Paper ID: 6246
student

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

Author: Mr. Genyong Wu
Northwestern Polytechnical University, China

Dr. Xingsuo He
Northwestern Polytechnical University, China

GEOMETRICALLY EXACT 3D BEAM ELEMENT FOR ARBITRARY LARGE RIGID-ELASTIC DEFORMATION ANALYSIS OF AEROSPACE STRUCTURES

Abstract

Presented here is a new displacement-based total-Lagrangian modeling and finite element formulation of multibody systems with highly flexible beams undergoing large rigid-body movement and elastic deformation. The theory accurately accounts for geometric nonlinearities and initial curvatures of beams by using Jaumann strains, exact coordinate transformations, and orthogonal virtual rotations. In the theory, we use three Euler angles to describe the coordinate tranformation between deformed and undeformed coordinate systems. Nonlinear dynamic analyses of two flexible multibody systems are performed to demonstrate the proposed methodology and its accuracy, including a free-falling flexible beam, and a slewing beam with a tip mass. In the first case,we consider a titanium alloy beam free falling under its own weight, the beam is initially twisted and bended due to static loads, and has a initial velocity.For static analysis,the beam is subject to a pair of force F applied on the right-upper corner and left-bottom corner of the beam in y-axis, because the force is not applied on the center line, so twist and bending happens at the same time.After that, the beam is thrown in x-direction with a initial velocity of 1m/s, perform a free falling motion under its own weight. Torsional vibration and bending vibration can be seen from the figures during such a motion. In the second case,we consider the same beam with a tip mass being slewed about the vertical z-axis. The beam's pinned end is rotated with a constant angular velocity of per second to a position at θ=180 and then stop. Although the beam is slewing and hence bending in the x-y plane, this bending and the gravitational force along the z-direction cause the beam to bend along the z-direction and hence torsional deformation occurs.The deflection increase as the tip mass increase.Finally we consider the spin-up of a clamped-free flexible rotor blade starting from it static equilibrium position under a linearly increasing angular speed 2πt rad/s with respect to the vertical z-axis. It is clear that the centrifugal force due to spin-up raises up the rotor tip and increases its transverse vibration frequency when the spinning speed increases. A fully nonlinear displacement-based beam theory with finite-element discretization for multibody systems with highly flexible beams undergoing large rigid/elastic deformations is presented.Numerical results show that the proposed nonlinear beam theory and finite element formulation is accurate for analysis of multibody systems with highly flexible beams.