IN-PLANE MECHANICAL PROPERTIES OF VECTRAN-STitched COMPOSITES BY HOMOGENIZATION METHOD

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Summary. Meso-model of Vectran-stitched composites derived from optical observation is proposed, and finite element method is employed to evaluate in-plane mechanical properties. Carbon/epoxy fabrics with 20-ply of [+45/0/-45/902/+45/0/-45/90]s lay-up are stitched with high-strength stitching yarn, namely Vectran. Stitched composite is represented by representative volume element (RVE) of four-ply meso-model. The model consists of fiber tows, resin channels and stitching yarn (z-direction fibers). In-plane properties of stitched composites obtained from FE analysis is compared with tension test results. It is found that, for instance, the stiffness obtained by FE analysis is in a good agreement with experiment. Important parameters affecting elastic, e.g. fiber volume fraction (V_f) of fiber tows and fiber undulation, are also studied.

1 INTRODUCTION

Stitched composites have gained popularity due to their ability to improve impact resistance and interlaminar strength by reducing the growth of delamination. Stitching, however, may affect the in-plane mechanical properties of composites since it gives rise to the formation of defects such as fiber undulation, resin pocket/channels and fiber breakage. These geometrical complexities require a three-dimensional analysis. Present paper discusses the evaluation of in-plane mechanical properties using homogenization methods. The mechanical properties of interest are elastic modulus (E_{11}), Poisson’s ratio (\nu_{12}) and shear modulus (G_{12}). Tensile test is also performed to validate the numerical results.

2 MESO-MODEL OF STITCHED COMPOSITES

The derivation of meso-scale model of stitched composites can be seen in Figure 1 (a) – (d). The model is derived from the microscopic observation. It is also assumed that stitched
composites consist of periodic meso-structure as shown in Figure 1(c). From this meso-structure, a finite element model with four plies is built (Figure 2(a)). To obtain stiffness in x-direction, for instance, a displacement $du = 0.1$ mm is applied, while other sides of model are constrained in their normal direction. Averaged stress $\sigma_l$ is obtained by extracting total reaction force and divide it by area. The macro-strain is readily obtained by $\varepsilon_l = du/L$, whereby $L$ is the length of the model.

![Figure 1: (a) T800 carbon/epoxy Vectran-stitched composites, (b) top-view of stitched composites, (c) segment of stitched composites for meso-modeling, (d) in-plane view of meso-model of stitched composites](image)

Figure 1: (a) T800 carbon/epoxy Vectran-stitched composites, (b) top-view of stitched composites, (c) segment of stitched composites for meso-modeling, (d) in-plane view of meso-model of stitched composites

![Figure 2: (a) Finite element unit cell model of stitched composites, (b) local stresses in 1-direction $\sigma_{11}$, (c) local strains in 1-direction $\varepsilon_{11}$](image)

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### 3 RESULTS

The elastic modulus obtained by standard homogenization method is in a good agreement with experiments. Elastic modulus obtained from FE analysis is 52.2 GPa, whilst that obtained from tensile test is 50.5 GPa. The small difference of elastic modulus implies that incorporating fiber tows, stitching yarns and resin channels into the meso-model are deemed important in this regard.

Since this is work-in-progress, which is just started a few months ago, additional data such as the comparison with other homogenization method (asymptotic expansion) and more experimental results will be included in the full paper upon acceptance.