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STABILITY AND OPTIMIZATION OF FLEXIBLE SPACE STRUCTURES

Birkhäuser **The aim of this book is to present up-to-date methodologies in the analysis and optimization of the elastic stability of lightweight statically determinate, and in-determinate, space structures made of flexible members which are highly stiff when loaded centrally at the nodes. These are flat and curved space pin- connected open or enveloped lattices and reticulated shells which, due to their high loadbearing capacity to weight ratios, are gaining in importance in aerospace and other fields. They are utilized, for example, in space stations, as support structures for large radio-telescopes and for other equipment on earth and in outer space, as roof structures for the coverage and enclosure of large areas on earth and as underwater shell-type structures enveloped by a cover-shell capable of withstanding high hydrostatic pressures. • Space structures of this type are generally subjected to considerable internal axial loads in the flexible members and they fail through the loss of global statical stability, usually precipitated by the intrinsic small imperfections at finite near-critical elastic deformations - and not primarily by the the break-down of the material of which they are made, as is the case in conventional systems. Thus, the criterion in the design of such structures calls for eliminating or isolating the onset of the elastic dynamic collapse thereby increasing their safe stability limit. • Standard finite element methods, as they are employed by most users today, are totally inadequate for such analyses since they do not account for the choice of the branching paths in the loading process of the structure nor for the existence of the relevant collapse modes. • These aspects are novel and they are presented here for the first time in comprehensive book form.**

STABILITY AND OPTIMIZATION OF FLEXIBLE SPACE STRUCTURES

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DESIGN METHODS OF CONTROL SYSTEMS

SELECTED PAPERS FROM THE IFAC SYMPOSIUM, ZURICH, SWITZERLAND, 4 - 6 SEPTEMBER 1991

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SUPPLEMENT

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13TH INTERNATIONAL CONFERENCE, BIC-TA 2018, BEIJING, CHINA, NOVEMBER 2–4, 2018, PROCEEDINGS, PART I

Springer **This two-volume set (CCIS 951 and CCIS 952) constitutes the proceedings of the 13th International Conference on Bio-inspired Computing: Theories and Applications, BIC-TA 2018, held in Beijing, China, in November 2018. The 88 full papers presented in both volumes were selected from 206 submissions. The papers deal with studies abstracting computing ideas such as data structures, operations with data, ways to control operations, computing models from living phenomena or biological systems such as evolution, cells, neural networks, immune systems, swarm intelligence.**

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INTERNATIONAL AEROSPACE ABSTRACTS

AN OPTIMIZATION-BASED INTEGRATED CONTROLS-STRUCTURES DESIGN METHODOLOGY FOR FLEXIBLE SPACE STRUCTURES

INCREASING THE MARGIN OF STABILITY OF ARBITRARILY FINITE MODES OF FLEXIBLE LARGE SPACE STRUCTURES WITH DAMPING

Major themes of research performed under the grant include: (1) increasing the margin of stability of arbitrarily finite modes of damped wave equations. Allocation of spectrum and of Riesz basis properties of eigenvectors; (2) Uniform stabilization (linear case) and strong stabilization (non-linear case) by a-priori, explicit boundary feedbacks for waves and plates; (3) exact boundary controllability for waves and plates; (4) study of the optimal quadratic cost problem for waves and plates, in particular of the associated Algebraic Riccati Equation which produces a boundary feedback based on the Riccati operator which uniformly stabilizes the system (compare with (2)); (5) structural damping for elastic systems under a natural, broad class of damping operators, and (6) numerical aspects related to some of the topics listed above, in particular related to the computation of the Riccati operator in case of boundary control problems for waves and plates. (jhd).

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DESIGN METHODS OF CONTROL SYSTEMS

SELECTED PAPERS FROM THE IFAC SYMPOSIUM, ZURICH, SWITZERLAND, 4-6 SEPTEMBER 1991

HIGH PERFORMANCE, ROBUST CONTROL OF FLEXIBLE SPACE STRUCTURES

Many spacecraft systems have ambitious objectives that place stringent requirements in terms of pointing and vibration control systems. Because of the difficulty of obtaining accurate models for flexible space structures, limitations must be placed on performance in order to ensure stability. In some cases, to achieve sufficiently high performance to accomplish mission objectives will require the ability to refine the control design model based on closed-loop test data and tune the controller based on the refined model. The objective of this thesis is to develop a procedure for control system design which maximizes achievable performance with robust stability guarantees. Two facts of this dissertation are control design and system identification. A control design and system identification. A control design procedure is developed based on mixed H2/H[Infinite symbol] [subscript] optimization which is used to design a set of controllers which explicitly trade between nominal performance and robust stability. A homotopy algorithm is presented which generates a trajectory of gains along the boundary which trades between robustness and performance. This set of controllers may be implemented to determine the maximum achievable performance for a given model error bound. Examples are given which show that a better balance between robustness and performance is obtained using the mixed H2/H[Infinite symbol][subscript] design method than either H2 or u-synthesis control design. A second contribution of this dissertation is a new procedure for closed-loop system identification. Using closed-loop response data, the parameters of a control design model in a canonical realization are refined. Examples are provided to demonstrate the convergence of the parameter esimation and improved performance realized by using the refined model for controller redesign. These developments result in an effective

mechanism for achieving high performance control of flexible space structures.

PRACTICAL APPLICATION OF FINITE ELEMENT ANALYSIS TO AIRCRAFT STRUCTURAL DESIGN

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THE 34TH AIAA/ASME/ASCE/AHS/ASC STRUCTURES, STRUCTURAL DYNAMICS AND MATERIALS CONFERENCE, ADAPTIVE STRUCTURES FORUM: 93-1446 - 93-1519

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HIGH PERFORMANCE, ROBUST CONTROL OF FLEXIBLE SPACE STRUCTURES

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Createspace Independent Publishing Platform **Many spacecraft systems have ambitious objectives that place stringent requirements on control systems. Achievable performance is often limited because of difficulty of obtaining accurate models for flexible space structures. To achieve sufficiently high performance to accomplish mission objectives may require the ability to refine the control design model based on closed-loop test data and tune the controller based on the refined model. A control system design procedure is developed based on mixed H2/H(infinity) optimization to synthesize a set of controllers explicitly trading between nominal performance and robust stability. A homotopy algorithm is presented which generates a trajectory of gains that may be implemented to determine maximum achievable performance for a given model error bound. Examples show that a better balance between robustness and performance is obtained using the mixed H2/H(infinity) design method than either H2 or mu-synthesis control design. A second contribution is a new procedure for closed-loop system identification which refines parameters of a control design model in a canonical realization. Examples demonstrate convergence of the parameter estimation and improved performance realized by using the refined model for controller redesign. These developments result in an effective mechanism for achieving high-performance control of flexible space structures. Whorton, M. S. Marshall Space Flight Center...**

ROBUSTNESS IMPROVEMENT OF ACTIVELY CONTROLLED STRUCTURES THROUGH INTEGRATED STRUCTURAL/CONTROL DESIGN

The problem of structural and control design of flexible structures is considered. Three major topics are investigated. The first topic deals with the dual passive/active control design for flexible structures. The interacting sub-structure decentralized control approach is developed for large flexible structures to eliminate the spillover problem and reduce the

model size for controller margin and robustness of controlled flexible structures. The second topic considers the robustness improvement for controlled flexible structures through structure modifications. The stability and engineering performance robustness indices are defined. The integrated structural/control design problem is considered as a multiobjective optimization problem in which three objectives- structural weight, stability robustness index and performance robustness index- are considered for minimization. The third topic involves the study of the actuator/sensor location selection problem. The sequential-best-adding, penalty function method and the genetic algorithm are considered.

INCORPORATING CONTROL INTO THE OPTIMAL STRUCTURAL DESIGN OF LARGE FLEXIBLE SPACE STRUCTURES

An eigenspace optimization approach is used to incorporate optimal control into the structural design process for large flexible space structures. The equations of motion for an uncontrolled system are developed by deriving the kinetic and potential energy for the system and then using assumed modes to discretize the energies. These expressions are then linearized, the Lagrangian formed, and lagrange equations written for the system. An existing optimal control law is incorporated to form the equations of motion for the controlled system. A parameter optimization technique is used to minimize the mass of the Draper/RPL configuration model involving eigenspace optimization. A computer algorithm is developed that effectively optimizes a global structural parameter vector to minimize the mass of the model, while constraining specified eigenvalues. The eigenvalue sensitivities are passed to a constrained function minimization program called CONMIN which minimizes the mass of the appendages. The constraints imposed restrict the first eigenvalue to the left half plane and the natural frequency of the third eigenvalue to a specified stable region. The result is an algorithm that incorporates an existing optimal control law into the structural optimization process. Originator-supplied keywords-included: Flexible Space Structures, Eigenspace Optimization, Equations of Motion, Draper/RPL Configuration Model Theses.

MULTIVARIABLE METHODS FOR THE DESIGN, IDENTIFICATION, AND CONTROL OF LARGE SPACE STRUCTURES. VOLUME 3. A STUDY OF THE INTEGRATED CONTROL/STRUCTURE DESIGN OPTIMIZATION PROBLEM FOR LARGE FLEXIBLE STRUCTURES

A comparison of optimal and suboptimal estimation applied to large flexible structures under perfect and imperfect model information conditions is presented. The filters estimate the modal positions and velocities of a simple pinned-pinned beam. Among the types of estimators investigated are full and reduced-order centralized estimators, reduced-order decentralized estimators, and one-mode and two-mode sensitivity-shaped estimators. The suboptimal estimators are shown to have lower position rms error values than the optimal estimator when 20% errors in the structural frequencies are present. The sensitivity-shaped estimators produce more accurate position estimates when velocity sensors are used than any of the reduced-order Linear Quadratic centralized or decentralized estimators. A method for choosing the gains of the sensitivity-shaped estimators given. Robustness of the system is discussed using a proposed phase-shaping method and the Lyapunov method. The closed-loop system with the one-mode sensitivity-shaped filter is proven to be marginally stable with the former method and asymptotically stable with the latter method, provided controller gains satisfy certain outlined requirements. (Author) (kr).

TECHNOLOGY FOR LARGE SPACE SYSTEMS: A BIBLIOGRAPHY WITH INDEXES (SUPPLEMENT 22)