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# MULTISCALE COMPUTATIONAL HOMOGENISATION OF 3D TEXTILE-BASED FIBER REINFORCED POLYMER COMPOSITES

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This paper presents a multiscale computational homogenisation approach for the calculation of homogenised structural level mechanical properties of 3D textile/woven based fiber reinforced polymer (FRP) composites. Textile or woven composites, in which interlaced fibres are used as reinforcement, are a class of FRP composites which provide flexibility of design and functionality and are used in many engineering applications, including ships, aircrafts, automobiles, civil structures and prosthetics [1]. The more recently developed 3D-textile composites, consisting of 3D arrangements of yarns in a polymer matrix, allow weaving of near-net-shape and complex structures as compared to the traditional 2D-textile composites. In addition, these 3D-textile composites provide high through-thickness mechanical properties, lower manufacturing cost and improved impact and delamination resistance. The macro or structural level mechanical properties of these composites are rooted in their underlying complicated and heterogeneous micro structures. The heterogeneous microstructure of these composites requires a detailed multiscale computational homogenisation, which results in the macroscopic constitutive behaviour based on their microscopically heterogeneous representative volume elements (RVE). Elliptical cross sections and cubic splines are used respectively to model the cross sections and paths of the yarns within these RVEs. The RVE geometry along with other input parameters, e.g. material properties and boundary conditions, are modelled in CUBIT/Trelis using a parameterised Python script.

The multiscale computational homogenisation scheme, with a unified imposition of RVE boundary conditions, is implemented in MoFEM (Mesh Oriented Finite Element Method) [2], which allows convenient switching between linear displacement, uniform traction and periodic boundary conditions. MoFEM utilises hierarchic basis functions [3], which permits the use of arbitrary order of approximation leading to accurate results for relatively coarse meshes. The matrix and yarns within the RVEs are modelled by considering isotropic and transversely isotropic materials models respectively. The principal direction of the yarns required for the transversely isotropic material model is calculated using a computationally inexpensive potential flow analysis along these yarns. Furthermore, the computational framework is designed to take advantage of distributed memory high-performance computing. The implementation and performance of the computational tool is demonstrated with a variety of 2.5D and 3D woven based FRP composites including 3D orthogonal interlock, 3D orthogonal layer-to-layer interlock, 3D orthogonal through-the-thickness angle interlock, 2.5D layer-to-layer angle interlock and 2.5D layer-layer angle interlock [4].

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