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PROCEEDINGS

Simulation of Tensile Progressive Damage in Thick Ply-Drop Composites with Open Holes

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ABSTRACT

The growing use of ultra-thick composite laminates in aerospace structures demands a deeper understanding of their unique damage mechanisms under tensile loading, which differ significantly from those of thin laminates. This study introduces a novel 3D progressive damage model combining solid elements, the LaRC05 3D failure criterion (enhanced with through-thickness in-situ strengthening effects), and a mixed-mode cohesive zone model (CZM) to predict interlaminar delamination. The model captures the interaction between in-plane damage and through-thickness failure modes in open-hole ultra-thick composites, and addresses stress redistribution, localized buckling, delamination migration, and in-situ strength enhancement. Mesh sensitivity analysis validates the robustness of the model under refined meshing near stress-concentrated regions. A quantitative linkage is established between stacking sequences, interlaminar normal/shear stresses, and delamination initiation, revealing that reduced interlaminar normal strength triggers early delamination and compressive strength degradation by up to 11%. The results highlight that thicker laminates exhibit pronounced "in-situ" strengthening effects and stress heterogeneity, leading to 0° ply micro-buckling near outer layers and 45° ply fiber fracture propagation. Furthermore, matrix cracks accelerate delamination depending on ply orientation, emphasizing the critical role of damage interaction in ultra-thick composites. This work provides a validated numerical tool for optimizing aerospace composite designs against progressive failure.

KEYWORDS

Ultra-thick composites; open-hole tensile failure; LARC05 failure criterion; cohesive zone model; delamination interaction

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