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Transient Response of Delaminated Composite Conical Shells Due to Multiple Low Velocity Impacts in Hygrothermal Environment

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Abstract

This paper presents a finite element based method to investigate the hygrothermal effects on the transient dynamic response of delaminated composite pretwisted conical shells with initial twist impacted at arbitrary locations by multiple spherical impactors. An eight-noded shell element has been used in the present analysis based on the Mindlin's theory. The generalized dynamic equilibrium equation is derived from Lagrange's equation of motion neglecting Coriolis effect for moderate rotational speeds. The multi-point constraint algorithm has been incorporated to ensure the compatibility of deformation and equilibrium of resultant forces and moments at the delamination crack front. The indentation laws as proposed by Hertz have been implemented to compute the contact force and displacement arising from each impact on specific locations of delaminated conical shells already prestressed by residual thermal or moisture strains. Results have been presented to depict the influence of important parameters like, twist angle, size and location of delamination, velocity and mass of the impactors and the time-delay between the impactors on the multiple impact response of delaminated composite conical shells in hygrothermal environment.
Key words: Conical Shell, Hygrothermal, Finite Element, Delamination, Composite, Multi-point constraint, transient response, multiple impact.

1. Introduction

With the advent of modern technology composite materials are finding manifold applications in aviation, automobile and marine industries wherein fuel economy combined with high strength to weight ratio is highly desirable. The specific properties of composite materials can be easily tailored by varying the stacking sequence of the laminates. In general all composite structures are highly sensitive to various environmental factors like temperature variation, moisture diffusion, exposure to chemicals, radiations, thermal oxidation, and impact on the surface. The widespread applications of composite conical shells are faced with situations wherein the shells are impacted by foreign bodies of arbitrary shapes moving at relatively low velocities (typically less than 100m/s). Impact of masses moving at relatively low velocities with underwater vehicles, windmill blades, automobile or aircraft bodies, steam turbine blades or spaceships is quite common in actual practice. Low-velocity impacts may also occur during manufacturing, processing, maintenance or transportation of the composite laminates as in tool drop or rough handling. Micro-voids or cracks may result in hygrothermal environment from the internal strains present in the conical shells owing to the difference in the thermal or moisture expansion coefficients of the fiber and the matrix comprising the laminate. An impact with a foreign mass may result in the coalescence of such micro-voids at several sites inside the laminate. These

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