

Book Review

VIBRATION CONTROL OF ACTIVE STRUCTURES — AN INTRODUCTION Second Edition

André Preumont, Kluwer Academic Publishers, Dordrecht, The Netherlands: 2002, 385 pp, £95 (hardback), £38 (paperback) (ISBN 1 402 00496 6)

There is a growing body of literature in which concepts traditionally associated with mechanical vibrations are integrated with the techniques developed by control engineers. In 1990, modern control theory, notably state-space methods, was linked to structural vibrations by Meirovitch [1]. In 1993, Junkins and Kim [2] provided a tutorial introduction to state-space methods applied to the active control of flexible aerospace structures. Both modern and classical approaches to the development of adaptive structures were provided by Clark and his colleagues [3]. Since 1992, various edited works and collections of research papers have served to emphasize the growing number of applications of both active and semi-active control schemes to structural vibration problems. For applications, the reader is referred to the books by Tzou and Anderson [4], Janocha [5] and Das and Wada [6].

The first edition of Professor Preumont's book appeared in 1997. It provided a predominantly tutorial introduction to classical and modern approaches to active control of structures and also served to inform the practising engineer, who had hitherto thought of mechanical vibrations and feedback control as distinct disciplines. The Second Edition of Preumont's book, the subject of the present review, builds upon the strengths of the First Edition; particularly welcome are the new sections on semi-active control and an extended study based upon the author's investigations into the tendon control of cable structures. In its present form, the book provides a most accessible and balanced treatment of active and semi-active vibration control. As such it provides an excellent introduction for practising engineers and will also be of great help to advanced postgraduate students.

The book begins by making clear the distinction between passive and active schemes for vibration control. Some essential mathematics is then introduced to explain techniques for modal decomposition and to relate these to the transfer function model. Perhaps as an antidote to the mathematics, the hardware of actuators and sensors is then described, making good use of particularly well-designed diagrams.

A detailed discussion of collocated versus non-collocated control leads to a chapter devoted to active damping with collocated sensors and actuators. More specifically, the author discusses direct velocity feedback, acceleration feedback, positive position feedback and integral force feedback. Some of these terms will not be familiar to the traditionally trained control engineer and the author provides lucid descriptions.

He then devotes a chapter to active vibration isolation. This chapter is written entirely in transfer function notation and is therefore accessible to those with only a knowledge of elementary classical control theory.

In the later stages of the book, the author focuses on modern control techniques. The chapter introducing state-space notation links vector-matrix techniques to transfer functions and poles and zeros, before treating pole-placement methods. Linear quadratic regulators and Kalman filters are touched upon briefly, but the interested reader can follow up the cited references. A minor criticism concerns the fact that the following chapter on classical frequency domain analysis comes in between the introduction to state space and the chapter on optimal control. This represents no major problem but may confuse the reader who is relatively new to the subject. Keeping essentially with the modern control focus, subsequent chapters deal with controllability/observability and stability.

Particularly welcome is the new chapter on semi-active control. The chapter is only short but describes magneto-rheological fluids and how these are applied in semi-active schemes. This might perhaps be worthy of expansion in the Third Edition.

As mentioned earlier, the section on applications has been substantially expanded. The First Edition covered applications to structures such as trusses, plates and beams. This new edition also describes in detail the author's work on active tendon control, which serves well to bring the theory to life. The book is warmly recommended as an introduction to the rapidly developing areas of fully active and semi-active vibration control. Not only does the author make the key concepts easily understandable but the balance between classical and modern techniques is just about ideal.

REFERENCES

- 1 Meirovitch, L. *Dynamics and Control of Structures*, 1990 (John Wiley, New York).
- 2 Junkins, J. and Kim, Y. *Introduction to Dynamics and Control of Flexible Structures*, 1993 (AIAA Publishing).
- 3 Clark, R. L., Saunders, W. R. and Gibbs, G. P. *Adaptive Structures: Dynamics and Control*, 1998 (John Wiley, New York).
- 4 Tzou, H. S. and Anderson, G. L. (Eds) *Intelligent Structural Systems*, 1992 (Kluwer, Dordrecht, The Netherlands).
- 5 Janocha, H. (Ed.) *Adaptronics and Smart Structures*, 1999 (Springer-Verlag, Berlin, Germany).
- 6 Das, A. and Wada, B. (Eds) *Selected Papers on Smart Structures for Spacecraft*, 2001, Milestone Series, Vol. MS167 (SPIE, Bellingham, Washington).

Roger Stanway
University of Sheffield

This book should be a valuable addition to an individual's collection or to an institution's library.

References

¹Bryson, A. E., and Ho, Y.-C., *Applied Optimal Control: Optimization, Estimation and Control*, rev. printing, Taylor

and Francis, London, 1975.

²Bryson, A. E., *Dynamic Optimization*, Addison-Wesley, Menlo Park, CA, 1999.

John L. Crassidis
State University of New York at Buffalo

Vibration and Control of Active Structures, An Introduction, 2nd Edition

Andre Pruemont, Kluwer Academic Publishers, Dordrecht, The Netherlands, 2002, 364 pp., \$120.00

This is the second edition of a popular book dealing with the vibration and control of structures, a topic also referred to as structural control or active structures. Previous books have not incorporated the use of smart materials as actuation and sensing devices together with the concepts of active control and structural dynamics, with the exception of Clark et al.¹ The previous books that have attempted to bridge the gap between the controls community and the structural dynamics community are Leipholz and Abdel-Rohman,² which focused on civil structures; Meirovitch,³ an undergraduate text combining topics from the two disciplines; Inman,⁴ a graduate text integrating topics in vibration and control; and of course the first edition of the Pruemont book, which addressed aerospace applications specifically. None really competes with the current Pruemont book, for it is tied to more practical hardware aspects, as well as ends with several chapters on applications. Later books, such as Clark et al.,¹ tend to focus more on smart structures and, although examples are provided, no problems are given. Pruemont provides a more complete list of references to the aerospace-oriented books and literature in active structures. Furthermore, the Pruemont book is the first of its type to make it to a second edition. Most of the other books do not include ample problems for use as a text, but the Pruemont text provides a full set of problems at the end of each chapter, and solutions are reportedly available from the author.

The format of the book is to present basic material from all of the fundamental subjects. The author relies heavily on root locus methods for explanations. The author also places strong emphasis on collocated controllers and the importance of open-loop zeros. These are points often missed by the pure controls community and hence form an extremely useful selection of topics and emphasis. The author and his laboratory have been key participants in the experimental side of space structures research. As such, the flavor of the book tends to methods that generally work well in the laboratory and hence are useful practical applications.

For those familiar with the first edition, it is worth noting that the second edition includes three more chapters and more problems. In particular, a chapter on active isolation is included that examines the classic "skyhook damper" approach and focuses on a Stewart Platform as an application. A new chapter on semi-active control examines the use of magnetorheological fluids as an actuator system. The content of this chapter exceeds the information available in any current text (including books on smart structures and materials) and is very useful. The third new chapter focuses on the control of cable-structures. In addition, material has been added to Chapter 3 on modeling piezoelectric-based structures, and there is new material on distributed sensing for vibroacoustics in Chapter 13.

For those approaching this book for the first time, the chapter coverage is as follows: The book starts with a light introduction to smart materials and structures and motivation for active vs passive control in Chapter 1. Basic concepts of structural dynamics are summarized in Chapter 2 with emphasis on modal decompositions and transfer functions. Chapter 3 examines actuators as components of active structures. Actuation devices considered are proof mass type actuators, gyrostabilizers, piezoelectric actuation, and sensing. This chapter also emphasizes the important interaction between transmission zeros in structures and collocated sensing and actuating. This leads very nicely into Chapter 4 on collocated vs noncollocated control designs. Although modern robust control analysis is avoided, the root locus plot is used nicely to point out the robustness offered by alternating poles and zeros as the result of collocation. Chapter 5 introduces the concept of active damping, again with collocation. Active damping is likely the most commonly used method by structural dynamicists approaching the control problem. However, most try to use simple velocity feedback, which generally fails to produce something more impressive than a standard passive damping treatment. The approach in Chapter 5 clearly points out the benefits of not using simple velocity feedback but incorporating some form of compensation.

Chapter 6 focuses on the active vibration isolation problem, taking the reader all of the way through the basics of single-degree-of-freedom isolation to an introduction to the Stewart Platform for six-degree-of-freedom isolation. Discussions of decentralized control, pointing control, and vehicle suspension in the context of isolation are also presented. Chapter 7 moves away from the author's theme of root locus explanations and introduces the state-space approach and corresponding control methods (including optimal control) and then ties the two approaches together using a four-degree-of-freedom example. This leads naturally to Chapter 8 on analysis and synthesis in the frequency domain. Here classical control methods are introduced and summarized. Chapter 9 extends the optimal control approach introduced in Chapter 7 for single-input, single-output systems to multiple-input, multiple-output systems. Emphasis is appropriately given to results rather than derivations, and these results are applied to structural systems.

Chapter 10 focuses on the concepts of controllability and observability with connection to structural aspects. This chapter ends with the use of controllability and observability to perform model reduction. Chapter 11 examines system stability and concludes with energy-absorbing controllers. Chapter 12 is truly unique and examines semi-active control, largely in the context of magnetorheological fluids. This is particularly timely because of the current use of such systems in automobile

suspensions. Chapter 13 focuses on applications and implementation issues, and Chapter 14 examines the specific application of tendon control in cable structures, a class of systems common to civil structures. The book ends with an excellent bibliography.

In summary, the second edition remains a viable and current reference book for structural control. It is a valuable addition to the collection of any researcher concerned with active aerospace structures. This latest edition now has enough problems to be used as a text in a senior-level elective or graduate course. This is a very useful book for graduate students, researchers, and professionals interested in structural control. I highly recommend it.

References

¹Clark, R. L., Saunders, W. R., and Gibbs, G. P., *Adaptive Structures: Dynamics and Control*, Wiley, New York, 1998.

²Leipholz, H. H. E., and Abdel-Rohman, M., *Control of Structures*, Martinus-Nijhoff, Dordrecht, The Netherlands, 1985.

³Meirovitch, L., *Introduction to Dynamics and Control*, Wiley, New York, 1985.

⁴Inman, D. J., *Vibration with Control Measurement and Stability*, Prentice-Hall, Upper Saddle River, NJ, 1989.

Daniel J. Inman
Virginia Polytechnic Institute and State University