Brian L. Wardle
Boeing Assistant Professor of Aeronautics and Astronautics

Buckling and Damage Resistance of Transversely-Loaded Composite Shells
Brian L. Wardle
Dissertation, MIT, June 1998

Abstract

Experimental and numerical work was conducted to better understand composite shell response to transverse loadings which simulate damage-causing impact events. The quasi-static, centered, transverse loading response of laminated graphite/epoxy shells in a [±45n/0n]s layup having geometric characteristics of a commercial fuselage are studied. The singly-curved composite shell structures are hinged along the straight circumferential edges and either free or simply supported along the curved axial edges. Key components of the shell response are response instabilities due to limit-point and/or bifurcation buckling. Experimentally, deflection-controlled shell response is characterized via load-deflection data, deformation-shape evolutions, and the resulting damage state. Finite element models are used to study the kinematically nonlinear shell response, including bifurcation, limit-points, and postbuckling. A novel technique is developed for evaluating bifurcation from nonlinear prebuckling states utilizing asymmetric spatial discretization to introduce numerical perturbations. Advantages of the asymmetric meshing technique (AMT) over traditional techniques include efficiency, robustness, ease of application, and solution of the actual (not modified) problems. The AMT is validated by comparison to traditional numerical analysis of a benchmark problem and verified by comparison to experimental data. Applying the technique, bifurcation in a benchmark shell-buckling problem is correctly identified. Excellent agreement between the numerical and experimental results are obtained for a number of composite shells although predictive capability decreases for stiffer (thicker) specimens which is attributed to compliance of the test fixture. Restraining the axial edge (simple support) has the effect of creating a more complex response which involves unstable bifurcation, limit-point buckling, and dynamic collapse. Such shells were noted to bifurcate into asymmetric deformation modes but were undamaged during testing. Shells in this study which were damaged were not observed to bifurcate. Thus, a direct link between bifurcation and atypical damage could not be established although the mechanism (bifurcation) was identified. Recommendations for further work in these related areas are provided and include extensions of the AMT to other shell geometries and structural problems.