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Book Reviews

Random Vibration: Theory and Practice

P. H. Wirsching, T. L. Paez, and K. Ortiz, Wiley, New York, 1995, 448 pp., $69.95

This book is a comprehensive account of the linear theory of random vibration and related topics such as the first passage-problem problem and parameter estimation. It is self-contained and well written by three qualified individuals. It consists of 14 chapters, five appendices, and an extensive list of references. Each chapter begins with an introduction stating its objectives, main topics, and link to other chapters and other published work in the open literature. Each chapter ends with a set of problems that make the book suitable for graduate courses in random vibration.

Chapter 1 is an introduction describing the purpose and scope of the book, and Chapter 2 introduces the concept of random variables, probability theory, statistical parameters, and moment-generating functions. Transformation of the probability density function from one set of coordinates to another set is well explained.

Chapters 3–5 deal with the description of random processes in the time and frequency domains and their classification according to statistical parameters. In random vibration studies, a random process refers to either the excitation or the response of a dynamical system to a random excitation. In particular, Chapter 3 addresses stationary and ergodic processes in the time domain. Statistical parameters include autocorrelation and cross-correlation functions and their characteristics for different stationary processes. This chapter is concluded by the properties of harmonic and Poisson processes, which are essentials for engineering problems and other chapters. Chapter 4 introduces the concept of the Fourier transform (FT) and its essential ingredients to decompose the random process into its frequency components. The properties of special functions such as the rectangle boxcar function, Dirac delta function, and sine and cosine functions, together with their FTs, are outlined and clearly defined. The description of random processes in the frequency domain is presented in Chapter 5. In this domain random processes are characterized in terms of the power spectral density function or the cross-spectral density function. These two functions are basically the FTs of the corresponding autocorrelation function and cross-correlation function, respectively. The chapter includes some practical issues concerning the estimation of the spectral density function, its units, and its definition. The basic concept of the coherence function and its role in the relationship between the input and output is briefly introduced.

Chapter 6 presents the basic concepts of the level-crossing (or the first-passage) problem and distributions of extrema for narrow- and non-narrow-band random processes. The role of the Poisson process for independent level crossings and the Rayleigh distribution are introduced. This chapter is closely related to Chapter 10, and the reader who is interested in random vibration can skip Chapter 6.

Chapters 7–9 deal with the random response of linear systems to random excitation. Chapter 7 includes the basic ingredients for Chapters 8 and 9. It begins with the deterministic linear theory of free and forced vibrations of single-degree-of-freedom (DOF) systems. It takes the reader systematically to the basic concepts of unit impulse response, convolution integral, the relationship between the unit impulse response and the complex frequency response function, and the relationship between the response and excitation through the complex frequency response function. Chapter 8 describes the response statistics of stationary processes. These include response mean values, autocorrelation function, mean square, and spectral density function. An analysis is given for the response to a white noise excitation and is supported by a few examples. Chapter 9 extends the analysis to the case of multi-DOF (MDOF) systems. The response-excitation relationship is established in terms of the transfer and impulse function matrices. The response statistics described in Chapter 8 are formulated for MDOF systems and demonstrated by simple examples. The normal mode method for undamped and damped systems is presented as a tool for decoupling the equations of motion. This chapter is concluded by some remarks on the available computer codes for analyzing MDOF systems.

Chapter 10 addresses the elementary models for ensuring structural integrity under random stress loading. These models include the three-Sigma design criterion, first-passage failure based on different approaches, and fatigue models. This material is very useful for designers and is supported by practical examples and algorithms. However, it does not address Pontryagin's equation, which is a fundamental tool for the first-passage problem.

The problem of parameter estimation is treated in Chapters 11 and 12. Chapter 11 introduces the problem in terms of the probability distribution of random variables. It includes some fundamental statistical parameters, such as the mean value and variance using the maximum-likelihood estimator based on normal distribution. It also addresses related topics, such as confidence intervals for estimating the mean, bias in variance estimators, and sampling distribution for variance. Chapter 12 presents statistical analysis for stationary and non-stationary random processes. The work is divided into ensemble average and temporal average (for ergodic processes) estimations. A special section is devoted to direct and indirect methods for estimating statistical parameters of nonstationary random processes.

The last two chapters revisit the FT. Chapter 13 deals with the discrete FT and related problems, such as periodicity, aliasing, leakage, and data windows. Computational aspects of fast FT are presented in this chapter, and the corresponding Fortran subroutine is listed in an appendix. Chapter 14 provides more analyses on spectral and cross-spectral density functions. The methods include direct estimation of the spectral density based on the discrete FT and the maximum-likelihood estimation, together with its practical aspects. The estimation of the cross-spectral density and ordinary coherence functions are revisited. The chapter is concluded by developing formulas for estimating the frequency response function for the single-input, single-output case and for the multi-input, single-output case.

The book is recommended for a first course in linear random vibration (the first nine chapters) and as a good reference for practical engineers. It is an excellent addition to the previous books on random processes and vibration.

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