

Article

Experimental Detection of Nonlinear Dynamics Using a Laser Profilometer

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Featured Application: Extension of the laser profilometer industrial applicability from static to dynamic measurements.

Abstract: This paper investigates a cantilever beam nonlinear dynamic behaviour, on which the nonlinearity is introduced with permanent magnet interactions or with a non-holonomic contact. The experimental time domain responses obtained from non-zero initial conditions are measured using a laser profilometer, conventionally adopted for product shape detections in online industrial applications. The Fourier transform, Continuous Wavelet transform, and Hilbert transform are used to investigate nonlinear phenomena in the frequency content, highlighting advantages and drawbacks of the three methods in catching instantaneous phenomena. Then, a Multi-Fit approach is proposed to describe the time evolution of nonlinear systems by means of a discrete number of linearised systems. Therefore, two linearised models have been developed and tuned to describe the dynamic behaviour of different Euler–Bernoulli cantilever beam configurations. The experimental data of nonlinear systems are compared with the corresponding ones of the linear system to evaluate the effects of introduced nonlinearities on the overall dynamic properties.

Keywords: laser profilometer; cantilever beam; non-holonomic constraints; magnetic stiffness; time-frequency analysis



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1. Introduction

In structural dynamics, linearisation is a common practice in approximating system behaviour. From a physical perspective, the behaviour is well approximated if deformations are small enough to not exceed the material limit of linear proportionality [1,2] and displacements do not introduce geometrical nonlinearities [3,4]. Additionally, devices such as rolling bearings [5,6], hyperelastic springs/beams [7,8], non-holonomic constraints [9–11], and mechanisms such as play and hysteresis [1], friction [12], polynomial forms of restoring forces [13,14], and bistability [15] are usually neglected if their influences on the macroscopic behaviour of the system are marginal.

From an analytical perspective, a linear system can be studied with second order linear differential equations, hence the superposition of the free and forced behaviour of the system. Moreover, modal analysis and techniques directly linked with the linearity of the model can be used [16]. The linearised model behaviour allows the assessment of the stability of the equilibrium [17]. The differences between the actual behaviour of a structure and the predicted one are often explained by the departure from linearity.

The linearisation of models is affirmed strategy in Model Order Reduction (MOR) methods, developed to reduce the number of Degrees of Freedom (DoFs) and, therefore, computational cost, with a marginal loss of accuracy. In structural dynamics, two classes of MOR methods can be identified: data-based and model-based.

Data-based MOR methods are based on a database of previous simulations of the full original nonlinear system [18,19]. Instead, model-based MOR methods are based on the

Experimental Approach To Nonlinear Dynam

Paulo Flores, Hamid M. Lankarani



Experimental Approach To Nonlinear Dynam:

Nonlinear Dynamics And Chaos Nicholas B. Tufillaro, Tyler Abbott, Jeremiah Reilly, 1992-05-20 This essential handbook provides the theoretical and experimental tools necessary to begin researching the nonlinear behavior of mechanical electrical optical and other systems The book describes several nonlinear systems which are realized by desktop experiments such as an apparatus showing chaotic string vibrations an LRC circuit displaying strange scrolling patterns and a bouncing ball machine illustrating the period doubling route to chaos Fractal measures periodic orbit extraction and symbolic analysis are applied to unravel the chaotic motions of these systems The simplicity of the examples makes this an excellent book for undergraduate and graduate level physics and mathematics courses new courses in dynamical systems and experimental laboratories

Experimental Approach to Nonlinear Dynamics and Chaos Nicholas B. Tufillaro, Tyler Abbott, Jeremiah Reilly, 1992

Modeling, Simulation and Optimization of Complex Processes Hans Georg Bock, 2005-02-14 This proceedings volume contains a selection of papers presented at the symposium International Conference on High Performance Scientific Computing held at the Hanoi Institute of Mathematics of the Vietnam National Center for Natural Science and Technology NCST March 10 14 2003 The conference has been organized by the Hanoi Institute of Mathematics SFB 359 Reactive Flows Transport and Diffusion Heidelberg Ho Chi Minh City University of Technology and Interdisciplinary Center for Scientific Computing IWR Heidelberg The contributions cover the broad interdisciplinary spectrum of scientific computing and present recent advances in theory development of methods and applications in practice Subjects covered are mathematical modelling numerical simulation methods for optimization and optimal control parallel computing symbolic computing software development applications of scientific computing in physics chemistry biology and mechanics environmental and hydrology problems transport logistics and site location communication networks production scheduling industrial and commercial problems

Optimal Design of Dynamic Experiments for Improved Parameter Identification Larry Edwin Murray, 1982

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

A Novel Experimental Approach Using a Reconfigurable Test Setup for Complex Nonlinear Dynamic Systems Aaron Rank, 2011 Experimental nonlinear dynamics is an important area of study in the modern engineering field with engineering applications in structural dynamics structural control and structural health monitoring As a result the discipline has experienced a great influx of research efforts to develop a versatile and reliable experimental methodology A technical challenge in many experimental studies is the procurement of a device that exhibits the desired nonlinear behavior As a result many researchers have longed for a versatile but accurate testing methodology that has complete freedom to simulate a wide range of nonlinearities and stochastic behaviors The objective of this study is to develop a reconfigurable test setup as a tool to be used in a wide range of nonlinear dynamic studies The main components include a

moving mass whose restoring force can accurately be controlled and reprogrammed with software based upon measured displacement and velocity readings at each time step The device offers control over nonlinear characteristics and the equation of dynamic motion The advantage of having such an experimental setup is the ability to simulate various types of nonlinearities with the same test setup As a result the data collected can be used to help validate nonlinear modeling system identification and stochastic analysis studies A physical test apparatus was developed and various mechanical electrical and programming calibrations were performed for reliable experimental studies To display potential uses for the reconfigurable approach examples are presented where the device has been used to create physical data for use in change detection and deterioration studies In addition a demonstration is presented of the device's ability to physically simulate a large scale orifice viscous damper devices commonly used for vibration mitigation in bridges and buildings For a large scale viscous damper physical testing is required to ensure structural design properties However due to the large scale of the dampers expensive dynamic loading tests can be carried out at a very limited number of facilities Using the reconfigurable test setup the dynamic signature of the large scale viscous damper can accurately be simulated with pre collected data The development of a system capable of emulating the restoring force of a nonlinear device with software is a novel approach and requires further calibration for increased reliability and accuracy A discussion regarding the challenges faced when developing the methodology is presented and possible solutions are recommended The methodology introduced by this apparatus is very promising The device is a valuable experimental tool for researchers and designers allowing for physical data collection modeling analysis and validation of a wide class of nonlinear phenomena that commonly occur in a wide variety of engineering applications

Parametric Resonance in Dynamical Systems Thor I. Fossen, Henk

Nijmeijer, 2011-12-14 Parametric Resonance in Dynamical Systems discusses the phenomenon of parametric resonance and its occurrence in mechanical systems vehicles motorcycles aircraft and marine craft along micro electro mechanical systems The contributors provides an introduction to the root causes of this phenomenon and its mathematical equivalent the Mathieu Hill equation Also included is a discussion of how parametric resonance occurs on ships and offshore systems and its frequency in mechanical and electrical systems This volume is ideal for researchers and mechanical engineers working in application fields such as MEMS maritime aircraft and ground vehicle engineering

Contact Force Models for Multibody Dynamics Paulo Flores, Hamid M. Lankarani, 2016-03-15 This book analyzes several compliant contact force models within the context of multibody dynamics while also revisiting the main issues associated with fundamental contact mechanics In particular it presents various contact force models from linear to nonlinear from purely elastic to dissipative and describes their parameters Addressing the different numerical methods and algorithms for contact problems in multibody systems the book describes the gross motion of multibody systems by using a two dimensional formulation based on the absolute coordinates and employs different contact models to represent contact impact events Results for selected planar multibody

mechanical systems are presented and utilized to discuss the main assumptions and procedures adopted throughout this work. The material provided here indicates that the prediction of the dynamic behavior of mechanical systems involving contact impact strongly depends on the choice of contact force model. In short, the book provides a comprehensive resource for the multibody dynamics community and beyond on modeling contact forces and the dynamics of mechanical systems undergoing contact impact events.

Dynamic Substructures, Vol. 4 Walter D'Ambrogio, Dan Roettgen, Maarten van der Seijs, 2025-08-07

Dynamics of Coupled Structures Volume 4 Proceedings of the 42nd IMAC A Conference and Exposition on Structural Dynamics 2024 the fourth volume of ten from the Conference brings together contributions to this important area of research and engineering. The collection presents early findings and case studies on fundamental and applied aspects of the Dynamics of Coupled Structures including papers on Linear Joints Nonlinear Joints and Coupling Modal and Frequency Based Substructuring Round Robin Test Bed on Dynamic Substructuring Transfer Path Analysis and Force Estimation Interface Dynamics

Applied Mechanics Reviews, 2004

Advances in Design, Simulation and Manufacturing IV Vitalii Ivanov, Ivan Pavlenko, Oleksandr Liaposhchenko, José Machado, Milan Edl, 2021-05-28

This book reports on topics at the interface between mechanical and chemical engineering emphasizing design simulation and manufacturing. Specifically, it covers recent developments in the mechanics of solids and structures numerical simulation of coupled problems including fatigue fluid behavior particle movement pressure distribution. Further, it reports on developments in chemical process technology heat and mass transfer energy efficient technologies and industrial ecology. Based on the 4th International Conference on Design Simulation Manufacturing The Innovation Exchange DSMIE 2021 held on June 8-11, 2021 in Lviv, Ukraine, this second volume of a 2-volume set provides academics and professionals with extensive information on trends, technologies, challenges, and practice-oriented experience in the above-mentioned areas.

Proceedings of the 2nd International Conference on Mechanical System Dynamics Xiaoting Rui, Caishan Liu, 2024-06-18

The 2nd International Conference of Mechanical System Dynamics ICMSD2023 is devoted to Technology Innovations by Understanding Mechanical Dynamics with 18 sessions to promote research in dynamic theories on complex structures multidisciplinary integration and advanced technologies for applications. It is held on September 1-5 in Peking University, Beijing, China. The conference is expected to provide a platform for academic researchers and engineers in the field of mechanical system dynamics to exchange scientific and technical ideas.

A Method of Parametric Identification for Chaotic Systems Ching-Ming Yuan, 1995

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 *Proceedings of the Second Specialty Conference on Dynamic Response of Structures--Experimentation, Observation, Prediction, and Control* American Society of Civil Engineers. Engineering Mechanics Division,1980

Proceedings of the ASME Conference on Smart Materials, Adaptive Structures, and Intelligent Systems ,2008

Applications of Nonlinear Dynamics Visarath In,Patrick Longhini,Antonio Palacios,2009-02-11 The field of applied nonlinear dynamics has attracted scientists and engineers across many different disciplines to develop innovative ideas and methods to study complex behavior exhibited by relatively simple systems Examples include population dynamics fluidization processes applied optics stochastic resonance locking and bifurcations lasers and mechanical and electrical oscillators A common theme among these and many other examples is the underlying universal laws of nonlinear science that govern the behavior in space and time of a given system These laws are universal in the sense that they transcend the model specific features of a system and so they can be readily applied to explain and predict the behavior of a wide ranging phenomena natural and artificial ones Thus the emphasis in the past decades has been in explaining nonlinear phenomena with significantly less attention paid to exploiting the rich behavior of nonlinear systems to design and fabricate new devices that can operate more efficiently Recently there has been a series of meetings on topics such as Experimental Chaos Neural Coding and Stochastic Resonance which have brought together many researchers in the field of nonlinear dynamics to discuss mainly theoretical ideas that may have the potential for further implementation In contrast the goal of the 2007 ICAND International Conference on Applied Nonlinear Dynamics was focused more sharply on the implementation of theoretical ideas into actual devices and systems **Robotics for Challenging Environments** ASCE Specialty Conference on Robotics for Challenging Environments,1998 **Aeronautical Engineering** ,1992 A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system and announced in Scientific and technical aerospace reports STAR and International aerospace abstracts IAA *Electrical & Electronics Abstracts* ,1994

Experimental Approach To Nonlinear Dynam Book Review: Unveiling the Magic of Language

In a digital era where connections and knowledge reign supreme, the enchanting power of language has become much more apparent than ever. Its ability to stir emotions, provoke thought, and instigate transformation is really remarkable. This extraordinary book, aptly titled "**Experimental Approach To Nonlinear Dynam**," written by a highly acclaimed author, immerses readers in a captivating exploration of the significance of language and its profound effect on our existence. Throughout this critique, we will delve into the book's central themes, evaluate its unique writing style, and assess its overall influence on its readership.

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