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Implementation and Validation of a Three-Dimensional Plasticity-Based Deformation Model for Orthotropic Composites

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Abstract

A new orthotropic elasto-plastic constitutive model has been developed to predict the inelastic response of composite materials under high velocity impact conditions. The model is driven by experimental stress-strain curve data stored as tabular input allowing for a very general material description. The theoretical details of the elasto-plastic deformation part of the material model are briefly summarized. This summary is then followed by details of the numerical implementation of the model as MAT213 (suitable for use with solid elements) into the commercial transient dynamic finite element code, LS-DYNA. The theoretical basis and the numerical implementation of the constitutive model are validated by using two sets of validation tests involving a widely used unidirectional composite, T800/F3900 - composite laminates used in coupon level tests and a low velocity impact test on a flat panel. Results show that the implementation is efficient, robust and accurate.

Keywords: Polymer-matrix composites; Plastic deformation; Finite element analysis; Impact behavior

1.0 Introduction

Composite materials are now beginning to provide uses hitherto reserved for metals, particularly in applications where impact resistance is critical. Such applications include structures such as airframes and engine containment systems, wraps for repair and rehabilitation, and ballistic/blast mitigation systems. While material models exist that can be used to simulate the response of a variety of materials in these demanding structural applications under impact conditions, the mature material models have focused on simulating the response of standard materials such as metals [1, 2, 3], elastomers [4] and wood [5]. Material models to simulate the nonlinear and/or impact response of composites have been developed, but the maturity and capabilities of these models are at a much lower level than those that have been developed for standard materials. General constitutive models designed for simulating the impact response of composite materials generally require three components – an elastic and inelastic deformation capability that relates deformations to strains and stresses, a damage capability that captures the stiffness degradation of the material, and a failure capability. Incorporating these three components into a single unified model that is applicable for use for a wide variety of composite material systems and architectures is a significant challenge. In this section, the details of some of publicly available models are briefly discussed,

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