Book Reviews

Probabilistic Methods in the Theory of Structures

Isaac Elishakoff, John Wiley & Sons, Inc., N.Y., 1986, 489 pp., $57.50

It has been 20 years since the publication of *Probablistic Theory of Structural Dynamics* by Y. K. Lin. During these two decades great strides have been made in the general application of probabilistic and stochastic methods to structures. This extremely well-written text, authored by one of the leaders in the field, incorporates many of these new applications. It provides beginning students with a means by which they may enter this fascinating application of probabilistic thinking and at the same time it can take the serious student through the advanced concepts required to understand a probabilistic treatment of dynamic buckling and random vibrations of continuous structures. Professor Elishakoff's techniques for developing the material are accomplished in a way that illustrates his deep insight into the topic as well as his expertise as an educator.

After the Introduction, Chapters 2 through 4 develop elementary probability theory from random event to conditional probabilities, distributions and expectations for scalar random variables. There is a well-chosen collection of examples and problems that illustrate the fundamental ideas included in each chapter, with a desirable slant towards engineering applications. The example at the end of Chapter 4, incorporating probabilistic thinking to determine the optimal height of dikes in Holland (due to Van Danzig) is especially well presented, and instructive for beginning students.

Having developed elementary probability analysis for a single random variable, Professor Elishakoff immediately applies the necessary methods to study problems of reliability of structures in Chapter 5. The student is taken from the simple problem of a deterministic bar under a random tensile force to bars with random properties, then to beams with random imperfections requiring nonlinear analysis to determine the statistics of the buckling loads. The definition of imperfection sensitivity is introduced and studied for bars with random initial imperfections. In this context, the concept of first passage time, for the first time which failure (such as buckling) occurs, is introduced. This concept is studied in detail for the imperfect bar under axial impact. The chapter concludes with many comprehensive and instructive problems of reliability and failure of simple structures with random loads and random properties.

This is essentially the style continued throughout the text. Thus, Chapter 6 develops the tools necessary to study functions of two or more random variables. In particular the concepts of conditional probabilities, and correlations are introduced. These are applied in Chapter 7, which makes it possible to include both random applied stresses and random allowable stresses, along with other parameters to be incorporated in the formulation of the reliability problem. In particular, bending of beams under several concentrated random forces or random moments can be treated.

In a sense, the first seven chapters of the text constitute the first half, which rests upon elementary probability methods for the study of the pertinent random variables. The author suggests Chapters 1-5 (plus Sections 1 to 3 of Chapter 11, on numerical methods and computer simulations) as a course for juniors or seniors without previous background in probability. For students having a first course in probability, then Chapters 1-7 (again with 11.1-11.3) form a natural first course on the topic of structures and reliability.

The second half of the text, Chapters 8-11, is concerned with probabilistic dynamics and, therefore, rests upon the concept of random functions. The elements of random function theory is the subject of Chapter 8. This includes usual topics such as the time parametric family of joint probabilities, moment functions, covariance functions, stationarity, weak stationarity, spectral densities, Wiener-Khintchine relations, the calculus of random functions and, finally, a detailed discussion of ergodicity with illustrative examples. The concepts discussed in Chapter 8 are sufficient to treat the probabilistic properties of the response of discrete (lumped parameter) linear systems subject to random excitations. This constitutes the central theme of Chapter 9. A careful and detailed development of the second order properties of the response in time and frequency domains for displacement and velocity of a single degree of freedom oscillator subjected to band-limited and ideal white noise is presented to build the student's understanding of random vibrations. Many figures are presented illustrating how significant statistics, such as second moments, vary with the oscillator and excitation parameters. For multi-degree of freedom systems, the author bases his development on modal methods. In particular, he stresses, by discussion and examples, the role of modal cross-correlation that is sometimes neglected in the literature on random vibrations. The explanation of these errors is nontrivial and an exact presentation of the errors incurred is given. The examples and problems of Chapter 9 are well chosen and quite illustrative.

In Chapter 10, the author continues development of structural response under random loadings for continuous parameter structures as formulated by partial differential equations, basing his approach on modal decomposition. He rests his development on the response of a beam to random distributed loadings, and then treats the case of point loads random in time, which is referred to as Crandall's problem. Finally, Chapter 10 closes with a discussion of random vibrations due to boundary layer turbulence using the piston theory formulation.

Professor Elishakoff completes the text with Chapter 11, which is titled "Monte Carlo Method," and is concerned with the problem of random number generation and computer simulation for the numerical study of the response of structures to random excitations. In this chapter it is shown that the analytical relations thus far studied are not enough for engineers, they must also be able to analyze numerically for design purposes. The author illustrates how to generate purely random numbers, random variables with a given distribution, random functions by eigenfunction representation and finally he presents a statistical study of buckling of an imperfect bar on a non-linear foundation by simulation. In this chapter, one is taken from analytical development to the practicality of numerical simulation and numerical experiment. Clearly, the second half of the text provides the basis for an excellent graduate course on random vibrations and buckling. There is a comprehensive selection of references at the end of each chapter with suggestions for further reading.

We must now ask, where does this book fit in the ever-increasing collection of books on probabilistic and stochastic methods? It does not contain an advanced development requiring ideas of stochastic differential equations, Ito calculus, etc., nor is it a text on elementary probability or elementary random function theory. It is, as was the author's goal, a development of tools and the applications of these tools to structural problems in which uncertainty is present. As such, in this reviewer's opinion, Professor Elishakoff has presented us with an outstanding instrument for teaching.

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Flow Induced Vibration of Circular Cylindrical Structures

Shoei-Sheng Chen, Hemisphere Publishing Corp., NY, 1987, 464 pp., $110.00.

Flow past a cylinder, or an arrangement of cylinders, represents a generic type of flow-structure interaction that has widespread practical ramifications. Offshore structures and heat exchanger tube bundles are typical of the variety of configurations of current importance. It is therefore no surprise that an entire book can be dedicated to flow-induced vibration of cylindrical structures. Such an overview is important not only for the practicing engineer but also for the researcher who, more than ever, is deluged with an ever-growing body of design information and research results.

This book methodically takes the reader through concepts of increasing complexity, starting with the simplest case of a single cylinder in quiescent fluid and extending to the very complicated case of fluid-elastic instabilities of arrays of cylinders in cross-flow. The types of flows addressed are not limited to incompressible, single-phase flows. The author creates an awareness of the importance of compressibility and its relevance to acoustically induced vibration of a cylinder. Effects of two-phase flow are also covered. Finally, in problems of this type, effects of nonlinearity and three-dimensionality are always of concern, and the author provides information on these aspects.

After addressing the (relatively) simple case of a single cylinder in quiescent fluid, the author points out many key physical features of multiple cylinders in quiescent fluids. Although certain of these aspects are not directly applicable to systems with flowing fluid, there are practical situations where cylinder vibration in non-flowing fluids does occur. Perhaps more important, however, is the effort to make the reader aware of important concepts such as multiple vibrational modes and multiple natural frequencies of groups of cylinders. This can be very nicely illustrated in absence of mean flow.

As a prelude to a discussion of circular cylinders immersed in flow in the direction of their axes (i.e., an axial flow), the reader is provided with a chapter on pipes conveying fluid. Of course, this topic is of obvious importance, and the effects of hydrostatic fluid pressure, gravity, and damping forces, as well as several other effects, are accounted for. For the case of circular cylinders in axial flow, the most common practical configuration involves a number of cylinders arranged so that their axes are parallel; an account is given of the behavior of such multiple cylinder arrays. This class of problems is also viewed with respect to the concept of near-field flow noise and its possiblity for exciting cylinder vibration.

In the event that a cylinder is oriented such that its axis is orthogonal to the flow direction, then there occurs massive flow separation on the downstream side of the cylinder, making it necessary to consider the intricacies of the unsteadiness of the separated flow region. In its complete form, this class of problems challenges our knowledge of transition and turbulence in shear flows, an area that is still not describable in simple terms, even when speaking of the fluid mechanics divorced from the body that generates the separated flow. The author provides a view of a number of aspects of a single cylinder in cross flow, including the variation of flow loading as a function of Reynolds number; this topic, in itself, provides the researcher and designer with a rich spectrum of