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Dynamics of Continuous Systems: From Time-Varying, Nonlinear, and Flexible Multibody Systems to Phononic Structures

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Abstract: Some interesting results on the dynamics of continuous systems are reviewed. They involve: 1) vibration and stability of translating media with time-varying lengths and/or velocities; 2) nonlinear vibrations of systems with large degrees of freedom and general nonlinearities; 3) new spatial discretization methods for one- and two-dimensional continuous systems; 4) new formulations of flexible multibody dynamics with application to elevator traveling cables; and 5) elastic wave propagation in nonlinear phononic structures. Two types of dynamic stability problems are addressed from the energy viewpoint in the first area: dynamic stability of translating media during extension and retraction, and parametric instabilities in continuous systems with periodically varying lengths and/or velocities. The incremental harmonic balance method is used in the second area to handle periodic responses of high-dimensional models of nonlinear continuous systems and their stability and bifurcations, as well as quasi-periodic responses. New spatial discretization methods in the third area ensures that all boundary conditions of continuous systems are satisfied, and hence uniform convergence of solutions. New nonlinear models of slack cables with bending stiffness and arbitrarily moving ends are developed for moving elevator traveling cables in the fourth area. A minimal number of degrees of freedom are needed to achieve the same accuracy as that of the finite element method. Wave propagation analysis of phononic structures with finite deformations are developed in the fifth area to study influences of nonlinearities on wave propagation characteristics. Some experimental results are presented to validate theoretical predictions.

Keywords: energy methods for finding dynamic stability of continuous systems with variable lengths and velocities, parametric excitation for second-order partial differential equations, nonlinear vibrations of systems with large degrees of freedom and general nonlinearities, new spatial discretization methods for continuous systems, and nonlinear wave propagation.

1. Introduction

All structural systems are continuous systems. While spatial discretization can be used to analyze the dynamics of continuous systems in some cases, spatially discretized, low-dimensional models can lead to misleading results. The goal of this research is to develop new methodologies to analyze the vibration of continuous systems, and to use the new methodologies to solve important industrial problems such as elevator systems. This work integrates vibrations of continuous systems, nonlinear vibrations, flexible multibody dynamics, and nonlinear wave propagation. Continuous system vibrations include time-varying translating media with variable lengths and/or velocities [1-5], and spatial discretization of continuous systems with complicated boundary conditions [6-8]. This deals with mostly time-varying linear systems with small deformations as well as nonlinear systems with intermediate deformations. Extensive nonlinear vibration research focuses on high-dimensional models of continuous systems with strong and complicated nonlinearities [9-13]. A new flexible multibody dynamics formulation with a minimum number of degrees of freedom is developed for continuous systems with large deformations with application to elevator traveling cables [14-16]. New methodologies for analyzing strongly nonlinear elastic wave propagation are also developed [17-19].

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