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INDEPENDENT MESH METHOD AND RX-FEM MODELING OF 3D INTERLOCK WOVEN COMPOSITES WITH OPEN HOLE

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ABSTRACT

Textile composite materials represent a vital class of materials utilized in aerospace structures. There are many potential advantages to using 3D woven composites including near-net-shape preforms, potentially lower cost for complex shapes, through-thickness property tailoring, and higher delamination resistance. These composites introduce additional geometric complexities compared to 2D textiles and unidirectional composite materials. Predicting the performance of such composites requires explicit consideration of the fiber tow architecture, i.e., mesolevel analysis.

The three general steps to damage modelling of 3D textiles are developing a realistic 3D fiber morphology for a given textile; meshing the model in such a way that will be fine enough to adequately allow damage development by using techniques, such as cohesive zone modelling, but feasible; and finally applying a progressive damage methodology previously verified and validated for other simpler composite architectures such as laminates. The Virtual Textile Morphology Suite (VTMS) developed by Zhou, et al. [1] was employed to generate realistic 3D textile morphologies. VTMS allows a user to build a textile preform, fiberize the tows using many smaller fibrils, and then perform several operations like those in the composites manufacturing process including virtual molds and virtual vacuum bagging. Following these processes, the fiberized tows have surfaces fit to them and then solid tows are generated. These solid tows are then clipped and meshed using linear hexahedral elements. These clipped tows can be exported to other programs for meshing and other applications. While tetrahedral meshing can be used to generate a conforming mesh through the volume, such a task remains extremely difficult to perform to date. To alleviate the burden of conforming meshes, an Independent Mesh Method (IMM) was proposed by Iarve et. al. [2] which uses a combination of independent nonconforming meshing of the tows and cut element-based approach to model complex textile geometries that may otherwise not be meshed using traditional methods. This methodology was demonstrated to correlate well with experimental strain fields calculated via moiré interferometry as well as provide accurate failure prediction in the unnotched 3D woven composites [3].

In the present work, 3D interlock woven composites with central Open Hole (OH) will be considered. The key difference between the approach to unnotched composites described in [3] and the present work is the implementation of a global-local analysis methodology based on ideas of IMM. The previous work [3] included failure prediction of approximately 22.5 mm by 11.1 mm meso representative volume element (RVE) under semi-periodic boundary conditions, which resulted in good correlation with the unnotched behaviour. In the present work a significantly larger, approximately 25.4mm by 38.1 mm, meso level tow architecture volume was embedded in a macro model of the test specimen in the central location containing the OH. The schematic of the model is shown in Figure 1.

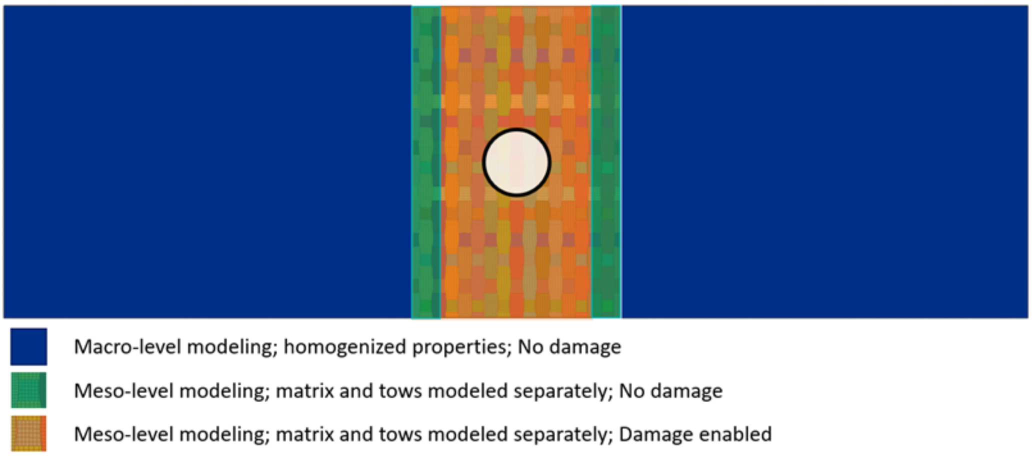

Figure 1: Schematics of the global-local model developed for OH strength prediction in 3D interlock woven composite

First a macro model of the test specimen is created containing a single mesh and two property partitions. The dark blue section of the micromodel contains homogenised properties and allows no damage development. The rest of the macro model has the properties of the neat resin of the textile and contains the interlock fiber tow architecture embedded by using IMM. Note that there is no partition between the two regions, which would correspond to the boundary between the dark blue and green region in Figure 1. Instead, the macro mesh is refined to accommodate the meso architecture in the central region. Despite the blended mesh between the homogenized and meso model regions the transition region still results in stress concentration and therefore the damage evolution is not permitted near the transition, i.e., in the green region. A mesh subtraction capability of VTMS is used for virtual hole drilling at the desired location.

Regularized Extended Finite Element Method (Rx-FEM) specifically outlined in [3] in application to textile composites is utilized for progressive failure analysis of the OH textile composites. Static tensile and compression loading was considered, and the results showed good correlation with the experimental data.

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