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Multiscale Modeling of Damage in Textile Composites

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Abstract : Textile composites, in which the reinforcing fibers are woven or braided, have become very popular in numerous applications in aerospace, automotive, and maritime industry. These textile composites are advantageous due to their ease of manufacture, damage tolerance, and relatively low cost. However, physics-based modeling of the mechanical behavior of textile composites is challenging. Compared to their unidirectional counterparts, textile composites introduce additional geometric complexities, which cause significant local stress and strain concentrations. Since these internal concentrations are primary drivers of nonlinearity, damage, and failure within textile composites, they must be taken into account in order for the models to be predictive. The macro-scale approach to modeling textile-reinforced composites treats the whole composite as an effective, homogenized material. This approach is very computationally efficient, but it cannot be considered predictive beyond the elastic regime because the complex microstructural geometry is not considered. Further, this approach can, at best, offer a phenomenological treatment of nonlinear deformation and failure. In contrast, the mesoscale approach to modeling textile composites explicitly considers the internal geometry of the reinforcing tows, and thus, their interaction, and the effects of their curved paths can be modeled. The tows are treated as effective (homogenized) materials, requiring the use of anisotropic material models to capture their behavior. Finally, the micro-scale approach goes one level lower, modeling the individual filaments that constitute the tows. This paper will compare meso- and micro-scale approaches to modeling the deformation, damage, and failure of textile-reinforced polymer matrix composites. For the mesoscale approach, the woven composite architecture will be modeled using the finite element method, and an anisotropic damage model for the tows will be employed to capture the local nonlinear behavior. For the micro-scale, two different models will be used, the one being based on the finite element method, whereas the other one makes use of an embedded semi-analytical approach. The goal will be the comparison and evaluation of these approaches to modeling textile-reinforced composites in terms of accuracy, efficiency, and utility.

Keywords : multiscale modeling, continuum damage model, damage interaction, textile composites
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