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Virtual Testbed for Numerical Homogenization of Elastic Behaviour and Damage Initiation in Bidirectional Composites

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ABSTRACT

Researchers and industrial partners have shown increased interest in novel 3D composite fabric architectures such as non-crimped, bidirectional (BD) and multidirectional (MD) architectures reinforced in the third direction by pinning, tufting, stitching, 3D braiding and knitting , as well as 3D weaving (orthogonal, layer-to-layer and angle interlock). The case for widespread use of these composites, as against traditional layered prepreg composites, is strengthened by higher interlaminar shear strength, better damage tolerance and impact resistance, and balanced in-plane properties [1]. Another driver to the widespread use of these composites results from their flexible processing capabilities including efficient manufacturing processes such as resin infusion technologies.

To ensure sustained use of advanced composites structures, there is a need to develop predictive constitutive models that predict deformation from small strains to the onset of failure and subsequent damage evolution. These are challenging tasks, and substantial research efforts both in universities and industry are being directed towards it. In this study, the adopted approach comprises numerical modelling informed by a 'virtual testbed' [2]. Incorporating a virtual testbed into the model development creates a possibility of assessing diverse and complex load cases which normally will have been difficult to replicate in real experiments. Consequently, the total number of real experiments for model development and validation can be reduced significantly. In this approach, a representative domain consistent with given material architectures at a relevant length scale (meso-II) is selected. The meso-II-scale represents the ply-level length scale of the given composite material (Figure 1). The corresponding representative volume element at the macroscopic scale will require homogenized elastic properties [3] as well as information on damage initiation and evolution generated at meso-II scale.

A three stage homogenization procedure is adopted to include: *Meso-II-scale Model Verification, Meso-II-scale Virtual Testing* and *Macro-scale Virtual Testing* (Figure 2). The *Meso-II-scale Model Verification* assesses the mechanical response of a given UD architecture using the Oxford UD damage model [4]. As a next development level, the *Meso-II-scale Virtual Testing* refers to a BD architecture modelled with a UD damage model. The aim of this stage is to obtain insights into the mechanical response of the BD system. The *Macro-scale Virtual Testing* stage simulates the behaviour of a BD architecture using a BD model verified by comparison between the meso-II-scale and

macro-scale virtual test cases. Initial results show that the proposed virtual testbed provides a reliable route for establishing elastic properties and defining damage initiation and evolution at macro-scale. This is set to provide the basis for development of homogenized macro-scopic constitutive model(s) for BD composites. This paper presents initial results of the virtual testing at meso-II-scale thus providing information on the elastic properties and damage initiation in BD composites.

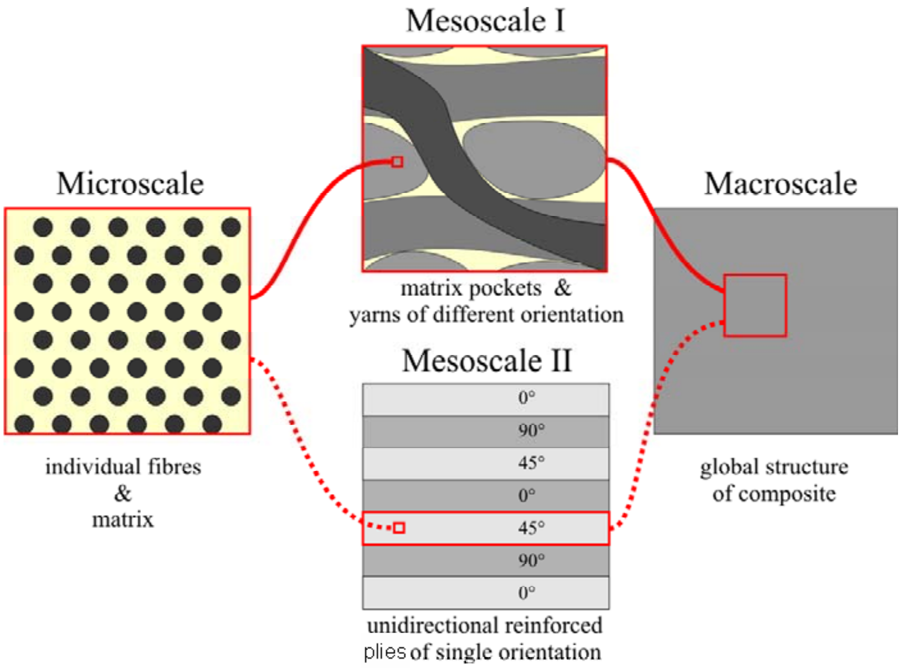

Figure 1: Associated Length scales for the Model Development.

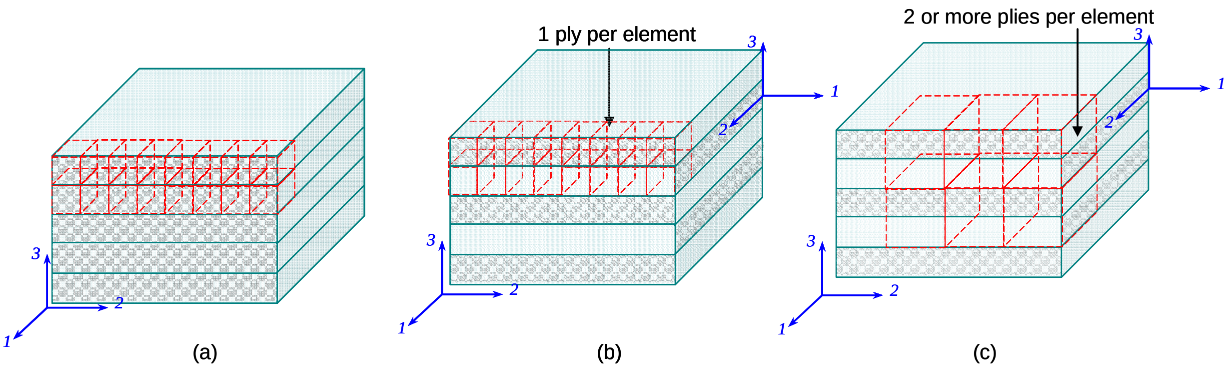

Figure 2: Three-stage Model Development: (a) Meso-II-scale Model Verification (b) Meso-II-scale Virtual Testing and (c) Macro-scale Virtual Testing

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