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BOOK REVIEWS

DESIGNING QUIET STRUCTURES: A SOUND POWER MINIMIZATION APPROACH, 1997, Gary H. Koopmann and John B. Fahnline. London: Academic Press. xiii + 244 pp. Price £35·00. ISBN 0-12-419245-9.

The authors introduce this book as describing the emerging technology which allows noise control to be included as one of the primary variables in the design stage of quiet structures. Specifically, it is aimed at engineers and scientists who wish to learn how to incorporate *sound power output* as a parameter in the conceptional design stage of a structure. It will also be very useful to acousticians in bringing together the research work in this area, to which the authors have significantly contributed over the past decade, in a consistent and accessible form. Although it is emphasized that the book does not present a complete set of tools for the noise control engineer, it does indicate how modern computational techniques, which may also include FE analysis and optimisation routines, can be used in a unified design methodology.

Over the course of eight chapters a lumped parameter approach is presented which allows a simple and intuitively appealing method of calculating the sound power output of vibrating structures. Sound power output is formulated in terms of the vector of volume velocities of a number of elements on the surface of the structure and the matrix of acoustic radiation resistances. This approach allows the optimization of the velocity distribution over the structure to minimize its sound power output either by changing its structural characteristics (passive control) or by the use of secondary acoustic or structural sources (active control).

Chapter 1 describes the basic equations of acoustics, starting with the wave equation and its representation for harmonic vibrations in terms of the Helmholtz equation. Freefield radiation is emphasised and acoustic sources are introduced via the freefield Green function. The sound power output is formulated in terms of the integral of surface intensity over the surface, and the radiation from compact sources is derived. Chapter 2 describes a lumped parameter model for acoustic radiation, using elements which are small compared with the acoustic wavelength. It is emphasized that the boundary conditions only need to be satisfied in an average sense over such elements, because the acoustic pressure over each element is an inherently smooth function. The errors involved in such an approximation are examined and it is emphasized that only the component of the surface pressure which is in-phase with the surface velocity needs to be accurately represented to calculate the sound power output. Although the elements must be assumed to be very small compared with the acoustic wavelength for the method's validity to be demonstrated analytically, it is shown by using numerical simulations that the accuracy of the method can be acceptable for engineering applications if the dimensions of the elements are of the order of one-fifth of the acoustic wavelength.

Chapter 3 is the major theoretical chapter of the book and begins with an informal discussion of the use of the FE method and BEM for radiation problems, emphasizing the problem of discontinuities in the latter approach. If only the sound power output is of concern, however, the effect of such discontinuities can average out, although some care must be taken to ensure that this is indeed the case. Several methods of approximating the boundary condition on the surface of a vibrating structure are then discussed when the boundary is discretized into a number of elements and a set of "equivalent" monopole

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and dipole sources are assumed interior to the surface of the radiator. The first method discussed is collocation, where the sources are placed on the boundary, as in the BEM, and the number of equivalent sources is equal to the number of elements on the boundary. It is shown that this method can result in significant errors in the calculated sound power radiation. In the second method the equivalent sources are assumed to be slightly inside the surface and the sum of squared differences is minimized between the true average velocity at the surface elements, and that created by the equivalent sources. This gives a better approximation to sound power output, but not as good as that obtained by the final method, in which the equivalent sources are adjusted to exactly match the volume velocity at the boundary elements. It is this volume velocity matching method which is then used throughout the remainder of the book for the numerical calculation of sound power output. Chapter 3 concludes with examples of the numerical calculation of sound power output from a block radiator, a piston inside a thin-walled cylinder and a muffler element. The estimated sound power output converges as the number of equivalent sources is increased to between 100 and 1000 in the different cases.

The fourth chapter is concerned with the experimental measurement of the acoustic resistance matrix. An experimental approach is necessary when the geometry of the vibrating structure is too complicated to model numerically. The measurements can be performed by using a "resistance probe" which is made up of a loudspeaker, whose volume velocity can be measured, and a closely-spaced pressure microphone. The resistance probe described has a diameter of about 3·8 cm and can thus be used to measure the radiation resistance matrix up to about 1·5 kHz. The loudspeaker source is placed at the centre of one of the surface elements and in-phase pressure measurements are then taken at the centre of all the surface elements to measure one row of the radiation resistance matrix. The measurements required for the complete radiation resistance matrix are then obtained by moving the loudspeaker source to the centre of each of the other surface elements in turn. For N surface elements $N \times N$ measurements would thus be required to obtain the complete radiation resistance matrix. It is thus wryly noted that "The main challenge to the experimenter is to muster the patience required . . . for large, highly complex structures.".

Chapter 5 is concerned with the properties of the radiation resistance matrix in various frequency ranges. It is noted that at low frequencies, when $kL \ll 1$ where k is the acoustic wavenumber and L is a characteristic dimension of the vibrating structure, then all the elements of this matrix are similar, since the sound power output is mainly determined by the total volume velocity of the structure. At high frequencies, when $kL \ll 1$, the matrix is diagonally dominant, since each element of the structure radiates almost independently. It is thus only at intermediate frequencies that the terms of the radiation resistance matrix must be individually evaluated, either numerically or experimentally.

Chapter 6 is concentrated on the minimization of the sound power output by material tailoring, e.g., changing the mass distribution or thickness of a structure to reduce its sound radiation. Such a structure is called a "weak radiator" and the required structural design could be achieved by numerical optimization to minimize total sound power, while maintaining constraints on strength, stiffness, etc. It is suggested that a frequency averaged approximation to sound power output can be obtained, for use in such an optimization, by adding together the sound powers radiated at each resonance frequency. Examples are presented of adding discrete masses to a beam and to a plate to minimize their power outputs. The optimum position of these masses tends to reduce the sound radiation by causing each of the modes of these structures to have a reduced volume velocity component.

Chapter 7 describes the use of active control in the reduction of total sound power. The discussion is restricted to secondary acoustic sources on the surface of the vibrating structure, although it could be readily extended to the case of secondary forces acting within the structure. The active control of tonal noise is formulated using the Hermitian quadratic form. Numerical examples are provided of the active control of complicated vibrating structures, and the control method proposed is shown to be most effective when $kL \leqslant 1$, as expected.

Finally, Chapter 8 describes the control of sound inside enclosures, when excited by vibrations of the walls. The soundfield is expanded by using a modal series in this case and the strategy suggested for control is the minimization of the total acoustic potential energy in the enclosure, rather than the total acoustic power generated by the vibration walls. An example is given of the active control of the total acoustic potential energy in a rectangular enclosure.

Overall, this book makes a very useful contribution to the literature in bringing together a number of themes and presenting them within the framework of a unified design strategy. Both problems and suggested laboratory exercises are given at the ends of each chapter, and the book also comes with a disc containing a FORTRAN program which calculates the power output of a structure whose elements are described by using the NASTRAN input file format. The authors emphasize, however, that this design method is still an emerging technology. To use confidently either the numerical or experimental techniques described in this book can still require a significant level of both understanding and skill.

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MECHANICAL AND STRUCTURAL VIBRATIONS, 1995, D. G. Fertis. New York: John Wiley & Sons, Inc., xviii + 804 pp. Price £100·00, $110·00. ISBN 0-471-10600-3

Many books on vibration analysis tend to present various techniques and then proceed to illustrate them with practical problems. In this book the emphasis is placed upon the understanding of the physical behaviour of vibrating systems. Simple accurate mathematical models are then developed to enable the engineer to design structural and mechanical systems effectively.

The first chapter starts with a discussion of the fundamentals of vibratory motion of both linear and non-linear systems. The equations of motion of several discrete and continuous systems are then derived. A brief discussion of chaos in non-linear systems is also included. Chapter 2 is devoted to free vibration of simple, discrete and continuous linear systems. Methods of representing damping are also described. The prediction of the response of simple systems to time-varying forces which are harmonic, period and arbitrary, is dealt with in Chapter 3. Both analytical and numerical methods are described. Beams, frames and elasto-plastic systems are all considered.

Chapter 4 begins by considering the free vibration of continuous systems such as mutli-supported beams, the transverse vibration of strings, cables and stretched membranes and the flexural vibration of rectangular plates. Axially-restrained beam columns on rigid or elastic supports are investigated in detail in order to illustrate special types of static and flutter type instabilities. This is followed by the response of uniform beams to point and distributed harmonic forces and support motion. Also introduced in this chapter is the concept of dynamically equivalent systems that have been developed by the author and his collaborators. This approach provides essential information which helps to a better understanding of the dynamic behaviour of complicated structural systems.

Several approximate methods of vibration analysis, including the Rayleigh, Stodola, Myklestad and transfer matrix methods are presented in Chapter 5. This is followed by a complete chapter on the finite element method. The stiffness and mass matrices of various beam and plate elements are derived. Free vibration analysis is illustrated using the Jacobi method, whilst forced response is analysed using either direct integration or modal analysis. In each case the time history of the response is obtained using the Newmark-beta method. Chapter 7 begins by describing the use of Lagrange's equations for deriving the equations of motion of multi-degree-of-freedom systems. This is followed by a more in-depth treatment of the modal superposition method for calculating the dynamic response of both discrete and continuous systems. The chapter ends by describing the use of the method for earthquake response analysis.

Chapter 8 treats the linear and non-linear response of members having continuously varying stiffness along their lengths. Both geometrical and material non-linearities are considered. The author's method of equivalent systems is used throughout. Chapter 9 uses Fourier and Laplace transforms to determine the dynamic response of systems that are subjected to periodic and non-periodic excitations. It ends with an analysis of machine foundations subjected to external excitation. Two topics are presented in Chapter 10, variational methods for deriving the equations of motion of dynamical systems and the response of systems to random excitation. This latter topic is utilized to determine the material and strength characteristics of concrete mixtures. The final chapter is devoted to dimensional and model analyses. It includes principles of dimensional analysis and the Pi theorem and discusses the design of scale models.

The book ends with twelve appendices containing information supporting the main text and a list of references. It contains many examples within the text and problems at the end of each chapter. The answers to a selection of these problems are given at the end of the book.

Both academia and industry should find this book useful, as its main theme is the use of simple yet accurate models to represent complex systems. Many of the topics are not often found in basic texts on the subject, since they are based upon recent research by the author. Overall, it is well written and has a good balance between theory and applications.

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