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Macro-Mechanical Damage Modeling of Fibrous Composite Materials Accounting for Non-Linear Material Behavior

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Abstract

In the present paper, a new macro-mechanical model for tracing damage-evolution in composite materials is proposed. The present model represents a new extension and a new approach to a previous model (Ghazi-Farid model), which can be applied for a general state of stress. The model is verified by comparing its results with those corresponding to Ghazi-Farid model for different composite materials and it seems to give very close correlations. The proposed model can be applied to both elastic and inelastic materials as well as generally orthotropic fibrous composite nonlinear-materials.

It was concluded that shear damage is always higher than any other damage types due to the high nonlinear-material shear behavior, which causes high plastic strain-energy density. Damage in a composite lamina causes a reduction in its stiffness. Therefore, a new quantum-damage variable is proposed: " tangential quantum-damage variable " to quantify the overall-damage in a composite lamina. Percentage reduction of composite stiffness depends mainly on the amount of resulting damage irrespective of fiber-orientation angle. So, a new trend for the behavior of composite materials is introduced which states that the relation between damage-evolution and corresponding stiffness-reduction follows a certain behavior and it is independent of fiber-orientation. Each composite material has a unique trend which is verified using three different composite materials; Boron-Epoxy-Narmco 5505, Graphite-Epoxy 4617/Modmore-II, and Carbon-Epoxy AS4/3501-6.

A new damage-term is introduced as: "directional damage-variable", to simplify tracing damage in the case of a uniaxial off-axis loading. The new damage-variable was used to predict damage-evolution in the three laminas made of the indicated composite materials. It is concluded that, Graphite-Epoxy 4617/Modmore-II has the minimum damage at all stress levels and Boron-Epoxy-Narmco 5505 has the maximum damage. The importance of the new damage-term makes it easier to predict damage and make preferences between several composite materials subjected to uniaxial off-axis loading.