Material Model Simplifications for Multiscale, Progressive Damage Modeling of Satin Weave Composite Structures

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Abstract

Multiscale material models that are used in finite element simulation of woven composite structures require the use of some form of coupling between the structural level finite element model and the micromechanical model that is used to represent the response of the woven composite material. The overall computational demands of the multiscale methodology depend upon *a)* the size and complexity of the micromechanical model used to define the woven composite material's response and *b)* the degree of coupling between the structural level finite element model and the micromechanical material model. In attempting to account for complex progressive damage behavior in the woven composite material, it is typically necessary to resort to a finite element micromechanical model of the woven composite material where stiffness degradation of the individual damaged constituent materials can be directly linked to anisotropic stiffness degradation of the woven composite material. This type of approach can be quite computationally demanding, especially in the case where the micro and macro finite element models are tightly coupled (i.e., the micromechanical finite element model must be solved for each integration point in the structural finite element model during each equilibrium iteration of the structural finite element model). For simple plain weave composites, the size of the representative volume element (RVE) is relatively small, but for satin weave composites, the size of the RVE can increase substantially,

thus increasing the computational demands that the micromechanical finite element model imposes on the structural finite element simulation.

In the present paper, we describe a novel multiscale simulation methodology for the progressive damage response of satin weave composite structures that is developed to be extremely fast and efficient without adversely affecting the accuracy of the structural simulation. These overall modeling attributes are achieved by a judicious combination of the following features:

a) a novel reduced-size finite element model of the satin weave composite material was developed to significantly reduce the computational time required to update the progressive damage response of the material,
b) damage and stiffness reduction of the composite material are predicted at the constituent material level using constituent average stress states which are obtained via macro/micro relationships that come directly from the reduced-size finite element model of the woven composite material,
c) the woven composite material's response is discretized into an adequate but finite number of discrete damage states which can be exhibited by the woven composite material which effectively permits the micromechanical model to be utilized prior to the structural level simulation to define the composite stiffness and the macro/micro relationships for all possible damage states that the woven material can exhibit.

In the present paper, we demonstrate the effectiveness of this multiscale simulation methodology, and we compare the results obtained with the reduced material model to those obtained with a micromechanical finite element model of the full-size RVE of the satin weave composite material. This comparison includes the overall structural response and overall damage evolution in the structure in addition to the damaged stiffness of the composite material and the resulting macro/micro relationships inherent in the two material models.