



The Analysis of Higher Order Nonlinear Vibrations of an Elastic Beam with the Extended Galerkin Method

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Abstract

The analysis of vibrations of an elastic beam is one of the persistently challenging problems in engineering and mathematics. The differential equation of vibrations of a beam under large deformation, or the typical vibrations of an elastica, is hard to approximate and solve with the formulation in Cartesian coordinates. As a novel approach, the extended Galerkin method is used to obtain the first- to third-order nonlinear vibration frequencies of a cantilever beam with the exact equation of an elastic beam with larger deflection, and the governing equation is transformed for improved analysis and solutions with the mode shape function from the linear solution. The numerical results show that the approximate fundamental solution is accurate in comparison to the exact solution for small amplitudes. The effectiveness of the extended Galerkin method in solving nonlinear vibration equations is further demonstrated with a novel procedure.

Keywords Nonlinear · Beam · Elastica · Galerkin · Vibration · Frequency

Introduction

The deformation of an elastic beam under static and dynamic loads is important as a typical problem of engineering applications and a challenge in mathematical methods. Mainly, if a large deformation occurs and the simplified beam equation, popularly known as the Euler–Bernoulli beam theory, is not enough to provide accurate solutions to satisfy the mathematical and application needs, additional efforts have to be devoted to accurate solutions with efficiency. This, of course, has been demonstrated in the development of beam theories as there is tremendous literature on the simplifications in addition to the accurate solutions of elastic beams with exact solutions in elliptical function. Many prominent scientists have constantly attempted the problem with the time spanned hundreds of years. Notably, it should be noted that the correct beam equation is the contribution of Love [1], and Bishopp and Drucker have made subsequent

approximations for the popular expression and solutions available from textbooks and applications [2–4]. By making it an elastica problem [5, 6], many leading mathematicians such as Bernoulli, Euler, and Newton, among many others, studied and contributed to the available solutions and methods for centuries up to today [7–13]. The improved analysis with large deformation has to be obtained with the accurate beam equation, which is further simplified with the adoption of the Eulerian coordinates of a beam, as shown in many studies [14, 15]. These solutions have also been acquired with many methods developed in the centuries of studies of differential equations of similar nature. Mainly, it is necessary to point out that the elliptical function solutions by Painvin [16] have been helpful in providing the exact solutions as the reference in the subsequent studies [17, 18]. Lately, the homotopy analysis method (HAM) by Liao has been utilized for studies to demonstrate explicit solutions through an iterative process with convergent results for some large parameters [19–22]. Other methods, including the finite-element method, have also been used for new solution procedures and results to demonstrate the effectiveness of methods in solving such typical nonlinear differential equations [23, 24]. The problem of a cantilever beam has been used as the benchmark to test new methods and solution techniques [3, 25–28].

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such the failure of these gates can have disastrous consequences and it is imperative to develop new methods to avoid these occurrences Dynamic Stability of Hydraulic Gates and Engineering for Flood Prevention is a critical reference source containing scholarly research on engineering techniques and mechanisms to decrease the failure rate of hydraulic gates Including a range of perspectives on topics such as fluid dynamics vibration mechanisms and flow stability this book is ideally designed for researchers academics engineers graduate students and practitioners interested in the study of hydraulic gate structure

Vibrational Mechanics: Nonlinear Dynamic Effects, General Approach, Applications Iliya I Blekhman,2000-01-15 This important book deals with vibrational mechanics the new intensively developing section of nonlinear dynamics and the theory of nonlinear oscillations It offers a general approach to the study of the effect of vibration on nonlinear mechanical systems The book presents the mathematical apparatus of vibrational mechanics which is used to describe such nonlinear effects as the disappearance and appearance under vibration of stable positions of equilibrium and motions i e attractors the change of the rheological properties of the media self synchronization self balancing the vibrational maintenance or deceleration retardation of the rotation of unbalanced rotors resonances in the motions of celestial bodies vibrational displacement and shift vibrational excitation of streams and the transportation of bodies in the fluid The book considers the use of these effects in creating new vibrational machines technologies and also principally new materials dynamical materials Vibrational Mechanics contains many results published only in Russian and therefore unknown to the specialists in the West and also a review of the new results obtained by researchers after the book was first published in Russia

An Analysis of a Nonlinear Mechanical Vibration Problem Ernest Cary Bryan,1960

Harmonic Balance for Nonlinear Vibration Problems Malte Krack,Johann Gross,2019-03-23 This monograph presents an introduction to Harmonic Balance for nonlinear vibration problems covering the theoretical basis its application to mechanical systems and its computational implementation Harmonic Balance is an approximation method for the computation of periodic solutions of nonlinear ordinary and differential algebraic equations It outperforms numerical forward integration in terms of computational efficiency often by several orders of magnitude The method is widely used in the analysis of nonlinear systems including structures fluids and electric circuits The book includes solved exercises which illustrate the advantages of Harmonic Balance over alternative methods as well as its limitations The target audience primarily comprises graduate and post graduate students but the book may also be beneficial for research experts and practitioners in industry

Wind Power Technology Alois Peter Schaffarczyk,2023-06-16 This textbook provides in depth treatment of all systems associated with wind energy including the aerodynamic and structural aspects of blade design the flow of energy and loads through the wind turbine the electrical components and power electronics including control systems It explains the importance of wind resource assessment techniques site evaluation and ecology and describes the integration of wind farms into the electrical grid The reader will also become familiar with the offshore technology the youngest and most promising aspect of wind

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Nonlinear Vibrations in Mechanical and Electrical Systems James J. Stoker (Mathematiker, USA),1957

Mechanical Vibrations S. Graham Kelly,2022-07-25 Mechanical Vibrations Theory and Applications presents the basic principles of engineering vibrations and introduces students to a strategic framework to advance their knowledge and skill in engineering problem solving The opening chapter reviews key topics including mathematical modeling dimensional analysis dynamics and more Chapter 2 focuses on the elements that comprise mechanical systems and the methods of mathematical modeling of mechanical systems Two methods for the derivation of differential equations for a linear system are presented the free body diagram method and the energy method Chapters 3 through 5 focus on single degree of freedom SDOF systems Chapter 3 concentrates on free vibration of SDOF systems Forced vibration of SDOF systems is covered in Chapter 4 harmonic excitation and Chapter 5 general transient excitation Chapter 6 is focused on free and forced vibration of two degree of freedom systems Chapters 7 through 9 cover general multiple degree of freedom MDOF systems Chapter 7 concentrates on the derivation of differential equations governing MDOF systems Chapter 8 concentrates on free vibration whereas Chapter 9 covers forced vibration The final chapter provides a brief overview of vibrations of continuous systems Mechanical Vibrations Theory and Applications is designed to serve as a primary textbook for advanced undergraduate courses on vibrations Chapters 7 through 10 are appropriate for use as a standalone resource for graduate level courses

Introduction to Experimental Nonlinear Dynamics Lawrence N. Virgin,2000-03-28 Nonlinear behavior can be found in such highly disparate areas as population biology and aircraft wing flutter Largely because of this extensive reach nonlinear dynamics and chaos have become very active fields of study and research This book uses an extended case study an experiment in mechanical vibration to introduce and explore the subject of nonlinear behavior and chaos Beginning with a review of basic principles the text then describes a cart on a track oscillator and shows what happens when it is gradually subjected to greater excitation thereby encountering the full spectrum of nonlinear behavior from simple free decay to chaos Experimental mechanical vibration is the unifying theme as the narrative evolves from a local linear largely analytical foundation toward the rich and often unpredictable world of nonlinearity Advanced undergraduate and graduate students as well as practising engineers will find this book a lively accessible introduction to the complex world of nonlinear dynamics

Theory of Vibration Ahmed A. Shabana,2018-10-12

This fully revised and updated third edition covers the physical and mathematical fundamentals of vibration analysis including single degree of freedom multi degree of freedom and continuous systems A new chapter on special topics that include motion control impact dynamics and nonlinear dynamics is added to the new edition In a simple and systematic manner the book presents techniques that can easily be applied to the analysis of vibration of mechanical and structural systems Suitable for a one semester course on vibrations the book presents the new concepts in simple terms and explains procedures for solving problems in considerable detail It contains numerous exercises examples and end of chapter problems

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Mechanical Vibrations J. P. Den Hartog,1985-01-01 This classic text combines the scholarly insights of its distinguished author with the practical problem solving orientation of an experienced industrial engineer Topics include the kinematics of vibration degrees of freedom gyroscopic effects relaxation oscillations Rayleigh s method and more Abundant examples and figures plus more than 230 problems and answers 1956 edition Mechanical Vibration Analysis and Computation D. E. Newland,2013-04-26 Focusing on applications rather than rigorous proofs this volume is suitable for upper level undergraduates and graduate students concerned with vibration problems In addition it serves as a practical handbook for performing vibration calculations An introductory chapter on fundamental concepts is succeeded by explorations of frequency response of linear systems and general response properties matrix analysis natural frequencies and mode shapes singular and defective matrices and numerical methods for modal analysis Additional topics include response functions and their applications discrete response calculations systems with symmetric matrices continuous systems and parametric and nonlinear effects The text is supplemented by extensive appendices and answers to selected problems This volume functions as a companion to the author s introductory volume on random vibrations see below Each text can be read separately and together they cover the entire field of mechanical vibrations analysis including random and nonlinear vibrations and digital data analysis *Nonlinear Vibrations in Mechanical and Electrical Systems* ,1957 **Report** Il'ja I. Blechman,1999

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