

APPLICATION OF NONLINEAR STOCHASTIC MECHANICS IN OFFSHORE ENGINEERING

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ABSTRACT

Nonlinear stochastic mechanics are widely used in the field of offshore engineering. In this paper we survey four applications: nonlinear collapse and fatigue analysis of jacket structures, dynamic analysis of jack-up structures, springing and slow-drift response of a tension leg platform, and hysteretic foundation behavior of a concrete gravity platform.

1. INTRODUCTION

Offshore engineering poses many challenges for structural and soil engineers, oceanographers, and hydrodynamicists. In particular, as current offshore oil reserves become depleted, oil exploration and production is moving into increasing water depths and offshore platforms are installed at water depths of several hundred meters. For example, fixed offshore structures exist at water depth exceeding 300 meters.

Nonlinear phenomena are present in both the loading process, the structural behavior and, for fixed platforms, in the soil mechanics. Nonlinearities in the loading arise from nonlinear waves (non-Gaussian sea surface elevation) and nonlinearities in force mechanisms, as given for example by the Morison equation or second-order diffraction theory. The structure itself may exhibit various nonlinearities. This is the case for example for fixed, dynamically sensitive jack-up and deep-water jacket structures, tethered tension leg platforms, and moored semi-submersible platforms. Depending on soil conditions, nonlinear soil effects may influence both fixed structures—either gravity-based or on piles—and temporarily installed jack-up structures with footings at the sea bed.

Extensive analysis of the behavior and strength of offshore structures takes place throughout the life cycle of the structure, i.e. in concept evaluation, design, construction and operation. In operation, analyses are performed because of damage caused by dropped objects, platform/ship collisions, and explosion damages. Furthermore, a need for substantial re-design of the (deck) structure often arises.

Nonlinear Stochastic Mechanics

Ren Wang



Nonlinear Stochastic Mechanics:

IUTAM Symposium on Advances in Nonlinear Stochastic Mechanics A. Naess, S. Krenk, 2012-12-06 The IUTAM Symposium on Advances in Nonlinear Stochastic Mechanics held in Trondheim July 3-7 1995 was the eighth of a series of IUTAM sponsored symposia which focus on the application of stochastic methods in mechanics. The previous meetings took place in Coventry UK 1972, Southampton UK 1976, Frankfurt/Oder Germany 1982, Stockholm Sweden 1984, Innsbruck/Austria 1987, Turin Italy 1991, and San Antonio Texas 1993. The symposium provided an extraordinary opportunity for scholars to meet and discuss recent advances in stochastic mechanics. The participants represented a wide range of expertise from pure theoreticians to people primarily oriented toward applications. A significant achievement of the symposium was the very extensive discussions taking place over the whole range from highly theoretical questions to practical engineering applications. Several presentations also clearly demonstrated the substantial progress that has been achieved in recent years in terms of developing and implementing stochastic analysis techniques for mechanical engineering systems. This aspect was further underpinned by specially invited extended lectures on computational stochastic mechanics, engineering applications of stochastic mechanics, and nonlinear active control. The symposium also reflected the very active and high quality research taking place in the field of stochastic stability. Ten presentations were given on this topic out of a total of 47 papers. A main conclusion that can be drawn from the proceedings of this symposium is that stochastic mechanics as a subject has reached great depth and width in both methodology and applicability.

Nonlinear Dynamics and Stochastic Mechanics

Wolfgang Kliemann, 2018-05-04 Engineering systems have played a crucial role in stimulating many of the modern developments in nonlinear and stochastic dynamics. After 20 years of rapid progress in these areas, this book provides an overview of the current state of nonlinear modeling and analysis for mechanical and structural systems. This volume is a coherent compendium written by leading experts from the United States, Canada, Western and Eastern Europe, and Australia. The 22 articles describe the background, recent developments, applications, and future directions in bifurcation theory, chaos, perturbation methods, stochastic stability, stochastic flows, random vibrations, reliability, disordered systems, earthquake engineering, and numerics. The book gives readers a sophisticated toolbox that will allow them to tackle modeling problems in mechanical systems that use stochastic and nonlinear dynamics ideas. An extensive bibliography and index ensure this volume will remain a reference standard for years to come.

Nonlinear Stochastic Mechanics Nicola Bellomo, Fabio Casciati, 2012-12-06 The Symposium held in Torino/Italy Villa Gualino July 1-5 1991 is the sixth of a series of IUTAM Symposia on the application of stochastic analysis to continuum and discrete mechanics. The previous one held in Innsbruck 1987 was mainly concentrated on qualitative and quantitative analysis of stochastic dynamical systems as well as on bifurcation and transition to chaos of deterministic systems. This Symposium concentrated on fundamental aspects: stochastic analysis and mathematical methods on specific applications in various branches of mechanics, engineering, and applied sciences as well as

on related fields as analysis of large systems system identification earthquake prediction Numerical methods suitable to provide quantitative results say stochastic finite elements approximation of probability distribution and direct integration of differential equations have also been the object of interesting presentations Specific topics of the sessions have been Engineering Applications Equivalent Linearization of Discrete Stochastic Systems Fatigue and Life Estimation Fluid Dynamics Numerical Methods Random Vibration Reliability Analysis Stochastic Differential Equations System Identification Stochastic Control We are indebted to the IUTAM Bureau for having promoted and sponsored this Symposium and the Scientific Committee for having collaborated to the selection of participants and lecturers as well as to a prompt reviewing of the papers submitted for publication into these proceedings A special thank is due to Frank Kozin the organization of this meeting was for him very important he missed the meeting but his organizer ability was present

Nonlinear Stochastic Mechanics Nicola Bellomo, Fabio Casciati, 1992-08-06 The Symposium held in Torino ISI Villa Gualino July 15 1991 is the sixth of a series of IUTAM Symposia on the application of stochastic analysis to continuum and discrete mechanics The previous one held in Innsbruck 1987 was mainly concentrated on qualitative and quantitative analysis of stochastic dynamical systems as well as on bifurcation and transition to chaos of deterministic systems This Symposium concentrated on fundamental aspects stochastic analysis and mathematical methods on specific applications in various branches of mechanics engineering and applied sciences as well as on related fields as analysis of large systems system identification earthquake prediction Numerical methods suitable to provide quantitative results say stochastic finite elements approximation of probability distribution and direct integration of differential equations have also been the object of interesting presentations Specific topics of the sessions have been Engineering Applications Equivalent Linearization of Discrete Stochastic Systems Fatigue and Life Estimation Fluid Dynamics Numerical Methods Random Vibration Reliability Analysis Stochastic Differential Equations System Identification Stochastic Control We are indebted to the IUTAM Bureau for having promoted and sponsored this Symposium and the Scientific Committee for having collaborated to the selection of participants and lecturers as well as to a prompt reviewing of the papers submitted for publication into these proceedings A special thank is due to Frank Kozin the organization of this meeting was for him very important he missed the meeting but his organizer ability was present

Nonlinear Stochastic Systems In Physics And Mechanics Nicola Bellomo, Riccardo Riganti, 1987-03-01 This book presents the conceptional line which goes from the observation of physical systems to their modeling and analysis by ordinary differential nonlinear stochastic equations First the problems of the mathematical modeling of physical systems are developed These mathematical models are then classified in terms of ordinary differential stochastic equations from which both qualitative and quantitative results are developed Each one of the various subjects are methods dealt with ends with an application in mathematical physics or in nonlinear mechanics

Nonlinear Stochastic Systems in Physics and Mechanics N. Bellomo, Riccardo Riganti, 1957 **IUTAM Symposium on Advances in**

Nonlinear Stochastic Mechanics A. Naess, S. Krenk, 2011-12-06 The IUTAM Symposium on Advances in Nonlinear Stochastic Mechanics held in Trondheim July 3-7 1995 was the eighth of a series of IUTAM sponsored symposia which focus on the application of stochastic methods in mechanics. The previous meetings took place in Coventry UK 1972, Southampton UK 1976, Frankfurt/Oder Germany 1982, Stockholm Sweden 1984, Innsbruck/Austria 1987, Turin Italy 1991, and San Antonio Texas 1993. The symposium provided an extraordinary opportunity for scholars to meet and discuss recent advances in stochastic mechanics. The participants represented a wide range of expertise from pure theoreticians to people primarily oriented toward applications. A significant achievement of the symposium was the very extensive discussions taking place over the whole range from highly theoretical questions to practical engineering applications. Several presentations also clearly demonstrated the substantial progress that has been achieved in recent years in terms of developing and implementing stochastic analysis techniques for mechanical engineering systems. This aspect was further underpinned by specially invited extended lectures on computational stochastic mechanics, engineering applications of stochastic mechanics, and nonlinear active control. The symposium also reflected the very active and high quality research taking place in the field of stochastic stability. Ten presentations were given on this topic of a total of 47 papers. A main conclusion that can be drawn from the proceedings of this symposium is that stochastic mechanics as a subject has reached great depth and width in both methodology and applicability.

Nonlinear Dynamics and Stochastic Mechanics Navaratnam Sri Namachchivaya, 1996 This volume contains the proceedings of the International Symposium on Nonlinear Dynamics and Stochastic Mechanics held at the Fields Institute for Research in Mathematical Sciences from August-September 1993 as part of the 1992-93 Program Year on Dynamical Systems and Bifurcation Theory. In recent years, mathematicians and applied scientists have made significant progress in understanding and have developed powerful tools for the analysis of the complex behaviour of deterministic and stochastic dynamical systems. By moving beyond classical perturbation methods to more general geometrical, computational, and analytical methods, this book is at the forefront in transferring these new mathematical ideas into engineering practice. This work presents the solutions of some specific problems in engineering structures and mechanics and demonstrates by explicit example these new methods of solution.

Nonlinear Random Vibration, Second Edition Cho W.S. To, 2011-08-10 This second edition of the book *Nonlinear Random Vibration: Analytical Techniques and Applications* expands on the original edition with additional detailed steps in various places in the text. It is a first systematic presentation on the subject. Its features include a concise treatment of Markovian and non-Markovian solutions of nonlinear stochastic differential equations, exact solutions of Fokker-Planck-Kolmogorov equations, methods of statistical linearization, statistical nonlinearization techniques, methods of stochastic averaging, truncated hierarchy techniques, and an appendix on probability theory. A special feature is its incorporation of detailed steps in many examples of engineering applications. Targeted audience: Graduates, research scientists, and engineers in mechanical, aerospace, civil, and environmental earthquake

wind and transportation automobile naval architectural and mining engineering Nonlinear Random Vibration Cho W.S. To, 2011-08-10 This second edition of the book *Nonlinear Random Vibration Analytical Techniques and Applications* expands on the original edition with additional detailed steps in various places in the text It is a first systematic presentation on the subject Its features include a concise treatment of Markovian and non Markovian solutions **Nonlinear Stochastic Systems in Physics and Mechanics** Nicola Bellomo, Riccardo Riganti, 1978 **IUTAM Symposium on Mechanics of Passive and Active Flow Control** G.E.A. Meier, P.R. Viswanath, 2012-12-06 The call for papers for the rUTAM Symposium on Mechanics of Passive and Active Flow Control brought an overwhelming response of applications for contributions Finally 12 invited lectures 48 papers and 23 posters were selected by the Scientific Committee to be presented in the conference 58 papers are published in this volume Due to the limited number of pages available poster presentations could not be considered for publication The editors would like to thank all the members of the Scientific Committee for their very valuable assistance The papers presented at the rUTAM Symposium were classified under three groups devoted to Passive Control Methods Active Control Methods and Control Concepts This was done to contrast at first between the passive techniques where the control power is mainly supplied by the flow itself and the active techniques where the power is provided by external sources the third group was devoted to control concepts for presenting methods of control theory and new techniques of flow control Random Vibration and Statistical Linearization John Brian Roberts, Pol D. Spanos, 2003-12-09 This self contained volume explains the general method of statistical linearization and its use in solving random vibration problems Numerous examples show advanced undergraduate and graduate students many practical applications 1990 edition *IUTAM Symposium on Computational Methods for Unbounded Domains* Thomas L. Geers, 2013-03-09 During 27-31 July 1997 thirty seven researchers in acoustics aeronautics elastodynamics electromagnetics hydrodynamics and mathematics participated in a Symposium on Computational Methods for Unbounded Domains The symposium was sponsored by the International Union of Theoretical and Applied Mechanics and was held at the University of Colorado in the United States of America The symposium was opened by Dr Richard Byrny Chancellor of the University's Boulder Campus who concluded his remarks by reading a letter from Professor Bruno A Boley JUTAM Representative on the Scientific Committee Thirty three papers were presented About two thirds of these focused on the classical wave equation of acoustics however three papers dealt with hydrodynamic surface waves two with electromagnetic waves three with elastodynamic waves and four with waves in aerodynamics Approximately two thirds of the papers addressed steady state problems with the rest treating problems in the time domain Extended abstracts of the papers appear in this volume arranged in alphabetical order according to the last name of the presenting author A key unifying aspect of the symposium was the creation of four working groups that labored in parallel to formulate benchmark problems for evaluating computational boundaries The working groups reviewed the papers presented each day searching for benchmark candidates Then they

considered other possibilities and organized the ensemble into logical categories. At the end of the symposium each group presented its benchmark candidates to the assembly of participants which subsequently made a preliminary consolidation of the benchmarks.

Multifaceted Uncertainty Quantification Isaac Elishakoff, 2024-09-23 The book exposes three alternative and competing approaches to uncertainty analysis in engineering. It is composed of some essays on various sub-topics like random vibrations, probabilistic reliability, fuzzy sets based analysis, unknown but bounded variables, stochastic linearization, possible difficulties with stochastic analysis of structures.

Engineering Design Reliability Handbook Efstratios Nikolaidis, Dan M. Ghiocel, Suren Singhal, 2004-12-22 Researchers in the engineering industry and academia are making important advances on reliability based design and modeling of uncertainty when data is limited. Non-deterministic approaches have enabled industries to save billions by reducing design and warranty costs and by improving quality. Considering the lack of comprehensive and definitive presentations on the subject, *Engineering Design Reliability Handbook* is a valuable addition to the reliability literature. It presents the perspectives of experts from the industry, national labs and academia on non-deterministic approaches including probabilistic interval and fuzzy sets based methods, generalized information theory, Dempster-Shafer evidence theory and robust reliability. It also presents recent advances in all important fields of reliability design including modeling of uncertainty, reliability assessment of both static and dynamic components and systems design, decision making in the face of uncertainty and reliability validation. The editors and the authors also discuss documented success stories and quantify the benefits of these approaches. With contributions from a team of respected international authors and the guidance of esteemed editors, this handbook is a distinctive addition to the acclaimed line of handbooks from CRC Press.

Probabilistic Methods for Structural Design Carlos Guedes Soares, 2012-12-06 This book contains contributions from various authors on different important topics related with probabilistic methods used for the design of structures. Initially, several of the papers were prepared for advanced courses on structural reliability or on probabilistic methods for structural design. These courses have been held in different countries and have been given by different groups of lecturers. They were aimed at engineers and researchers who already had some exposure to structural reliability methods and thus they presented overviews of the work in the various topics. The book includes a selection of those contributions which can be of support for future courses or for engineers and researchers that want to have an update on specific topics. It is considered a complement to the existing textbooks on structural reliability which normally ensure the coverage of the basic topics but then are not extensive enough to cover some more specialised aspects. In addition to the contributions drawn from those lectures, there are several papers that have been prepared specifically for this book, aiming at complementing the others in providing an overall account of the recent advances in the field. It is with sadness that in the meanwhile we have seen the disappearance of two of the contributors to the book and in fact two of the early contributors to this field.

Mechanical Behaviour of Materials Dominique François, André Pineau, André Zaoui, 2012-12-06 Advances in

technology are demanding ever increasing mastery over the materials being used the challenge is to gain a better understanding of their behaviour and more particularly of the relations between their microstructure and their macroscopic properties This two volume work of which this is the first volume aims to provide the means by which this challenge may be met Starting from the mechanics of deformation it develops the laws governing macroscopic behaviour expressed as the constitutive equations always taking account of the physical phenomena which underlie rheological behaviour The most recent developments are presented in particular those concerning heterogeneous materials such as metallic alloys polymers and composites Each chapter is devoted to one of the major classes of material behaviour As the subtitles indicate Volume I deals with elasticity and plasticity and Volume II with viscoelasticity viscoplasticity damage phenomena and the mechanics of fracture and of contact Annexes to Volume I give the relevant basic tools and techniques of continuous media mechanics crystallography and phase changes Most of the chapters end with a set of exercises to many of which either the full solution or hints on how to obtain this are given each volume is profusely illustrated with explanatory diagrams and with electron microscope photographs Mechanics of Material Behaviour grew out of the Paris Diplôme d'études Approfondies DEA Advanced Studies Diploma in Mechanics and Materials In addition to Diploma level students it is addressed to students reading for a first degree in engineering practising engineers and research workers in this field The treatment is mathematical but the mathematical arguments should not prove difficult the real difficulties of the subject stem from the frequent and considerable changes of scale that have to be appreciated and the need to acquire a firm grasp of the underlying physics

IUTAM Symposium on Rheology of Bodies with Defects Ren Wang, 2006-04-11 The IUTAM Symposium on Rheology of Bodies with Defects was held in Beijing in September 1997 It was aimed at the development of Rheology in Solid Mechanics Rheology is classified in Applied Mechanics Review under fluid mechanics however in its broadest content as was envisaged in its earlier days it covers the whole spectrum of material behavior from elasticity plasticity and fluid mechanics to gas dynamics It was thought of as a branch of continuum mechanics but emphasized the physical aspects of different materials and frequently proceeded from basic physical principles As the temperature rises the distinction between solid and fluid and the distinction between their micro mechanical movements become blurred The physical description of such materials and their movements must be based on the thermodynamic principles of state variable theory the classical division between solid and fluid mechanics disappears Under the classification adopted by Applied Mechanics Reviews the subjects dealt with in this symposium come closer to viscoelasticity and viscoplasticity especially close to the subdivision of creep dealing with creep rupture The symposium focused at building a bridge between macroscopic and microscopic research on damage and fracture behavior of defective bodies made of metal polymer composite and other viscoelastic materials Two different approaches are presented at the symposium The first is a continuum damage theory for time dependent evolution of defects at the macro meso microscopic levels

IUTAM Symposium on Synthesis in Bio Solid Mechanics Pauli

Pedersen, Martin P. Bendsøe, 2006-04-11 This book contains the edited version of invited lectures presented at the IUTAM Symposium Synthesis in Bio Solid Mechanics held at Hotel Frederiksdal Virum Copenhagen Denmark May 24 to May 27 1998 The symposium was attended by 48 scientists from 14 countries Biomechanics has been a very active research area in the last 25 years and covers a very broad class of problems The present symposium concentrated on the solid mechanics main of biomechanics where important problems of synthesis presently are an active and challenging part Characteristics of biomechanical materials are not only the inhomogeneity and anisotropy but also the capability to change in relation to actual use These living materials call for new methods of analysis and also new methods for synthesis By the synthesis in this context is meant design of implants or artificial control of material growth Bone mechanics is closely related to recent work on analysis and design of microstructural anisotropic materials Also recent work in shape design can to some extent be useful in the more complicated problems of biomechanics Here interface problems play an essential role The symposium brought together scientists from mechanics mathematics and medicine

The Top Books of the Year Nonlinear Stochastic Mechanics The year 2023 has witnessed a remarkable surge in literary brilliance, with numerous engrossing novels enthralling the hearts of readers worldwide. Lets delve into the realm of top-selling books, exploring the captivating narratives that have captivated audiences this year. Nonlinear Stochastic Mechanics : Colleen Hoover's "It Ends with Us" This heartfelt tale of love, loss, and resilience has captivated readers with its raw and emotional exploration of domestic abuse. Hoover masterfully weaves a story of hope and healing, reminding us that even in the darkest of times, the human spirit can prevail. Uncover the Best : Taylor Jenkins Reids "The Seven Husbands of Evelyn Hugo" This captivating historical fiction novel unravels the life of Evelyn Hugo, a Hollywood icon who defies expectations and societal norms to pursue her dreams. Reids compelling storytelling and compelling characters transport readers to a bygone era, immersing them in a world of glamour, ambition, and self-discovery. Discover the Magic : Delia Owens "Where the Crawdads Sing" This mesmerizing coming-of-age story follows Kya Clark, a young woman who grows up alone in the marshes of North Carolina. Owens weaves a tale of resilience, survival, and the transformative power of nature, entrancing readers with its evocative prose and mesmerizing setting. These top-selling novels represent just a fraction of the literary treasures that have emerged in 2023. Whether you seek tales of romance, adventure, or personal growth, the world of literature offers an abundance of captivating stories waiting to be discovered. The novel begins with Richard Papen, a bright but troubled young man, arriving at Hampden College. Richard is immediately drawn to the group of students who call themselves the Classics Club. The club is led by Henry Winter, a brilliant and charismatic young man. Henry is obsessed with Greek mythology and philosophy, and he quickly draws Richard into his world. The other members of the Classics Club are equally as fascinating. Bunny Corcoran is a wealthy and spoiled young man who is always looking for a good time. Charles Tavis is a quiet and reserved young man who is deeply in love with Henry. Camilla Macaulay is a beautiful and intelligent young woman who is drawn to the power and danger of the Classics Club. The students are all deeply in love with Morrow, and they are willing to do anything to please him. Morrow is a complex and mysterious figure, and he seems to be manipulating the students for his own purposes. As the students become more involved with Morrow, they begin to commit increasingly dangerous acts. The Secret History is a brilliant and thrilling novel that will keep you speculating until the very end. The novel is a warning tale about the dangers of obsession and the power of evil.

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