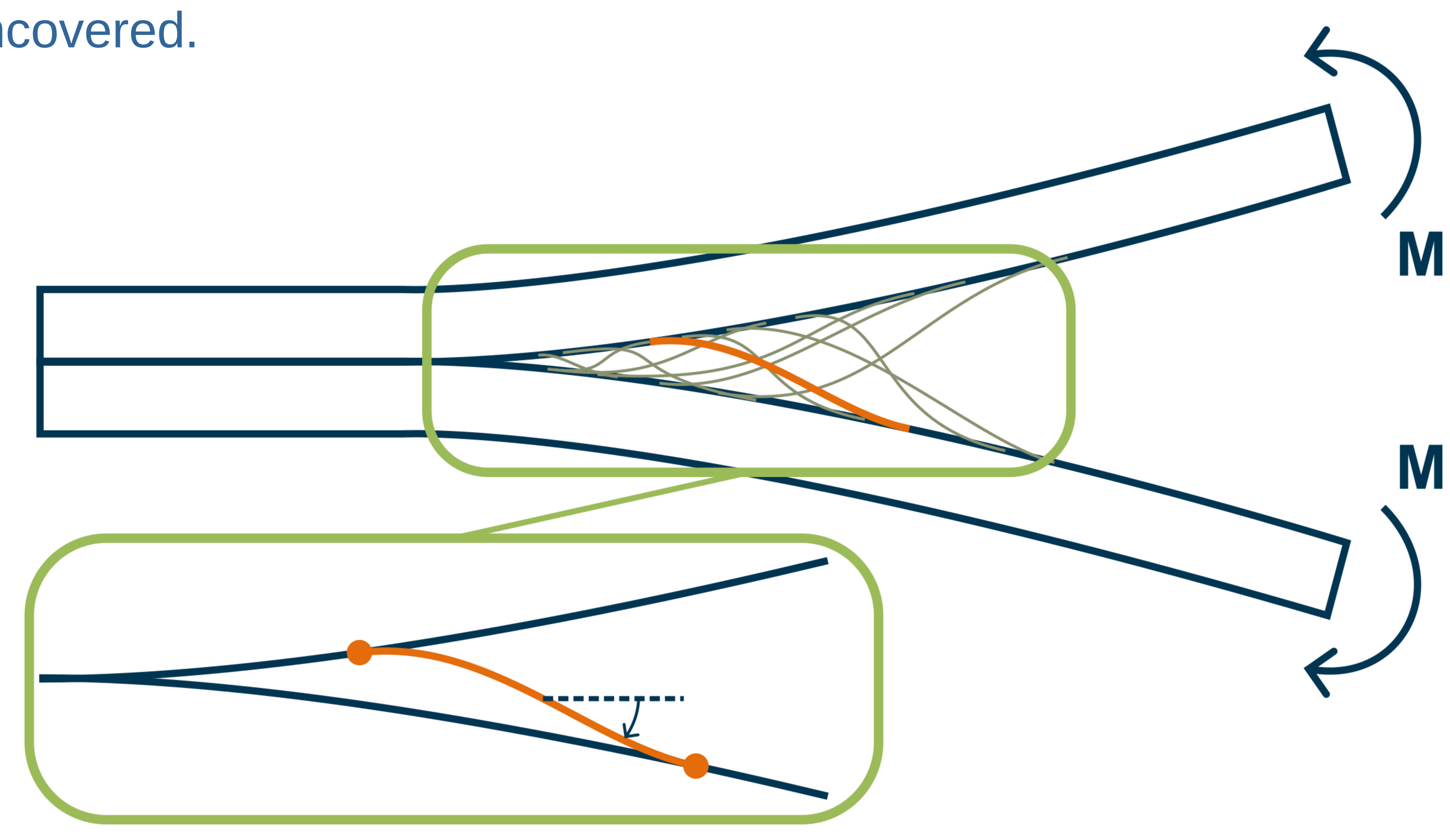
This PhD project aims to further the understanding of the governing mechanics and apply this knowledge to develop a fatigue delamination model capable of predicting delamination crack growth under variable amplitude fatigue loading.

2. Bridging the Gap in Knowledge

The main effect hypothesised to govern the increased crack growth of delaminations under variable amplitude fatigue loading is fibre bridging. As delamination cracks grow, fibres tend to bridge the crack faces behind the crack tip. These fibres apply closing tractions on the crack faces, effectively shielding the crack tip and increasing delamination resistance. Using inverse methods, the bridging tractions will be characterised experimentally under variable amplitude fatigue loading to gauge the effect of fibre bridging on the crack growth.

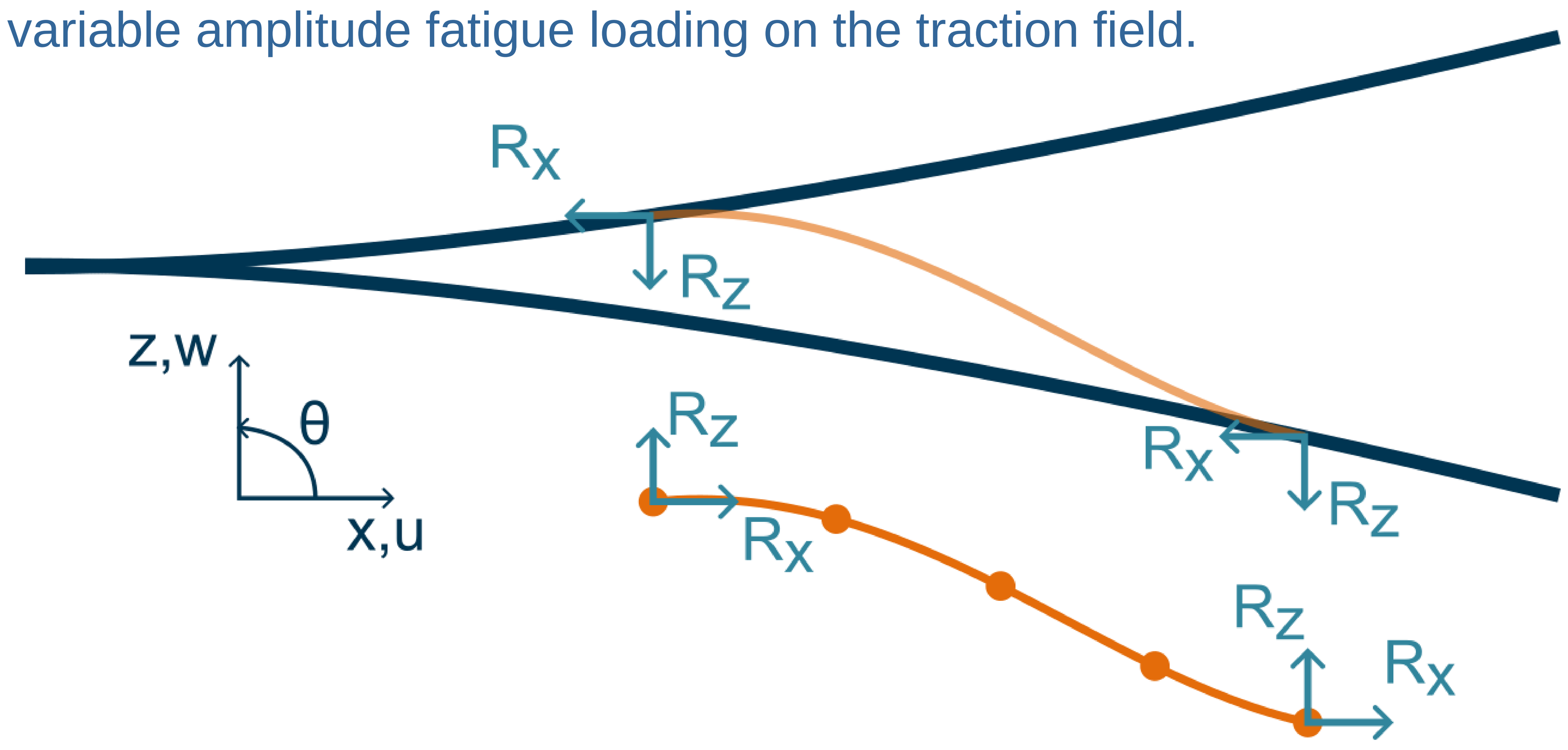


The bridging traction field will be further investigated through a characterisation of the micromechanical behaviour of individual bridging fibres. By monitoring the damage development of individual bridging fibres, the underlying micromechanics behind the traction field will be uncovered.

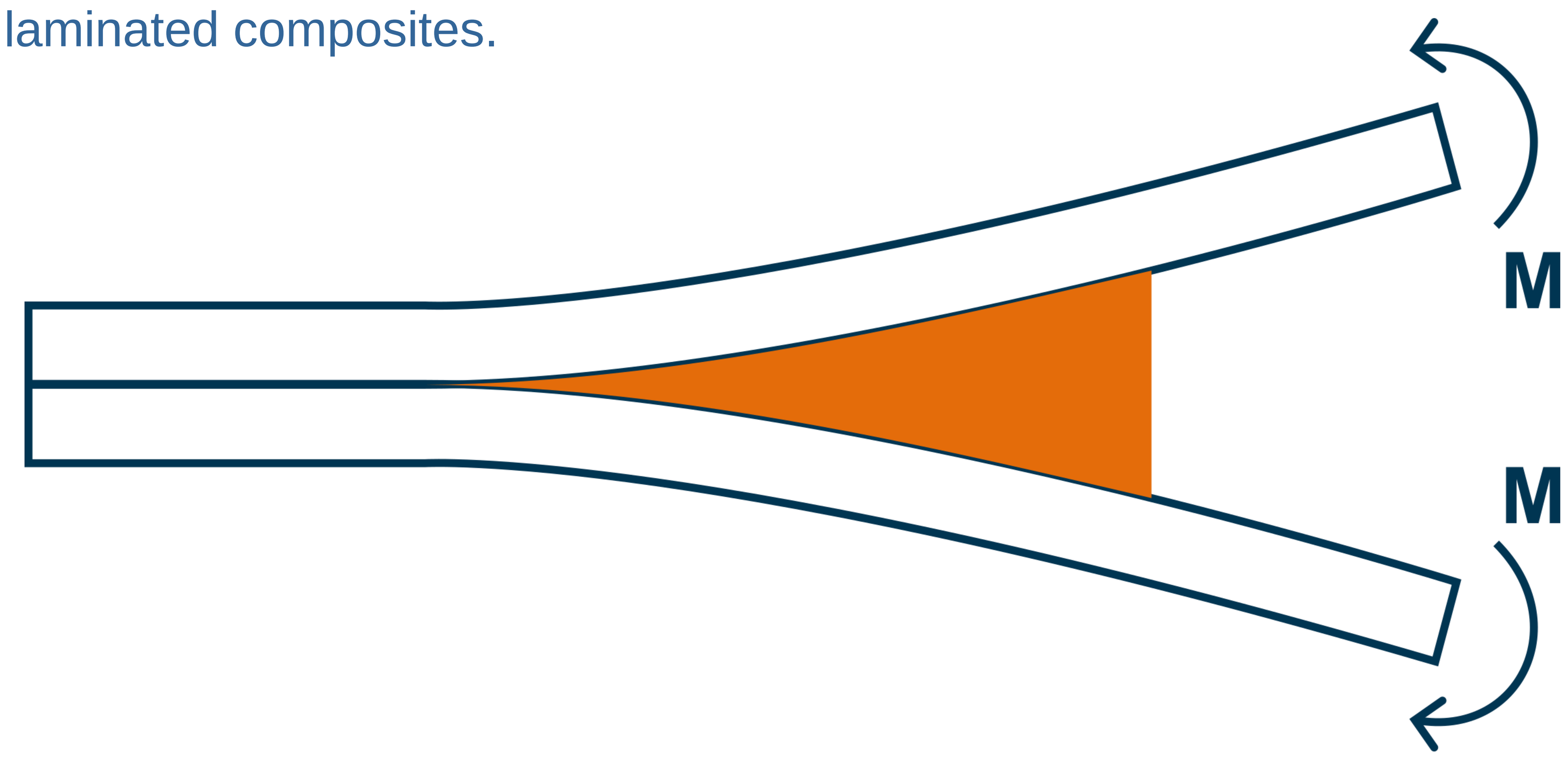


3. Bridging the Gap in Delaminations

Using the knowledge gained on the behaviour of individual fibres, current micromechanical models can be expanded to account for effects associated with variable amplitude fatigue loading. This will be used to develop a fatigue delamination model of the bridging tractions using a discrete representation of bridging fibres to capture the effect of variable amplitude fatigue loading on the traction field.



A micromechanical approach to modelling fibre bridging with a discrete representation of bridging fibres will be very computationally expensive. To reduce the computational cost, a computationally efficient surrogate model will be developed to replicate the response of the traction field obtained with the micromechanical model. This will be used to expand the capabilities of current delamination models to account for variable amplitude fatigue loading. The knowledge of fibre bridging behaviour on the microscale can then be applied to macroscale simulations of laminated composites.



4. Conclusion

An experimental investigation of the bridging tractions and the behaviour of individual bridging fibres will give insight into the increased growth of delaminations under variable amplitude fatigue loading. This insight will form the basis of a micromechanical model able to account for variable amplitude fatigue loading. Finally, a computationally efficient surrogate model for macroscale simulations will enable the knowledge gained to be used for predicting delamination crack growth under variable amplitude fatigue loading.

DCAMM Symposium 2024