Journal of Sound and Vibration (2000) **232**(5), 1011–1016
doi:10.1006/jsvi.2000.2899, available online at http://www.idealibrary.com on IDEAL®

BOOK REVIEWS

SOUND REINFORCEMENT ENGINEERING: FUNDAMENTALS AND PRACTICE, 1999 by W. Ahnert and F. Steffen. London: E & FN Spon. 424 pp. Price hard cover: £85.00 ISBN 0419218106.

This is a notable book because it covers, in traditional European text book style, free of acronyms and jargon, a subject that is largely non-academic and indeed too often wholly empirical in its practice.

The book has a conventional format, beginning with a well-compacted overview of room acoustics and psychoacoustics (should psychoacoustics perhaps come first?), moving through descriptions of system elements to the most interesting sections (at least for the practitioner) namely system design, calibration and testing and case studies. The chapter heading Reproduction of Classical Music is misleading.

Who should and will buy this book? Certainly acoustic consultants and electroacoustic consultants (the latter a small group!) who will value the collation of previously distributed material and its value as a training text for less experienced staff. Similarly, universities and colleges with students studying electroacoustics courses, for which this will be a good textbook.

Who should but probably will not buy this book? Many sound system designers and installers who would benefit from the wealth of information contained within the text, but who will be put off by the traditional textbook style. The next edition — for this book should continue to be available — should throw off the unnecessary Greek nomenclature and discard the dated looking photographs. The latter are always a problem in technical texts, but the problem is exacerbated in *Sound Reinforcement Engineering* by the dated installation images, featuring some of the worst of Eastern European design. The book has clearly been updated, but the next impression should lose references to gramophone records and 100 V loudspeaker systems in theatres and embrace fast-moving technologies such as auralization, multi-function digital signal processors and flat panel loudspeakers.

The book usefully covers considerable ground but there are risks to this, particularly for readers unfamiliar with acoustics. The inclusion of many standard but quite old graphs is an example: few acoustic consultants today would consider 1·8 s to be an appropriate reverberation time for a lecture hall. Similarly, outdoor sound propagation is complex and treatment in the book is perhaps too simplistic, it might be better to place greater reliance on the references, which are comprehensive.

ROB HARRIS

NON-LINEAR DYNAMICS OF ACTIVE AND PASSIVE SYSTEMS OF VIBRATION PROTECTION, 1999, by M. Z. Kolovsky, V.I. Babitsky and J. Witten Borg (translated by A. K. Belyaev). Heidelberg: Springer-Verlag, xii plus 426 pp., price (hard cover) DM 189,00, ÖS 1.38,00, SFr 171,00, GBP 72,50, US $119,00.

This book is a synthesis of two monographs edited by M. Z. Kolovsky which were previously only available in Russian; "Nonlinear theory of vibration protection systems"

0022-460X/00/201011 + 06 $35.00/0

originally published in 1966 and "Automatic control of vibration protection systems", originally published in 1976.

It is divided into six chapters. Chapter 1 is concerned with the dynamic characteristics and efficiency of vibration isolation or "vibration protection" systems, and provides a general treatment of linear, passive vibration isolation systems. These vibration protection systems are assumed to consist of a 2 December 1999 base structure coupled to an object by a series of isolators. Two cases are considered, vibration protection of the base (from the driven object) or vibration protection of the object (from the driven base). The object and base are both assumed to be flexible in general and are described in terms of their modal behaviour. The driving point and transfer characteristics of these systems is defined in terms of their dynamic compliance, e, which is characterized in particular examples by its polar frequency response. The response of the isolators is described in terms of an effective feedback law, w, from a displacement to a force acting on the system and the overall behaviour is characterized in terms of the "efficiency" of the vibration protection system, $k = (1 + ew)^{-1}$. Various cases of passive isolation system are then considered within this framework, including those with an intermediate mass and/or a vibration absorber.

Chapter 2 considers linear active systems. The transfer function of such systems is deduced from a general block diagram which considers not only the dynamics of the base and object but also those of the sensors, compensators and actuators in the feedback loop. A brief review is then given of the dynamics of different types of sensors, including accelerometers and strain gauges, compensators, including "integrators" and "differentiators" (implemented using first order RC circuits) and phase lag and lead networks, and actuators, including hydraulic, pneumatic and electromagnetic devices. One-dimensional, i.e., single channel, linear active systems are then considered in general terms. The particular cases of collocated feedback of displacement, velocity or acceleration are analyzed in detail, together with the case of feeding back a control force proportional to integrated displacement. This latter control strategy is described as being "astatic" and is important when the position of an object has to be kept fixed when subject to steady accelerations, in spacecraft, ship engine suspensions and machine tools for example. The stability of these systems is then analyzed with various "non-ideal elements", i.e., actuator and sensor dynamics, present in the feedback loop. The stability of such a system is considered, initially by using a state-space formulation and then by using the Nyquist criterion, and it is shown that an uncompensated feedback loop which generates a control force proportional to integrated displacement is stable only for feedback gains below a certain limit. After considering the effect of these local feedback loops on the rest of the structure, the transient response of an active system is analyzed to assess the protection from impacts. The power supplied by the actuator in an active system is then considered and it is shown that this is zero for ideal displacement or acceleration feedback, that it is positive for ideal velocity feedback, but that it is negative for ideal integrated displacement feedback, i.e., power is supplied to the system by the actuator under these conditions. Finally, in Chapter 2 the analysis of multi-dimensional systems, i.e., those with many actuators and sensors is considered.

Chapter 3 is entitled "Nonlinear passive single-degree-of-freedom systems" and begins by discussing a number of methods of analyzing the response of non-linear systems. These include the "method of harmonic linearization" (better known as the describing function method) and the method of equivalent linearization. The forced response of several types of non-linear single-degree-of-freedom systems to harmonic excitation are then considered, particularly those with a non-linear stiffness. This analysis is used to quantify the increase in "resonance" frequency with excitation amplitude for a hardening spring, for example, and the jump phenomena which can occur at higher amplitudes of excitation. The response of systems with Coulomb, or dry, friction is then discussed, emphasizing their stick–slip behaviour, together with systems having "internal friction" in which the coefficient of friction, depends on a power law of the amplitude of the response, which also has the effect of making the resonance frequency rise with excitation level. Hysteresis loops are mentioned only in passing in connection with the definition of absorption factor for systems with internal friction.

The response of non-linear single-degree-of-freedom systems to polyharmonic excitation is then treated by using the distribution function method to calculate the amplitude of response for non-linear springs or Coulomb friction. It is then demonstrated by using Galerkin's approach how a subharmonic response is generated when the damping is less than a critical value, with the particular example of systems with rigid stops. Rigid stops can also lead to undesirable resonances which can only be suppressed by increasing the clearance or the dissipation in the system. Finally, the response of non-linear systems to random excitation is analyzed by using statistical linearization.

Chapter 4 is concerned with non-linear passive multi-degree-of-freedom systems, particularly for the case of a rigid object suspended by elastic elements. This chapter starts with the analytic determination of static deflection, after which small-amplitude vibrations are considered by using a linearized analysis. Lagrange's equations are then used to treat the general problem of a rigid body suspended on non-linear isolators. Both the free vibration and resonant behaviour are considered. The forced vibration of systems with Coulomb friction and the phenomenon of locking are considered next, before that of forced vibration of elastic bodies.

Chapter 5 is where the two strands of this book come together, in the analysis of non-linear active systems. The first part of this chapter investigates the effect of linear feedback on the dynamic behaviour of a non-linear system. After a brief review of the material covered in Chapters 3 and 4 for systems with non-linear springs, the influence on the behaviour is considered of a feedback loop having a generalized transfer function between meausred displacement on a moving object and the active force applied. The imaginary part of the feedback loop's frequency response adds damping to the system and a positive real part in this frequency response adds stiffness and thus raises the resonance frequency, both as one would expect. Both forms of feedback can help prevent the impact resonance, referred to above, in systems with rigid stops. The issue of subharmonic vibrations is also revisited for a system with a non-linear spring but linear feedback and again actively increasing system damping reduces the range of parameters over which such vibrations can be excited.

The second topic dealt with in this chapter is the effect of non-linearities in the feedback loop, particularly the dead zones and saturations which will generally be present in high-powered actuators such as hydraulic devices. It is shown by using harmonic linearization how both these effects reduce the effective gain of the feedback loop and thus reduce its efficiency. The non-linear elements in the feedback loop also generate high-frequency vibration due to harmonic distortion. If the system is subject to simultaneous excitation at both low and high frequencies, then the high-frequency excitation may affect the control performance at a low frequency. High-frequency excitation for example can "smooth out" the effects of non-linearities such as Coulomb friction. Finally, the stability of vibration in non-linear systems is considered using a form of equivalent linearization.

The final chapter is concerned with optimal systems of vibration protection. This begins with a list of the most important types of constraints which are met in the synthesis of vibration isolation systems, including constraints on the absolute level of an object's acceleration, on the maximum force transmitted to the base, on the relative displacement between the object and the base and on the magnitude of the maximum control force.

Optimal control involves the minimization of a chosen cost function subject to these constraints and is first solved for impulsive, i.e., shock, excitation of linear single-degree-of-freedom systems. Although simple problems can be solved analytically for excitations of this form, for more complicated excitations "graphical – analytical" methods must be used. These often consist of solving a series of optimization problems over sequential time intervals, with the control law changing sign depending on the sign of a "switching function", so that the control law becomes non-linear. For several examples considered in this chapter the optimal isolation system includes a Coulomb damper, which is a special case of such a control law.

Overall, this is not a book for the beginner in either non-linear systems or active isolation systems. As a first text the reader is probably better off, for example, with the introductory chapter on vibration isolation by E. E. Ungar in "Noise and Vibration Control Engineering", edited by Beranek and Vér and the non-linear control sections of textbooks such as "The Art of Control Engineering" by Dutton *et al.* The treatment in Kolovsky's book is very largely mathematical and physical explanations of certain phenomena are rather thin on the ground. There is no discussion of the numerical simulation of non-linear systems or the use of particular, the complete lack of figure captions, and the labelling of an axis in terms of symbols rather than words, makes each graph rather difficult to understand without reading the entire text up to that point. The index is also of limited use. There are many idiosyncrasies in the way the text is expressed, for example a first order low-pass filter is often referred to as an "aperiodic element". The references are also very largely to Russian-language sources, even to the extent of referencing Russian translations of classic texts such as Bellman's.

In conclusion this book is not for the fainthearted. It requires considerable effort from the reader to establish the physical significance of many of the results. Nevertheless, for research workers with some background in non-linear isolation systems and/or non-linear control, this book brings together a wide range of approaches from a rich analytic tradition.

S. J. ELLIOTT

VIBRATION ANALYSIS OF PLATES BY THE SUPERPOSITION METHODS, 1999, by D. J. Gorman. London, New Jersy and Singapore; World Scientific. xx plus 361 pp. Price GBP 56.00. ISBN 9810236816 396711.

The monograph entitled *Vibration Analysis of Plate by the Superposition Method*, by Professor D. J. Gorman, presents a comprehensive study of vibration and buckling problems of plates using the superposition method developed by Gorman in the 1970s. The author incorporated into this monograph many recent advances in applications of the powerful analytical method to a variety of dynamical problems concerning vibration of orthotropic and laminated plates, effects of in-plane loads on vibrational behaviour and buckling of plates, effects of shear deformation using Reissner's and Mindlin's plate theories, vibration of non-rectangular plates, arbitrary classical and non-classical boundary conditions along any edge of a plate, interior and corner point supports, interor line supports, mixed boundary conditions leading to the investigation of effects of a linear crack on the vibrational behaviour, continuous plates with application to dynamic response of bridges, etc.

In writing this monograph, the author paid great attention to detail involving use of the superposition method. This is extremely useful and important for interested researchers to learn and explore the methodology. To help readers better understand how an accurate analytical solution may be obtained using the superposition method, the author presented a clear mathematical procedure for each topic covered, and completed the topic with carefully chosen examples, numerical results, and a brief summary.

This monograph is also of great reference value to engineers seeking to understand the fundamental behaviour of plate vibration, extract data for use in design of plates, and verify results obtained using different methods.

Professor Gorman has made many significant contributions to plate vibration research. We believe that this monograph will be well received by researchers working in the field of plates.

S. D. YU
W. L. CLEGHORN

INTEGRATING DYNAMICS, CONDITION MONITORING AND CONTROL FOR THE 21ST CENTURY, 1999, A. G. Starr, A. Y. T. Leung, J. R. Wright and D. J. Sandoz, editors. Rotterdam: A. A. Balkema, Price Euro 102.00, ISBN 90 5809 1120.

This book contains the proceedings of the first International Conference on the Integration of Dynamics, Monitoring and Control, which was held in Manchester, England on 1–3 September 1999. The aim of the conference, as indicated by the title, was to encourage the integration of technologies and cross-fertilization of ideas between disciplines, and to demonstrate integrating technologies and applications. Such conferences are increasingly important because integration of technology will be a major theme of the 21st century. The volume contains a total of 87 papers, with the authors spread throughout the world. Interestingly, just over half of the first authors are from Asia, giving the reader ready access to research that is often difficult to uncover. As expected, the proceedings contain papers on a wide range of subjects, and it would be impossible to mention all of them here. However, some themes within the conference will be identified.

The three main themes of the conference were, of course, dynamics, condition monitoring and control, and the papers were evenly spread among these areas. Many of the papers are concerned with applications, and this helps by integrating any technique which might be useful in the application. In dynamics, machines dynamics and non-linear models are prominent and there are papers modelling separation equipment, vibration mills, transmission systems, ship lifts, roller chains, suspended cables, cantilever pipes containing fluid, a pendulum, ship motion, non-linear vibration absorbers, bonded joints and plates. Rotor dynamics applications are well represented, often concerned with the control of rotating machinery or the representation of faults, with papers on the chaotic vibration caused by rotor–stator rubs, the identification of faults from run ups and the identification of unbalance and sensor runout.

The papers on condition monitoring demonstrate the huge variety of techniques that are available. Techniques such as principal component analysis, higher order spectra, wavelet and other time–frequency types analysis, acoustic emission, neural networks and other types of feature extraction are all used. Several papers discuss combining data from different sensors or techniques, for example using fault trees or other data fusion technologies. These approaches are demonstrated on a wide variety of equipment such as gear teeth, gearboxes, bearings, power transformers, textile machinery, CNC machine tools, hydraulic actuators, coke ovens and pumps. There is a section on condition monitoring of electrical machines that is particularly comprehensive.

On the control side the emphasis is once again on applications, which includes vehicle airbags, noise and vibration control, temperature control of a glass furnace, power systems, mirror systems and flow control, using a variety of actuators, such as speakers, piezoceramic materials and magnetostrictive and jet actuators. Aspects of tracking control of robots are also covered.

Overall, the range and quality of papers is impressive, and these proceedings are a worthwhile addition to the bookshelf.

M. I. Friswell