

ANALYSIS OF BENDING STIFFNESS REDUCTION IN THIN WOVEN COMPOSITES UNDER LARGE CURVATURES

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Space structures are often bent to extreme curvatures as they require to be stored in highly compacted configurations for launching. Thin woven fibre composites have emerged as a leading candidate as a material for design of deployable aerospace structures owing to their exceptional stiffness to weight ratio and tailorable material properties. It has been identified that there is a significant reduction of bending stiffness when these composites are subjected to high curvatures. Failure moments measured in experimental studies have shown that this reduction can be as high as 20%. To address this discrepancy, this study investigates the mechanisms contributing to this reduction in bending stiffness, focusing primarily on the complex effects of nonlinear geometry and variation in cohesive interaction leading to inter-tow slipping within the laminate.

A representative unit cell modelled in ABAQUS commercial finite element package, facilitated detailed investigation into the nonlinear geometric deformations and cohesive behaviour between plies. The study focused on two-ply plain weave laminates made of T300-1k fibres and HexPly 913 resin. Nonlinear geometric effects arise predominantly from curvature-induced reductions in tow undulation amplitude and tow thickness. The results showed that reducing tow waviness or overall laminate thickness alone had a negligible influence on bending-stiffness reduction.

Cohesive interactions between plies were found to play a pivotal role. Surface-based cohesive contact models revealed that slipping between plies initiated at moderate curvatures (around 0.07 mm^{-1}) and intensified with increased curvature, leading to bending plies independently further reducing the stiffness. Comparison of the modelled moment-curvature response against experimental results showed a good agreement, confirming the critical influence of slipping of plies and negligible non-linear geometric effect on the bending performance of thin woven composites. Notably, cohesive slip occurred more prominently where transverse tows prevented sufficient stretching, highlighting the anisotropic nature of deformation within the laminates. The study concludes that the reduction of bending stiffness in thin woven fibre composites under high curvatures is mainly due to slip between the structural constituents.

Future research is recommended to extend the current model by incorporating damage initiation and propagation in the resin phase to capture post-slipping behaviour more accurately. This research enhances the predictive capability for the design and analysis of deployable composite structures, offering vital new insights for aerospace applications where precise mechanical behaviour under extreme folding and deployment conditions is critical.

Keywords: Thin woven fibre composites, Large curvatures, Bending stiffness reduction, Nonlinear geometric effects, Inter-tow slippage

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