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Predicting the non-linear mechanical response of triaxial braided composites

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Abstract

In this paper, the non-linear mechanical response of triaxial braided composites under multiple loading conditions was investigated with a meso-scale simulation strategy. Numerical predictions made by three-dimensional finite element unit cells with a realistic internal geometry in two nesting configurations correlated well with experimental stress-strain curves and damage mechanisms. Although the investigated braid topologies exhibited considerable geometric variability, the unit cell modelling approach with a compacted geometry model built from average input parameters was capable of correctly predicting the homogenised constitutive response, localisation, and damage evolution. Further, the mechanical response was predicted under variable uni-axial off-axis load cases and the effect of the textile topology on the ultimate strength of the material was investigated. Aside from providing a valuable insight into how damage propagation is affected by the meso-structure, the predicted stress-strain curves can be used to calibrate macroscopic material models suitable for large-scale crash simulations of textile composites.

Keywords: A. Fabrics/textiles; C. Damage mechanics; E. Braiding; Unit cell

1. Introduction

As a result of tight constraints on manufacturing costs and cycle-time in the industry, braided composites have recently been receiving increased attention. Aside from significant processing advantages over traditional laminates, their high specific energy absorption and excellent damage tolerance characteristics make them an ideal choice for designing primary load-carrying structures [1]. The accurate prediction of their non-linear mechanical response, however, remains a challenging task. Owing to the inherent textile nature with its out-of-plane waviness, interacting fibre bundles, resin pockets, and nesting of compacted plies, the material exhibits a complex failure and damage behaviour. In light of the fact that the textile architecture can vary significantly on a composite component with a multitude of parameters effecting the material properties, the determination of robust material properties by experimental test campaigns is highly cost- and time-intensive.

Finite-element (FE) modelling of mesoscopic unit cells provides powerful means for investigating the material behaviour of braided composites via virtual testing. In textile composites, a representative domain of the internal geometry is considered wherein the constituent reinforcing yarns are explicitly rendered as homogeneous continua. This approach can be applied to a variety of problems, ranging from the simulation of a dry fabric to the composite mechanical

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