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KEY=AND - TRISTIAN SELAH

Large Space Structures: Dynamics and Control

Springer **This monograph is intended to provide a snapshot of the status and opportunities for advan cement in the technologies of dynamics and control oflarge flexible spacecraft structures. It is a reflection ofthe serious dialog and assessments going on all over the world,across a wide variety of scientific and technical disciplines, as we contemplate the next major milestone in mankind's romance with space: the transition from exploration and experimentation to commercial and defense exploitation. This exploitation is already in full swing in the space communications area. Both military and civilian objectives are being pursued with increasingly more sophisticated systems such as large antenna reflectors with active shape control. Both the NATO and Warsaw pact alliances are pursuing permanent space stations in orbit: large structural systems whose development calls for in-situ fabrication and/or assembly and whose operation will demand innovations in controls technology. The last ten years have witnessed a fairly brisk research activity in the dynamics and control oflarge space structures in orderto establish a technology base forthe development of advanced spacecraft systems envisioned for the future. They have spanned a wide spectrum of activity from fundamental methods development to systems concept studies and laboratory experimentation and demonstrations. Some flight experiments have also**

been conducted for various purposes such as the characterization of the space enviroment, durability of materials and devices in that environment, assembly and repair operations, and the dynamic behavior of flexible structures. It is this last area that has prompted this monogram.

The Dynamics and Control of Large Flexible Space Structures-XIII

Final Report

Structural Dynamics and Control of Large Space Structures

Studies of Control Dynamics and Modeling Problems in Large Space Structures

Advanced Structural Dynamics and Active Control of Structures

Springer **Science is for those who learn; poetry for those who know. —Joseph Roux This book is a continuation of my previous book, Dynamics and Control of Structures [44]. The expanded book includes three additional chapters and an additional appendix: Chapter 3, “Special Models”; Chapter 8, “Modal Actuators and Sensors”; and Chapter 9, “System Identification. ” Other chapters have been significantly revised and supplemented with new topics, including discrete-time models of structures, limited-time and - frequency grammians and reduction, almo- balanced modal models, simultaneous placement of sensors and actuators, and structural damage detection. The appendices have also been updated and expanded. Appendix A consists of thirteen new Matlab programs. Appendix B is a new addition and includes eleven Matlab programs that solve examples from each chapter. In Appendix C model data are given. Several books on structural dynamics and control have been published. Meirovitch’s textbook [108] covers methods of structural dynamics (virtual work, d’Alambert’s principle, Hamilton’s principle, Lagrange’s and Hamilton’s**

equations, and modal analysis of structures) and control (pole placement methods, LQG design, and modal control). Ewins's book [33] presents methods of modal testing of structures. Natke's book [111] on structural identification also contains excellent material on structural dynamics. Fuller, Elliot, and Nelson [40] cover problems of structural active control and structural acoustic control.

The Dynamics and Control of Large Flexible Space Structures

Technology for Large Space Systems

Supplement

Structural Dynamics and Control of Large Space Structures, 1982

Proceedings of a Workshop Held at NASA Langley Research Center, Hampton, Virginia, January 21-22, 1982

Structural Dynamic and Control of Large Space Structures

Dynamics and Control Analysis of

Large Flexible Space Structures Using the Generalized Multiple Scales Method

The Dynamics and Control of Large Space Structures After the Onset of Thermal Shock

Studies on Control, Nonlinear Dynamics and Modeling Problems in Large Space Structures

Large Space Structures: Dynamics and Control

Springer **This monograph is intended to provide a snapshot of the status and opportunities for advan cement in the technologies of dynamics and control oflarge flexible spacecraft structures. It is a reflection ofthe serious dialog and assessments going on all over the world,across a wide variety of scientific and technical disciplines, as we contemplate the next major milestone in mankind's romance with space: the transition from exploration and experimentation to commercial and defense exploitation. This exploitation is already in full swing in the space communications area. Both military and civilian objectives are being pursued with increasingly more sophisticated systems such as large antenna reflectors with active shape control. Both the NATO and Warsaw pact alliances are pursuing permanent space stations in orbit: large structural systems whose development calls for in-situ fabrication and/or assembly and whose operation will demand innovations in controls technology. The last ten years have witnessed a fairly brisk research activity in the dynamics and control oflarge space structures in orderto establish a technology base forthe development of advanced spacecraft systems envisioned for the future. They have spanned a wide spectrum of activity from fundamental**

methods development to systems concept studies and laboratory experimentation and demonstrations. Some flight experiments have also been conducted for various purposes such as the characterization of the space enviroment, durability of materials and devices in that environment, assembly and repair operations, and the dynamic behavior of flexible structures. It is this last area that has prompted this monogram.

Ground Facility for Large Space Structures Dynamics and Control Verification

Structural Dynamics and Control of Large Space Structures

Proceedings of a Workshop Held at NASA Langley Research Center, Hampton, Virginia, October 30-31, 1980

Dynamics and Control of Structures

John Wiley & Sons **A text/reference on analysis of structures that deform in use. Presents a new, integrated approach to analytical dynamics, structural dynamics and control theory and goes beyond classical dynamics of rigid bodies to incorporate analysis of flexibility of structures. Includes real-world examples of applications such as robotics, precision machinery and aircraft structures.**

Advances and Trends in Structures and Dynamics

Papers Presented at the Symposium on Advances and Trends in Structures and Dynamics, Held 22-25 October 1984, Washington,

Elsevier **Advances and Trends in Structures and Dynamics contains papers presented at the symposium on Advances and Trends in Structures and Dynamics held in Washington, D.C., on October 22-25, 1984. Separating 67 papers of the symposium as chapters, this book documents some of the major advances in the structures and dynamics discipline. The chapters are further organized into 13 parts. The first three parts explore the trends and advances in engineering software and hardware; numerical analysis and parallel algorithms; and finite element technology. Subsequent parts show computational strategies for nonlinear and fracture mechanics problems; mechanics of materials and structural theories; structural and dynamic stability; multidisciplinary and interaction problems; composite materials and structures; and optimization. Other chapters focus on random motion and dynamic response; tire modeling and contact problems; damping and control of spacecraft structures; and advanced structural applications.**

Dynamics and Robust Digital Control for Large Orbiting Space Structures

Computational Methods and Software Systems for Dynamics and Control of Large Space Structures

Createspace Independent Publishing Platform **Two key areas of crucial importance to the computer-based simulation of large space structures are discussed. The first area involves multibody dynamics (MBD) of flexible**

space structures, with applications directed to deployment, construction, and maneuvering. The second area deals with advanced software systems, with emphasis on parallel processing. The latest research thrust in the second area involves massively parallel computers. Park, K. C. and Felippa, C. A. and Farhat, C. and Pramono, E. Unspecified Center NASA-CR-187669, NAS 1.26:187669, CU-CSSC-90-17 NAG1-756...

Structural Dynamics and Control

Interaction of Flexible Structures

Technology for Large Space Systems

Supplement

The Dynamics and Control of Large Flexible Space Structures

Createspace Independent Publishing Platform **The dynamics and attitude and shape control of very large, inherently flexible spacecraft systems were investigated. Increasingly more complex examples were examined, beginning with a uniform free-free beam, next a free-free uniform plate/platform and finally by considering a thin shallow spherical shell structure in orbit. The effects devices were modeled. For given sets of assumed actuator locations, the controllability of these systems was first established. Control laws for each of the actuators were developed based on decoupling techniques (including distributed modal control) pole placement algorithms and a application of the linear regulator problem for optical control theory. Bainum, P. M. and Krishna, R. and Kumar, V. K. and Reddy, A. S. S. R. Unspecified Center NASA-CR-164982 NSG-1414**

Control of Large Space Structures and Associated Precision-Pointed Payloads

Createspace Independent Publishing Platform **Stability and robustness of a two-level control system for large space structures were investigated. In**

particular, the effects of actuator/sensor nonlinearities and dynamics on the closed-loop stability were studied and the problem of control-systems design for fine-pointing of several individually pointed payloads mounted on a large space platform was examined. A composite controller is proposed and is stable and robust. Joshi, S. M. and Goglia, G. L. Unspecified Center NASA-CR-168920, NAS 1.26:168920 NAG1-102

Modeling, Analysis, and Optimization Issues for Large Space Structures

This document contains the proceedings of the Air Force/NASA Workshop on Modeling, Analysis, and Optimization Issues for Large Space Structures held in Williamsburg, Virginia, May 13-14 1982. The theme of the workshop was modeling, analysis, and optimization of large space structures, including structure control interaction. Speakers were drawn primarily from industry, with participation from universities and government. The workshop was organized into three sessions: mathematical modeling, analysis methodology, and optimization for controllability. Results of the workshop were discussed in a final session. The workshop presentations ranged over many topics in large space structures, including structure-control interaction, structural and structural dynamics modeling, thermal analysis, testing, design, and optimization. The interdisciplinary area of structure-control interaction, which is a challenge to analysts, designers, and test engineers, was clearly emphasized. Not addressed in the workshop was the important subject of structural deployment.

Handbook of Experimental Structural Dynamics

Springer Nature **The SEM Handbook of Experimental Structural Dynamics stands as a comprehensive overview and reference for its subject, applicable to workers in research, product design and manufacture, and practice. The Handbook is devoted primarily to the areas of structural mechanics served by the Society for Experimental Mechanics IMAC community, such as modal analysis, rotating machinery, structural health monitoring, shock and vibration, sensors and instrumentation, aeroelasticity, ground testing, finite element techniques, model updating, sensitivity analysis, verification and validation, experimental dynamics sub-structuring, quantification of margin and uncertainty, and testing of civil infrastructure. Chapters offer comprehensive, detailed coverage of decades of scientific and technologic advance and all demonstrate an**

experimental perspective. Several sections specifically discuss the various types of experimental testing and common practices utilized in the automotive, aerospace, and civil structures industries. · History of Experimental Structural Mechanics · DIC Methods - Dynamic Photogrammetry · LDV Methods · Applied Digital Signal Processing · Introduction to Spectral - Basic Measurements · Structural Measurements - FRF · Random and Shock Testing · Rotating System Analysis Methods * · Sensors Signal Conditioning Instrumentation · Design of Modal Tests · Experimental Modal Methods · Experimental Modal Parameter Evaluation · Operating Modal Analysis Methods * · Analytical Numerical Substructuring · Finite Element Model Correlation · Model Updating · Damping of Materials and Structures · Model Calibration and Validation in Structures* · Uncertainty Quantification: UQ, QMU and Statistics * · Nonlinear System Analysis Methods (Experimental) · Structural Health Monitoring and Damage Detection · Experimental Substructure Modeling · Modal Modeling · Response (Impedance) Modeling · Nonlinear Normal Mode Analysis Techniques (Analytical) * · Modal Modeling with Nonlinear Connection Elements (Analytical) · Acoustics of Structural Systems (VibroAcoustics) * · Automotive Structural Testing * · Civil Structural Testing · Aerospace Perspective for Modeling and Validation · Sports Equipment Testing * · Applied Math for Experimental Structural Mechanics * Chapter Forthcoming Contributions present important theory behind relevant experimental methods as well as application and technology. Topical authors emphasize and dissect proven methods and offer detail beyond a simple review of the literature. Additionally, chapters cover practical needs of scientists and engineers who are new to the field. In most cases, neither the pertinent theory nor, in particular, the practical issues have been presented formally in current academic textbooks. Each chapter in the Handbook represents a 'must read' for someone new to the subject or for someone returning to the field after an absence. Reference lists in each chapter consist of the seminal papers in the literature. This Handbook stands in parallel to the SEM Handbook of Experimental Solid Mechanics, where this Handbook focuses on experimental dynamics of structures at a macro-scale often involving multiple components and materials where the SEM Handbook of Experimental Solid Mechanics focuses on experimental mechanics of materials at a nano-scale and/or micro-scale.

Dynamics and Robust Control of Sampled Data Systems for Large Space Structures

The objective of this research is to develop practical design procedures that can be used in conjunction with optimal digital controllers for future

orbiting large space structural systems. In practice, the observational data used to verify the orientation and shape of large flexible systems will, in general, be collected on a sampled basis (discrete-time data system). The system is assumed to be completely observable and deterministic. Systems which will be designed to control both the overall orientation as well as the shape of some of the subsystems (such as antenna mesh form) must function in the discrete-time domain. The aim of this research is to develop methods that can be used to design linear quadratic regulator (LQR) controllers for orbiting large flexible systems. The digital control of an orbiting thin square plate system is analyzed in this volume of the final report ... Digital control, Large space structures, Observable deterministic system, Linear quadratic regulator technique.

Dynamic Modeling and Active Vibration Control of Structures

Springer Nature **This book describes the active vibration control techniques which have been developed to suppress excessive vibrations of structures. It covers the fundamental principles of active control methods and their applications and shows how active vibration control techniques have replaced traditional passive vibration control. The book includes coverage of dynamic modeling, control design, sensing methodology, actuator mechanism and electronic circuit design, and the implementation of control algorithms via digital controllers. An in-depth approach has been taken to describe the modeling of structures for control design, the development of control algorithms suitable for structural control, and the implementation of control algorithms by means of Simulink block diagrams or C language. Details of currently available actuators and sensors and electronic circuits for signal conditioning and filtering have been provided based on the most recent advances in the field. The book is used as a textbook for students and a reference for researchers who are interested in studying cutting-edge technology. It will be a valuable resource for academic and industrial researchers and professionals involved in the design and manufacture of active vibration controllers for structures in a wide variety of fields and industries including the automotive, rail, aerospace, and civil engineering sectors.**

Dynamics of Smart Structures

John Wiley & Sons **Dynamics of Smart Structures is a practical, concise and integrated text that provides an introduction to the fundamental principles of a field that has evolved over the recent years into an independent and identifiable subject area. Bringing together the concepts, techniques and systems associated with the dynamics and control of smart structures, it comprehensively reviews the differing smart materials that are employed**

in the development of the smart structures and covers several recent developments in the field of structural dynamics. Dynamics of Smart Structures has been developed to complement the author's new interdisciplinary programme of study at Queen Mary, University of London that includes courses on emerging and new technologies such as biomimetic robotics, smart composite structures, micro-electro-mechanical systems (MEMS) and their applications and prosthetic control systems. It includes chapters on smart materials and structures, transducers for smart structures, fundamentals of structural control, dynamics of continuous structures, dynamics of plates and plate-like structures, dynamics of piezoelectric media, mechanics of electro-actuated composite structures, dynamics of thermo-elastic media: shape memory alloys, and controller designs for flexible structures.

Scientific and Technical Aerospace Reports

Dynamic Identification for Control of Large Space Structures

Twelve Lectures on Structural Dynamics

Springer Science & Business Media **This text addresses the modeling of vibrating systems with the perspective of finding the model of minimum complexity which accounts for the physics of the phenomena at play. The first half of the book (Ch.1-6) deals with the dynamics of discrete and continuous mechanical systems; the classical approach emphasizes the use of Lagrange's equations. The second half of the book (Ch.7-12) deals with more advanced topics, rarely encountered in the existing literature: seismic excitation, random vibration (including fatigue), rotor dynamics, vibration isolation and dynamic vibration absorbers; the final chapter is an introduction to active control of vibrations. The first part of this text may be used as a one semester course for 3rd year students in Mechanical, Aerospace or Civil Engineering. The second part of the text is intended for graduate classes. A set of problems is provided at the end of every chapter. The author has a 35 years experience in various aspects of Structural dynamics, both in industry (nuclear and aerospace) and in academia; he was one of the pioneers in the field of active structures. He is the author of several books on random vibration, active structures and**

structural control.

The Dynamics and Control of Large Flexible Space Structures

Independently Published **A mathematical model is developed to predict the dynamics of the proposed Spacecraft Control Laboratory Experiment during the stationkeeping phase. The Shuttle and reflector are assumed to be rigid, while the mass connecting the Shuttle to the reflector is assumed to be flexible with elastic deformations small as compared with its length. It is seen that in the presence of gravity-gradient torques, the system assumes a new equilibrium position primarily due to the offset in the mass attachment point to the reflector from the reflector's mass center. Control is assumed to be provided through the Shuttle's three torquers and throught six actuators located by painrs at two points on the mass and at the reflector mass center. Numerical results confirm the robustness of an LQR derived control strategy during stationkeeping with maximum control efforts significantly below saturation levels. The linear regulator theory is also used to derive control laws for the linearized model of the rigidized SCOLE configuration where the mast flexibility is not included. It is seen that this same type of control strategy can be applied for the rapid single axis slewing of the SCOLE through amplitudes as large as 20 degrees. These results provide a definite trade-off between the slightly larger slewing times with the considerable reduction in over-all control effort as compared with the results of the two point boundary value problem application of Pontryagin's Maximum Principle. Bainum, Peter M. and Reddy, A. S. S. R and Diarra, Cheick M. and Li, Feiyue Unspecified Center...**

Space Structure (dynamics and Control) Theme Development

Dynamics and Control of Structures

A Modal Approach

Springer Science & Business Media **This book addresses problems in structural dynamics and control encountered in applications such as robotics, aerospace structures, earthquake-damage prevention, and active noise suppression. The rapid developments of new technologies and computational power have made it possible to formulate and solve engineering problems that seemed unapproachable only a few years ago. This presentation combines concepts from control engineering (such as**

system norms and controllability) and structural engineering (such as modal properties and models), thereby revealing new structural properties as well as giving new insight into well-known laws. This book will assist engineers in designing control systems and dealing with the complexities of structural dynamics.

Dynamics and Robust Control of Sampled Data Systems for Large Space Structures

Optimal linear quadratic regulator digital control of a free-free orbiting platform

The objective of this research is to develop practical design procedures that can be used in conjunction with optimal digital controllers for future orbiting large space structural systems. In practice, the observational data used to verify the orientation and shape of large flexible systems will, in general, be collected on a sampled basis (discrete-time data system). The system is assumed to be completely observable and deterministic. Systems which will be designed to control both the overall orientation as well as the shape of some of the subsystems (such as antenna mesh form) must function in the discrete-time domain. The aim of this research is to develop methods that can be used to design linear quadratic regulator (LQR) controllers for orbiting large flexible systems. The digital control of an orbiting thin square plate system is analyzed in this volume of the final report ... Digital control, Large space structures, Observable deterministic system, Linear quadratic regulator technique.

Structural Dynamics and Control Interaction of Flexible Structures

Proceedings of a Workshop Held at

George C. Marshall Space Flight Center, Huntsville, Alabama, April 22-24, 1986

Applied Mechanics Reviews

The Dynamics and Control of Large-Flexible Space Structures, Part 10

Createspace Independent Publishing Platform **A mathematical model is developed to predict the dynamics of the proposed orbiting Spacecraft Control Laboratory Experiment (SCOLE) during the station keeping phase. The equations of motion are derived using a Newton-Euler formulation. The model includes the effects of gravity, flexibility, and orbital dynamics. The control is assumed to be provided to the system through the Shuttle's three torquers, and through six actuators located by pairs at two points on the mast and at the mass center of the reflector. The modal shape functions are derived using the fourth order beam equation. The generic mode equations are derived to account for the effects of the control forces on the modal shape and frequencies. The equations are linearized about a nominal equilibrium position. The linear regulator theory is used to derive control laws for both the linear model of the rigidized SCOLE as well as that of the actual SCOLE including the first four flexible modes. The control strategy previously derived for the linear model of the rigidized SCOLE is applied to the nonlinear model of the same configuration of the system and preliminary single axis slewing maneuvers conducted. The results obtained confirm the applicability of the intuitive and appealing two-stage control strategy which would slew the SCOLE system, as if rigid to its desired position and then concentrate on damping out the residual flexible motions. Bainum, Peter M. and Reddy, A. S. S. R. Unspecified Center MATHEMATICAL MODELS; PREDICTION ANALYSIS TECHNIQUES; SLEWING; SPACE SHUTTLE PAYLOADS; SPACECRAFT CONTROL; SPACECRAFT MANEUVERS; ACTIVE CONTROL; EQUATIONS OF MOTION; FLEXIBLE SPACECRAFT; GRAVITATIONAL EFFECTS; LINEAR QUADRATIC REGULATOR; REFLECTORS...**

Spacecraft Dynamics Characterization and Control System Failure Detection

Independently Published **Two important aspects of the control of large space structures are studied: the modeling of deployed or erected structures including nonlinear joint characteristics; and the detection and isolation of failures of the components of control systems for large space structures. The emphasis in the first task is on efficient representation of the dynamics of large and complex structures having a great many joints. The initial emphasis in the second task is on experimental evaluation of FDI methodologies using ground-based facilities in place at NASA Langley Research Center and Marshall Space Flight Center. The progress to date on both research tasks is summarized. Vandervelde, Wallace E. NASA-CR-192190, NAS 1.26:192190 NAG1-968...**

Vibration Suppression in a Large Space Structure

Independently Published **The Yale University Center for Systems Science and the NASA Johnson Space Center collaborated in a study of vibration suppression in a large space structure during the period January 1985 to August 1987. The research proposal submitted by the Center to NASA concerned disturbance isolation in flexible space structures. The general objective of the proposal was to create within the Center a critical mass of expertise on problems related to the dynamics and control of large flexible space structures. A specific objective was to formulate both passive and active control strategies for the disturbance isolation problem. Both objectives were achieved during the period of the contract. While an extensive literature exists on the control of flexible space structures, it is generally acknowledged that many important questions remain open at even a fundamental level. Hence, instead of studying grossly simplified models of complex structural systems, it was decided as a first step to confine attention to detailed and thorough analyses of simple structures. Narendra, Kumpati S. NASA-CR-182831, NAS 1.26:182831 NAS9-17395...**