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TECHNICAL PAPER

First-ply failure load prediction of delaminated pre-twisted rotating composite conical shells

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Abstract

A finite element-based method for determining the first-ply failure (FPF) strengths of delaminated composite pre-twisted shallow rotating conical shells subjected to a central point load is presented in this work. The influence of transverse shear deformation and rotary inertia are accounted for in the eight-noded shell element employed in the present analysis based on Mindlin's theory. The delamination of the crack front is modeled using the multi-point constraint algorithm, while the initial stresses arising out of rotation are determined iteratively. The present study uses the maximum strain, maximum stress, Hoffman, Tsai–Hill, and Tsai–Wu failure criteria to arrive at the FPF loads. The results illustrate the effect of some vital parameters like stacking sequence, pre-twist angle, aspect ratio, presence and location of delamination, and rotational speed on the FPF in the delaminated composite conical shell with an initial twist. The spatial distributions of the stresses in the material directions and deflections identify the first-ply failure zones at the failure loads obtained. It is found that the FPF strengths increase on increasing the aspect ratio and non-dimensional rotational speed whereas the strength decreases with size and number of delaminations. The stresses developed at the FPF loads are lower in non-rotating conical shells compared to rotating shells.

Keywords Conical shell · Failure criteria · FEM · Delaminated composites · First-ply · Pre-twist

List of symbols

z	Mid-plane of the conical shell laminate.
R_y, R_{xy}	Chord-wise radius and pre-twist radius of the conical shell.
L, b_o, α_0, β_0, h, θ_v, θ_0	Span length, base width, major radius, minor radius, thickness, vertex angle, base subtended angle of the actual cone of which the conical shell is assumed a part of.
ψ, ω_z, Ω, ω_0	Pre-twist angle, rotational speed (rad/s), non-dimensional rotational speed ($\Omega = \frac{\omega_z}{\omega_0}$), angular speed at resonance.
d, d_1, L	Delamination size, span-wise location of the delamination center from the fixed end, span length of the conical shell.
h_{Del}	Delaminated ply location from bottom.
n_{d}	Number of delaminations (for multiple-delaminations).
E, G, ν, ρ	Young's modulus, rigidity modulus, Poisson's ratio and density.

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