Computational generation of NCF RVE geometries for multi scale simulations

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Non-Crimp Fabric composites (NCF's) consist of unidirectional layers of fibers assembled by a stitching yarn in the direction vertical to the layers. NCF's are characterized by their high in-plane stiffness and large resistance to delamination. However, the stitching process causes out-of-plane undulations, elliptical stitching holes and nesting of UD lamina in these holes. These heterogeneities alter the mechanical properties of NCF and more importantly, they create stress concentrations leading to earlier damage initiation and propagation.

Up to now, these heterogeneities have been approximated by a priori analytical CAD geometries where the shape and size of the heterogeneities are determined from NCF specimens [1]. Therefore, a computational generation tool is proposed which is able to predict and model the arbitrary shape of fiber bundles in NCF's for different stitching parameters. The RVE generator is based on distance field calculations and is an extension of the work prescribed in [2] for specific NCF features.

The RVE generator is mainly geometry-based and starts from a set of discretized lines representing the stacking sequence and stitching yarns. The stiffness of the fibers and stitching yarns are implicitly taken into account as the number of line discretisations. No friction is included in the model. First, the discretized lines are tensioned in a simplified manner. Afterwards, the lines are contoured via extracting the outer facets from a Delaunay Triangulation of the vertices of the discretized lines. Last, a Level set-based post processing is used to prevent interpenetrations of geometrical entities. The meshing of the geometry is performed in GMSH.

The RVE generator is able to predict the shape of the stitching holes and out-of-plane undulations for various stitching parameters and stacking sequences. Furthermore, it allows to investigate the effect of these heterogeneities on the stress concentrations. The RVE generator will be further illustrated by performing a parametric study of the different stitching parameters on the in-plane stiffness and the stress concentrations.

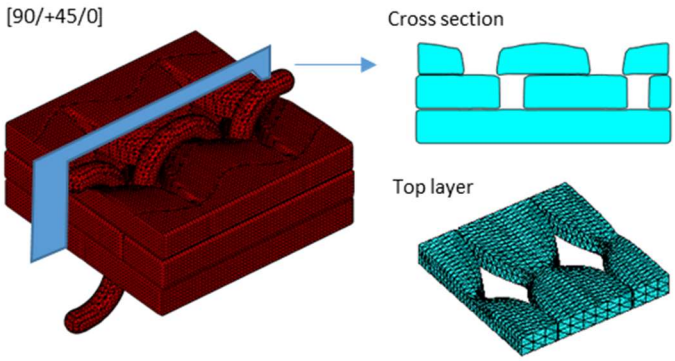

Figure: shape of fiber bundles in NCF obtained by the computational generation procedure.

[1] Zeng, Xuesen, et al. "Geometrical modelling of 3D woven reinforcements for polymer composites: Prediction of fabric permeability and composite mechanical properties." Composites Part A: Applied Science and Manufacturing 56 (2014): 150-160.
[2] Sonon, Bernard, and Thierry J. Massart. "A Level-Set based Representative Volume Element generator and XFEM simulations for textile and 3D-reinforced composites." Materials 6.12 (2013): 5568-5592.