HOMOGENISATION OF ULTRA-THIN WOVEN FIBRE COMPOSITE STRUCTURES UNDER HIGH CURVATURES

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Utilising fibre-based textile structure as the composite reinforcement results in making composite more tailorable and effective for applications where various types of loads are anticipated to be supported by the structure. Owing to that, growing demand for ultra-thin woven composites can be identified in weight-sensitive applications, especially in space engineering applications such as self-deployable structures. Both complex geometry and non-linear behaviour of constituents of these composites make it more difficult to forecast the overall mechanical behaviour. Multiscale modeling approach can be identified as a popular strategy to overcome this issue where several models at various scales are utilised simultaneously to describe the system. For woven fibre composites, considered scales are micromechanical, meso-mechanical and macro-mechanical scales.

Physical experiments revealed in the literature that these ultra-thin structures have experienced a significant drop in bending stiffness when subjected to extreme curvatures. This is a numerical study in meso-mechanical scale on the homogenised response of two-ply plain woven carbon fibre composites considering the inter-connection behaviour between contact surfaces within the ply and in between two plies. With dry fiber geometry and resin pocket introduced geometry, two distinct models were used in the analysis. To estimate the behaviour under higher curvatures, the study has been advanced further into the non-linear regime.

Due to the severe curvatures that these ultra-thin woven composites are subjected to, slippage behaviour between yarns and between plies may take place, which would result in a drop in bending stiffness at those higher curvatures. Surface based cohesive constraints were defined to simulate the slipping behaviour using linear elastic traction-separation stiffness values.

The dry fibre model captured the bending stiffness and Poisson's ratio with good accuracy while the resin model captured the shear response better than the dry fibre model. Axial stiffness predictions remained almost the same for both cases. It is demonstrated that the proposed models can accurately predict the nonlinear flexural behaviour based on the experimental findings. Both models have shown their ability to accurately capture the bending stiffness reduction up to a curvature value of 0.14mm^{-1} and the stiffness reduction was overpredicted beyond that point. Reason behind the overprediction can be the allowance of relative moment between plies which can lead to the loss of compatibility between two plies and hence, each lamina contributes separately to the second moment of area instead of full thickness.

Further development of resin model to capture both in-plane and out of plane properties in a single model can be recommended for future studies and also the effect of relative movement of plies to the second moment of area of laminate is recommended for further studies.

Keywords: Cohesive behaviour, Multiscale modelling, Non-linear bending behaviour, Representative unit cell, Woven fibre composites

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