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IAF MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Space Structures - Dynamics and Microdynamics (3)

Author: Prof. Alfonso Pagani
Associazione Italiana di Aeronautica e Astronautica (AIDAA), Italy

Mr. Rodolfo Azzara
Politecnico di Torino, Italy
Ms. Marianna Valente
Politecnico di Torino, Italy
Prof. Erasmo Carrera
Associazione Italiana di Aeronautica e Astronautica (AIDAA), Italy

NONLINEARITIES AND HIGH ORDER EFFECTS ON MEMBRANES VIBRATION

Abstract

The design of membrane structures for aerospace applications such as solar sails, antenna reflectors, and habitat modules has become increasingly popular due to their thinness and inflatable or deployable nature. These structures are convenient to stow in a launcher, taking up minimal space, and once deployed in orbit they provide a large volume with a very low weight/volume ratio. To ensure the successful design and deployment of the structure, extensive structural analysis is necessary, including modal analysis to understand how the membrane will respond to vibrations. Despite the difficulty of the task, due to the nonlinearity of geometrical deformation, initial stress, and air-elastic effects, determining the natural frequencies and mode shapes is essential for proper verification and analysis of the structure. In this work, the results of modal analyses conducted on pre-stressed membrane shapes of a square, triangle and L-shape are presented. These solutions are developed under the Carrera Unified Formulation (CUF), which exploits a generalized kinematics that applies an arbitrary expansion to the generalized variables. The structures have been analysed using a low thickness shell model, and the results have been compared to analytical solutions for the simplest forms (square and triangle) and by using the commercial software ABAQUS for the more complex shapes, as only a semi-analytical solution is available. It was found that for the simpler shapes, the bending stiffness of the shell structures does not influence the natural frequencies and the system behaves like a membrane. However, for the L-shape membrane, the natural frequencies of the shell model are higher due to the bending stiffness. To assess this effect, the thickness of the L-shape plate was reduced until it produced the same frequencies as the membrane model analysed with ABAQUS. Furthermore, the impact of the kinematic theory along the thickness was evaluated by using various Taylor polynomials and Lagrange functions. The effects on the modal shape due to the ratio between the sides were evaluated, and it was found that mode aberration phenomena occur in some cases when the ratio is less than a certain value. The results document the good accuracy and reliability of the presented methodology and show this numerical tool's potentialities.