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Space Structures II - Development and Verification (Deployable and Dimensionally Stable Structures) (2)

Author: Mr. Andrew Gomez-Delrio
University of Central Florida (UCF), United States, agomez321@knights.ucf.edu

Dr. Kawai Kwok
University of Central Florida (UCF), United States, kawai.kwok@ucf.edu

VISCOELASTIC BEHAVIOR OF THIN-PLY COMPOSITES FOR DEPLOYABLE STRUCTURES

Abstract

Thin-ply composites have shown potential for improving performance of deployable structures for space applications due to its high mass efficiency, bending curvature, and deployed stiffness. Deployable structures made of thin-ply composites can be folded into a compact configuration for stowage and self-deploy to recover their initial, operational geometry in orbit. Since these structures rely on the stored strain energy for deployment, viscoelastic response of the composite is critical to the deployment reliability and accuracy. Previous experimental investigations have shown that stress relaxation of the polymer matrix during stowage could stall the deployment and reduce accuracy of the deployed shape. However, viscoelastic behavior of thin-ply composites has not been investigated sufficiently for analysis of deployable structures. In particular, computational models that consider anisotropic relaxation behavior and characterization methods of relaxation under high-curvature bending are not directly available.

This paper investigates the viscoelastic response of thin-ply composites both computationally and experimentally. Although viscoelastic properties of a composite are inherited from its polymer matrix, the reinforcement fiber architectures also significantly influence relaxation behavior. To avoid the computational cost of directly modeling the micro-scale fiber geometry in large deployable structure simulations, a micromechanical model of the thin-ply composites is employed. The model computes the ABD relaxation matrix of the composite based on the fiber and matrix properties. This matrix, a viscoelastic analog to the ABD stiffness matrix, is a function of time and temperature describing the anisotropic behavior of a thin composite plate. The computed ABD relaxation matrix is applied in finite element simulation of a composite plate undergoing folding, stowage, deployment and recovery. It is shown that the moment on the composite plate relaxes over time during stowage, and the shape accuracy during recovery is dependent on the stowage time and temperature. To validate the simulation results, experimental measurements of the moment relaxation and curvature variation over time are conducted using a special fixture. In this paper, the numerical implementation of the ABD relaxation matrix in finite element simulations via a user-defined subroutine will be presented. The accuracy of the model and the effects of stowage time and temperature will be discussed.