Book Review

Introduction to Dynamics and Control of Flexible Structures, by John L. Junkins and Youdan Kim. Published by the American Institute of Aeronautics and Astronautics, Washington, DC, 1993, 452 pp. with computer disk.

More and more often in applied research and professional engineering work, the problems to be faced lie at the interface of two or more disciplines that are considered "different" "disjoint" from the viewpoint of the classical scientific training in university courses all over the world. This is the case in engineering mechanics and control engineering, which are strictly interconnected in many theoretical and experimental aspects of modern engineering activities.

The authors' point, as stated in the preface, is that "effective control laws for mechanical systems are best designed by one who understands both the basic mechanics of the system under consideration and the control methodology being used to design the control law." This constitutes the basic approach and perspective of the whole book.

A central set of selected ideas in dynamics and control are considered and the most important up-to-date methods that derive from them are illustrated in the attempt to integrate theory, analysis, computation techniques, and experimental results, striving to obtain a profitable balance between accuracy, completeness, and economy of exposition. The authors' goal is achieved with clarity and effectiveness.

Each of the seven chapters develops the basic ideas and theoretical discussions, provides a number of worked-out examples, and ends with a significant case study to illustrate how the issues pertain to a prototype problem specifically associated with modeling and controlling a flexible structure, such as the NOVA spacecraft launched a few years ago. A set of problems for the reader and a detailed list of references is given at the end of each chapter and a significant number of MATLAB® operators, mostly for didactical purposes, were developed by the authors in a diskette appended to the text.

The first chapter contains some "biased" (in the authors' words) historical notes on the development of classical mechanics, a discipline that reached its peak in the late 1800s, and of control engineering, which, in its turn, witnessed tremendous advances only in the latest 30–40 years and stresses the trend toward unification in modern engineering problems. The second chapter presents the requisite background material in linear algebra and matrix computations, focusing on matrix decompositions (spectral, Cholesky, Shur, etc., with special emphasis on the singular value decomposition) and on eigenvalue–eigenvector sensitivity issues in order to achieve robust control. This chapter is undoubtedly profitable reading for any researcher or professional in engineering disciplines.

Chapter 3 deals with Lyapunov stability theory including some recent extensions. Methodology for both linear and nonlinear systems are developed, ordinary and partial differential equation models are illustrated, and the "energy rate principle" is presented, allowing a considerable economy of algebra in Lyapunov analysis. The case study considers analytical, numerical, and experimental results in detail.

The fourth chapter considers the principles of classical mechanics that allow the formulation of

Shock and Vibration, Vol. 3, No. 4, pp. 321–322 (1996)

CCC 1070-9622/96/040321-02

ordinary differential equation models for discrete systems, hybrid ordinary/partial differential equation systems and their natural boundary conditions for distributed parameter systems, and a generalization of Lagrange's equations for a significant family of distributed parameter systems. The differential eigenvalue problem is discussed and two methods (finite element and assumed modes) are given to discretize distributed parameter systems.

Chapters 5–7 are devoted to analysis and design of linear controllers for structural systems. Chapter 5 discusses the linear-quadratic regulator (LQR) and eigenstructure assignment regulator (EAR) and their analytical development in modern feedback control theory. Examples are given and a set of interesting results and algorithms are presented. Chapter 6 introduces the concepts of controllability, observability, modal cost analysis, and a new measure of controllability that combines different ideas for guiding the placement of actuators to control vibrating structures. The related issues of sensor and actuator optimization, with applications to vibration suppression problems for flexible structures, is the context in which these ideas are discussed. Undoubtedly this is a topic that will see future developments in many fields of engineering other than advanced aerospace research.

Finally, Chapter 7 deals with the necessity to overcome some computational difficulties that are encountered in developing active and passive control methods for suppression of vibration as well as maneuvering large flexible structures, errors that always exist in the mathematical models of large structures.

The feature of the most challenging problems of interest is that there is a significant overlap in the desired controller bandwidth and the natural frequencies of the open loop structure. An extensive literature survey is given, but the attention is on an important subset of the methodology. The theoretical background for a guaranteed stabilizing symmetric parametrization of the feedback gain matrix is provided and the issues of stability and robustness characteristics are discussed. A nonlinear programming algorithm is introduced based on the symmetric gain matrix parametrization, and a homotopic continuation method is used to enhance convergence of a gain-tuning algorithm. Three case studies illustrate the utility of the methods.

Nine appendices are given at the end of the text. Each of them deals with specific issues such as proofs of theorems and analytical aspects that, if inserted in the main body of the text, would have probably weighed on the flow of ideas and methods in the exposition.

The text, despite the title, is difficult reading and is written for a specialized public in mechanics and control eigineering. In the authors' words, "it may not be considered as an adequate replacement for a traditional specialty course in either advanced analytical dynamics or control system analysis," because many traditional topics in these fields to not appear in the text (for example, Hamilton–Jacobi theory, plane–phase analysis, the linear control topics on Laplace domain transfer function and frequency response analysis, the classical frequency domain control design method for single-input single-output controllers, or other frequency domain concepts).

The material included has been carefully selected with no intention to make a comprehensive treatise; a central set of ideas, methods, and recent developments were considered and brought together in textbook form. Few other books of the same kind and with a similar approach are available at present.

Reviewed by:
Paolo L. Gatti
Tecniter
Milano, Italy