A biphasic continuum model for large deformation visco-elastic mechanics of uncured carbon fibre prepregs

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Abstract

Composite materials are widely used in high value manufacturing industries like aerospace and auto- motive. However, they are often compromised by high costs, long development time, and poor quality due to manufacturing defects. Therefore, numerical simulation for composite manufacturing processes has attracted much attention in academic and industrial communities, with the twin objectives of improving product quality and decreasing production time.

Typically, carbon fibre composite components are made by layering a series of thin carbon fibre layers, pre-impregnated with resin, onto a tool surface. During this lay-up process the stack of plies is consolidated at moderate temperatures and pressures to remove air trapped between layers. The consolidation of composite laminates prior to curing strongly influences the formation of defects such as wrinkles, folds, and in-plane waviness, which ultimately hinder the components structural integrity.

The deformation of uncured composite laminates is complex. It depends on the individual constitutive behaviour of the plies and interface, as well as the geometric constraints that arise from the layers fitting and moving together. Theoretically, uncured composites can be modelled using detailed finite element calculations in which each layer and interface is defined explicitly [1]. Experimental characterization have led to much better understanding of the shearing, bending, flow and consolidation mechanics of uncured laminate composites [2]. This data has been parameterized largely via simplified heuristic models [3] and have yet to be translated into rigorous 3D continuum models.

At In this study, we have developed a new continuum model for uncured carbon fibres plies to capture the non-linear visco-elastic behaviour of uncured laminates considering shear, bending, flow, and consolidation mechanisms based on the recent experimental characterization results [4]. The model is developed from a biphasic continuum theory [5] allowing for coupling between the solid and fluid responses. It includes the deformation mechanisms of the fibres as an anisotropic hyper-elastic material as well as resin flow through the fibre network. This model is then implemented as an user-defined material subroutine (UMAT) for ABAQUS package and also within the high performance finite element framework called Dune-composites. This work is the first part of a larger research effort to develop an efficient multi-scale numerical framework for composite manufacturing process of full scale components.

Keywords: **Finite element analysis (FEA), Consolidation, Process modelling**

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