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MICROMECHANICAL MODEL OF CROSS-OVER FIBER BRIDGING

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ABSTRACT

A micromechanical model of cross-over fiber bridging is developed for the prediction of macroscopic mixed mode bridging laws (traction-separation laws). The bridging ligament/fiber is treated as a beam, using moderately large deflection beam theory. The model includes debonding between fiber and matrix as well as buckling of fibers in compression. The predictions made by the proposed semi-analytical micromechanical model are shown to be in excellent agreement with those made by detailed finite element models. The computational efficiency of the novel model enables parameter studies that would otherwise be unfeasible. Further, the proposed model can be implemented as a physics based cohesive law for use in meso and macroscale finite element models.

Due to development of fiber bridging in the wake of the crack tip, the fracture process zone (FPZ) can be relatively long in some fiber reinforced polymer laminates. Fibers that bridge the fracture surfaces transfer tractions between the two surfaces and can enhance the delamination resistance substantially as the crack extends [1-3]. Micromechanical models of cross-over fiber bridging can be valuable tools for studying the underlying mechanisms and how to utilize fiber bridging to maximize the fracture resistance and the damage tolerance.

A number of micromechanical models for the prediction of macroscopic traction-separation laws for cross-over fiber bridging have been developed [2-4]. However, the existing models are either restricted to the very initial stage where deflections are very small compared to the fiber diameter [3, 4], or to the final stage of bridging where the fiber is so long and slender that the bending stiffness can be neglected [2].

The scope of the present work is to establish a micromechanical model applicable to the full range of deformations that the bridging ligaments are subjected to in mixed mode I/II delamination.

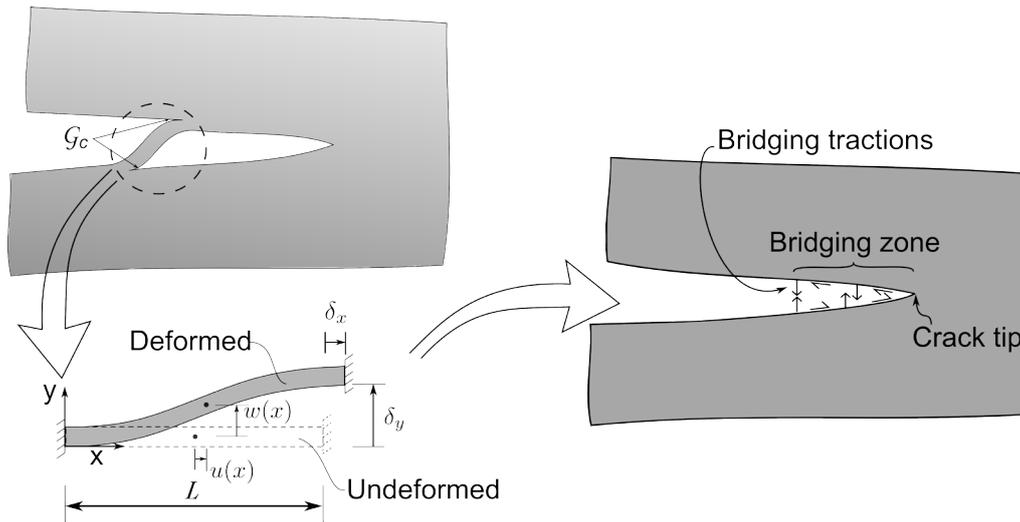


Figure 1: Schematic of the micromechanical model.

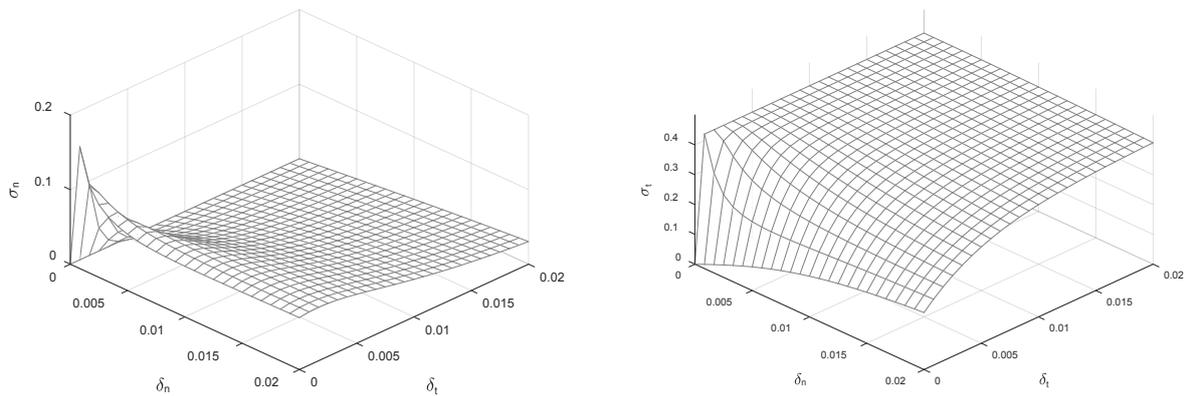


Figure 2: Prediction of macroscopic bridging law.

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REFERENCES

- [1] S. Hashemi, A.J. Kinloch, J.G. Williams, *The Analysis of Interlaminar Fracture in Uniaxial Fibre-Polymer Composites*, Proceedings of the Royal Society of London Series A, Mathematical and Physical Sciences, **427**, 1990, p. 173-99.
- [2] D.A.W. Kaute, H.R. Shercliff, M.F. Ashby, *Delamination, fibre bridging and toughness of ceramic matrix composites*, Acta Metallurgica et Materialia, **41**, 1993, p. 1959-70.
- [3] B.F. Sørensen, E.K. Gamstedt, R.C. Østergaard, S. Goutianos, *Micromechanical model of cross-over fibre bridging – Prediction of mixed mode bridging laws*, Mechanics of Materials, **40**, 2008, p. 220-34.
- [4] S.M. Spearing, A.G. Evans, *The role of fiber bridging in the delamination resistance of fiber-reinforced composites*, Acta Metallurgica et Materialia, **40**, 1992, p. 2191-9.