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Chaotic Vibrations of Beams: Numerical Solution of Partial Differential Equations

The objective of this paper is to examine the utility of direct, numerical solution procedures, such as finite difference or finite element methods, for partial differential equations in chaotic dynamics. In the past, procedures for solving such equations to detect chaos have utilized Galerkin approximations which reduce the partial differential equations to a set of truncated, nonlinear ordinary differential equations. This paper will demonstrate that a finite difference solution is equivalent to a Galerkin solution, and that the finite difference method is more powerful in that it may be applied to problems for which the Galerkin approximations would be difficult, if not impossible to use. In particular, a nonlinear partial differential equation which models a slender, Euler-Bernoulli beam in compression is solved to investigate chaotic motions under periodic transverse forcing. The equation, cast as a system of first-order partial differential equations is directly solved by an explicit finite difference scheme. The numerical solutions are shown to be the same as the solutions of an ordinary differential equation approximating the first mode vibration of the buckled beam. Then rigid stops of finite length are incorporated into the model to demonstrate a problem in which the Galerkin procedure is not applicable. The finite difference method, however, can be used to study the stop problem with prescribed restrictions over a selected subdomain of the beam. Results obtained are briefly discussed. The end result is a more general solution technique applicable to problems in chaotic dynamics.

Introduction

Researchers, during the last two decades, have been intrigued by the existence of aperiodic or randomlike responses resulting from periodic inputs to nonlinear, deterministic dynamical systems. The wealth of new problems which developed from these observations has led to a new branch of study termed chaotic dynamics. The so-called chaotic responses have been observed in a wide range of problems involving both iterated mappings and nonlinear ordinary differential equations which model physical phenomena. The problems have also come from a wide range of fields including engineering mechanics, fluid mechanics, biological sciences, chemistry, and plasma physics. As such, there have been papers and entire books written about the characteristics of chaotic systems. Helleman (1980), Pippard (1982), Abraham and Shaw (1982), Garrido (1982), and

Moon (1986, 1987) are just a few references which provide good general information about chaotic systems.

In structural mechanics, the first evidence of chaotic vibration in a buckled beam was recorded in the work of Tseung and Dugundji (1971). They solved the problem of a fixed, buckled beam in a two mode approximation by the harmonic balancing method. The beam was excited at the base without any transverse loading, and their observation of aperiodic responses to periodic excitation was verified with experimentation. Later, Holmes (1979) presented a study of the most basic model for a buckled beam, Duffing's equation. He also found chaotic responses, and his work laid the foundation for much of the subsequent chaos studies in structural mechanics. Moon and Holmes (1983), and Moon and Shaw (1983) next reported chaotic behavior in problems involving a cantilever beam with magnetic attractors at its free end, and involving a cantilever beam with a stop restricting the motion of its free end. A further extension was completed by Dowell (1982) when he predicted chaos in the flutter of a buckled plate governed by an autonomous system of ordinary differential equations.

At the present time, almost all studies pertaining to chaos have been restricted to the solution of simple iterated mappings and ordinary differential equations. Moore, Toomre, Knobloch, and Weiss (1983) were the first to solve a partial differential equation exhibiting chaotic behavior directly in their

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Chaotic Vibrations

Guangxuan Li



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Vibration of Structures and Machines Giancarlo Genta, 1999 This book addresses important aspects of nonlinear vibration analysis presenting cases of interest to researchers and engineers Developing the subject from its foundations the book takes readers through vibrations in linear systems and then into nonlinear vibrations including a treatment of chaotic vibrations

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Applied Mechanics Reviews, 1985 **Dynamics and Control of Technical Systems** José Manoel Balthazar, Paulo Batista Gonçalves, Stefan Kaczmarczyk, André Fenili, Marcos Silveira, Ignacio Herrera Navarro, 2014-12-17 Special topic volume with invited peer reviewed papers only **Chaotic Vibrations of a Nonlinear System with Five Equilibrium States** Guangxuan Li, 1984 **Forefronts**, 1985 **Shell Structures, Theory and Applications** Wojciech Pietraszkiewicz, Czesław Szymczak, 2005-09-22 Shells are basic structural elements of modern technology Examples of shell structures include automobile bodies domes water and oil tanks pipelines ship hulls aircraft fuselages turbine blades loudspeaker cones but also balloons parachutes biological membranes a human skin a bottle of wine or a beer can This volume contains full texts of over 100 papers presented by specialists from over 20 countries at the 8th Conference Shell Structures Theory and Applications 12-14 October 2005 in Jurata Poland The aim of the meeting was to bring together scientists designers engineers and other specialists in shell structures in order to discuss important results and new ideas in this field The goal is to pursue more accurate theoretical models to develop more powerful and versatile methods of analysis and to disseminate expertise in design and maintenance of shell structures Among the authors there are many distinguished specialists of shell structures including the authors of general lectures I V Andrianov Ukraine V A Eremeyev Russia A Ibrahimbegovic France P Klosowski Poland B H Kröplin Germany E Ramm Germany J M Rotter UK and D Steigmann USA The subject area of the papers covers various theoretical models and numerical analyses of strength dynamics stability optimization etc of different types of shell structures their design and maintenance as well as modelling of some surface related mechanical phenomena

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