Multi-scale Modeling of Braided Textile Composites under Compressive Loads

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Abstract

Textile composites are attractive replacements for conventional pre-preg based laminates due to reduced manufacturing costs, ease of producing components to specific shapes and increased damage tolerance. Woven, braided and 3D textile composites are currently receiving a great deal of attention in the composite mechanics research community.

In this study, the compression response of 2D Triaxial Braided Composites (2DTBC) is investigated, with a specific focus on understanding post-peak behavior. 2DTBC has a well defined microstructure. Thus, it becomes necessary to consider two scales: macro-scale and micro-scale for the purpose of describing mechanical response, particularly with respect to modeling failure mechanisms. On the macro-scale, 2DTBC is regarded as a *homogenous* continuum while on the micro-scale, 2DTBC is regarded as a *heterogeneous* continuum-certain field variables can suffer discontinuities. The introduction of two scales immediately implies the existence of a unit cell, the smallest representative volume of material which reproduces the geometric structure of the material when expanded periodically. The Representative Unit Cell (RUC) then is defined as the smallest repeating structure in the textile composite material, based on geometry alone, and this is used as a repeat unit to represent the textile composite material. Figure 1 shows the microstructure of one, four, and nine RUCs. One aspect of the present study is to understand the smallest number of RUCs that are needed to represent the 2DTBC as a macro-continuum for the purpose of predicting post-peak compression response. It is clear that with perfect periodicity, one RUC suffices for computing the macroscopic linear *stiffnesses* of the material.

Experimental observations from previous studies have shown that matrix micro-cracking, and tow buckling, with attendant tow kinking are the dominant modes of failure in 2DTBC under compression. Consequently, the focus of the present study is to introduce appropriate modeling strategies for capturing the micro-cracking of the matrix and for reproducing the observed tow buckling when 2DTBC is subjected to compression. By carrying out coupon level tension and compression tests of the 2DTBC, it is possible to extract the matrix in-situ inelastic behavior (including micro-cracking and plasticity), in conjunction with a finite element model of 2DTBC. This information is used in performing a geometrically nonlinear compression response study of these models, and the post-peak softening behavior is captured as a structural instability of the 2DTBC microstructure.

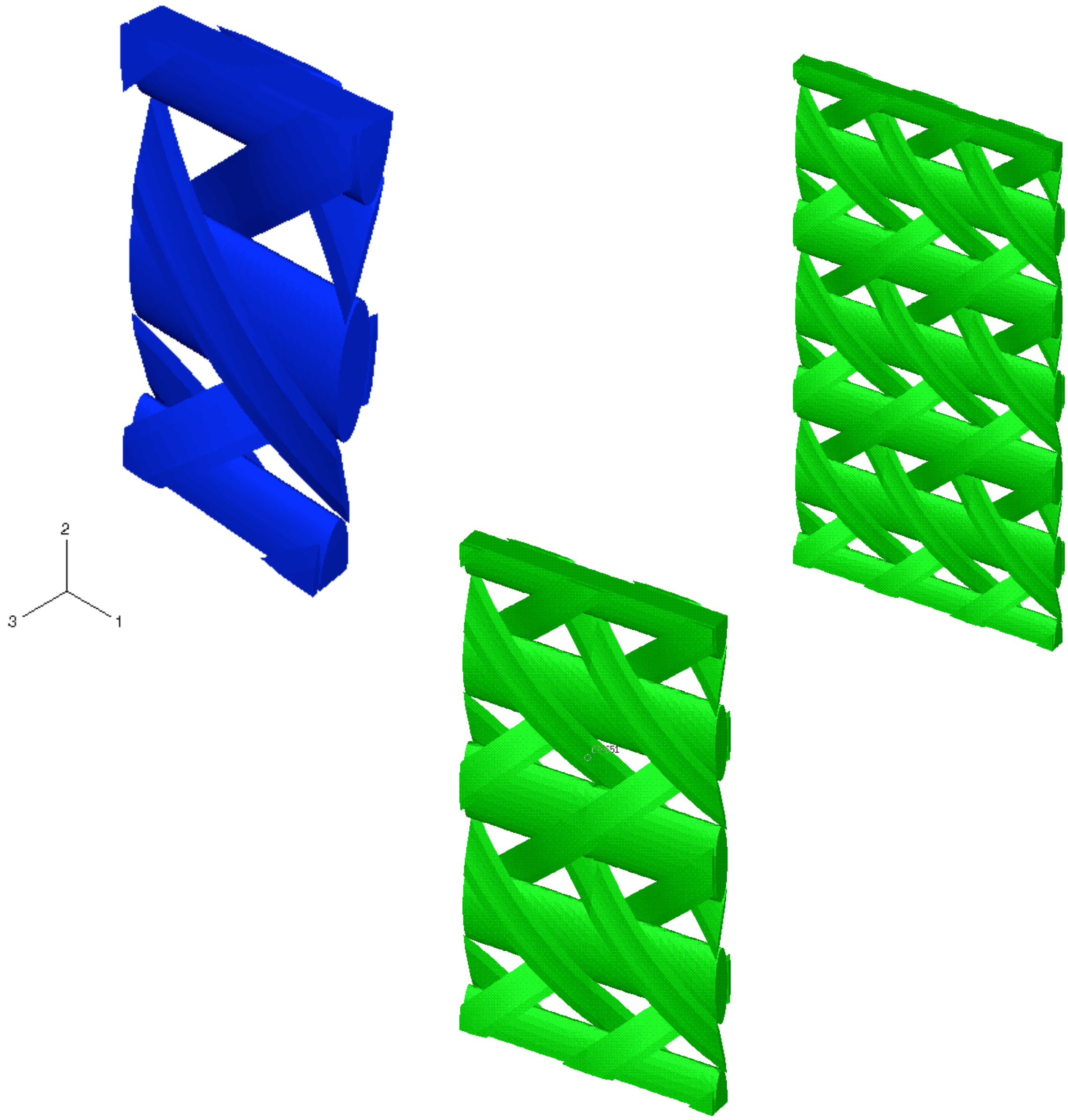

Figure 1 Microstructure of one, four, and nine RUCs