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Comparison of Two Progressive Damage Models for Studying the Notched Behavior of Composite Laminates under Tension

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Abstract

Two continuum damage models with different underlying assumptions are investigated to assess their predictive capabilities and limitations with respect to progressive intra-laminar damage in notched IM7/8552 CFRP composite laminates under tension.
The recently modified continuum damage model, CODAM2, implemented in LS-DYNA is compared to a Ladevèze-based damage model, ABQ_DLR_UD, implemented as a user-material model (VUMAT) in Abaqus/Explicit. Fundamental similarities and differences between the two models are first investigated by various single element simulation case studies before assessing their predictive capabilities at the more global coupon level. Over-height Compact Tension (OCT) tests with dispersed and blocked lay-ups as well as a wide range of scaled Center-Notched Tension (CNT) specimens are used to evaluate characteristic damage-related quantities such as strength, post-peak behavior and fracture energies. Experimental data are also used to further validate the two different meso-scopic damage models.
The results of this study clearly demonstrate the layups, geometries and loading conditions that are suitable for applying intra-laminar damage models with confidence to this class of CFRP material system. Conversely, the study shows limitations of the continuum damage modeling techniques and suggests strategies that can be used to address these drawbacks.

Keywords: Finite Element Analysis, Continuum Damage Mechanics, Progressive Damage Simulation, Meso-scale Modeling

1. Introduction

Progressive damage simulation in composite structures faces a large number of challenges due to the complex and interactive nature of the various failure mechanisms in the heterogeneous material. A comprehensive overview of Finite Element (FE) modeling strategies, commercially available software and future trends in the field has been provided recently [1].
While fully discrete crack models allow for representing physically realistic damage mechanisms and their interaction, they also lead to significantly increased computational cost and numerical complexity. State-of-the-art adaptive discrete methods based on partition of unity have emerged, namely the eXtended Finite Element Method (X-FEM) [2] or the Floating Node Method [3]. Examples for the successful use of such discrete computational methods in composite structures are the simulation of delamination migration [4], matrix cracking induced delamination [5], mesh-independent matrix crack modeling [6] or progressive failure in notched laminates [7].
Another FE modeling strategy for damage simulation in composites is to smear the structural response while maintaining the continuity of the FE mesh. Continuum Damage Mechanics (CDM) based

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