

Parametric Random Vibration*

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PARAMETRIC random vibration is an applied scientific discipline that covers problems from the broad field of applied dynamics, e.g. structural dynamics, aerodynamics, naval architecture etc. The system equations are characterized by random perturbed parameters while, in many practical situations, non-linearities and random forcing terms create additional complications. Various textbooks have appeared covering the field of random vibration of time-invariant systems. This monograph, a state of the art presentation of parametric random vibration, based on an enormous number of published papers and reports, is a great credit to the author.

In the first chapter the reader is introduced to the basic definitions of parametric and autoparametric instabilities, chaotic motion, pseudo-random excitation and crypto-deterministic systems and a brief review of parametric random vibration is given. In random vibrations, the emphasis is on the response and stability of systems under wide band random parametric excitations. Unfortunately system equations with physical wide band noise excitation are very difficult to handle, therefore physical Gaussian wide band noise is often replaced by idealized white noise, or the wide band noise is generated by a shaping filter driven by white noise. This is usually the point where many engineers get lost. They are referred to books on stochastic processes and stochastic differential equations and are encouraged to go into theories which are embedded in mathematical abstraction. For these engineers the root of all evil (which is at the same time a source of pleasure for many mathematicians) is the unbounded variation of the Brownian motion, which has white noise as its derivative, in a formal sense. For these processes a new stochastic calculus is needed. In Chapters 2–4 the author provides the necessary tools for deriving response statistical functions and techniques for examining stochastic parameter stability, as required in later chapters. The author has chosen an engineering approach without mathematical abstraction, which implies that some important theorems are verified in a heuristic way, while many others are only mentioned. The result is a nice reference frame for readers with a reasonable background in stochastic processes and stochastic differential equations. Readers without this background will certainly get into trouble, for example, when reading the definitions of random variables and random processes. Obviously, the author could not resist the temptation to give some flavour of mathematical abstraction by introducing a random variable as a function of a sample space Ω , which is confusing in the context it is used. Also, the introduction of probability space and Borel field in a footnote to the last section of Chapter 3, and the use of the term “measurable random process” in the following chapter, which is not essential in his further discussions, will certainly discourage readers with an engineering background. In contrast with this, the concepts of Riemann and Riemann–Stieltjes integrals are introduced in a very elaborate way. Of course these minor flaws are of no significance for readers with an adequate background in this material.

The contents of Chapters 2–4 are restricted to those subjects of stochastic calculus needed for understanding the following chapters. In Chapter 2 the basic facts of probability theory and

stochastic processes are presented with emphasis on the essential features of Gaussian and non-Gaussian density functions. The non-Gaussian density function is presented in terms of the Edgeworth or the Gram–Charlier asymptotic series. In Chapter 3 the elements of stochastic calculus operations are outlined: the various modes of stochastic convergence, stochastic limit theorems, mean square derivative and Riemann–Stieltjes integral. Chapter 4 contains an accurate definition and discussion of Brownian motion, white noise processes, the related Markov process and a definition of the Fokker–Planck–Kolmogoroff equations. In the last section of this chapter the main results of stochastic calculus as developed by Itô and Stratonovich are presented in a straightforward way without mathematical abstraction. Perhaps readers with an engineering background would prefer an exposition giving more physical insight; for example, in the same style as the paper of R. E. Mortensen, celebrated in engineering circles. In Chapter 5 two methods are presented to generate the response statistical function of a system: the Fokker–Planck–Kolmogoroff equation method and the method based on Itô calculus. The principles of Gaussian and non-Gaussian closure methods to handle the infinite hierarchy problem are outlined. In Chapter 6 the standard form of stochastic averaging based on the principle of Bogoliubov and Mitropol'skii is presented, followed by some extensions: the Papanicolaou and Kohler asymptotic theorem, the Weidenhammer method and a method based on a stochastic averaging of the response energy curve. These methods are applied to linear and non-linear systems to study response and stability conditions. Many practical applications are added to show the relevance of these techniques. The last section of the chapter considers second order averaging methods. A concise general presentation is followed by an extensively elaborated example which is very instructive.

Chapters 7 and 8 form the centre of gravity of the book dealing with parametric stochastic stability and parametric random response, respectively. The amount of literature on these subjects is enormous and scattered over many engineering fields. For this reason both chapters have an historical review of the literature in the first section, together with their fields of application. In Chapter 7 this review centres round the Lyapunov direct method, almost sure stochastic stability, perturbation techniques and other mathematical methods referring to Lie algebraic methods, stability of higher moments and some very recent developments. In the next section of this chapter the various methods of stochastic stability of an equilibrium position are defined, usually based on a linearized approximation of the system equations of motion. The last two sections deal with the theory of the stability of moments and with almost sure stability of linear systems with a random coefficient. The stability-of-moments method is described in much detail including the application of closure schemes in the case of an infinitely coupled set of moment equations. With respect to the almost sure stability the various theorems of different authors are summarized and compared.

Chapter 8 starts with an introduction and historical review of the various methods of investigating the response of non-linear systems or linear systems involving random time-dependent coefficients. This field is very complicated since there is no general rule as to which method should be applied for a specific case, while further application of the various methods to one and the same problem do not give identical results. Many references are given to enable the reader to investigate the subject in specific directions. A historical review of the problems encountered in determining the random response and stability

* *Parametric Random Vibration*, by R. A. Ibrahim. Published by John Wiley, Chichester (1986), £34.70.

of helicopter rotor blades in atmospheric turbulent flow is also given. In a later section a great variety of models of this problem with all sorts of complications are discussed to demonstrate the various techniques of studying the random response and stability of systems. In the reviewer's opinion this form of presentation, with its constant feedback on the physics of the problem, is well chosen and for engineers, attractive to read. Other subjects discussed in this chapter are linear time-variant systems under random external excitation, which may depend on time only or on both time and space, and the moment equation method for linear systems with random uncertainties in the coefficients. The last section deals with the response of non-linear systems which is, as the author explains, "the most difficult task in the area of parametric random vibration". He certainly knows what he is talking about, as he is the author of a number of recent papers on this subject. The existing techniques (stochastic averaging, Gaussian and non-Gaussian closure) can be applied only to specific forms of non-linear systems. The results of these techniques are compared and evaluated. The response of dynamic systems with autoparametric interaction are discussed with reference to the author's recent results. In this case the Gaussian closure scheme yields a non-stationary response while a Gaussian closure results in a stationary response.

After reading Chapters 7 and 8 one may indeed wonder how reliable the methods are in dealing with the stability and response of non-linear systems and linear parametric systems coupled with linear shaping filters. An experimental verification would be an ideal method of assessing the value of the various methods. Unfortunately, these experiments are very few, mainly due to the difficulties in measuring small random disturbances. For that reason, the validity of closure procedures is usually

examined by verifying whether or not the resulting moments have realistic values.

In the last chapter the author gives a state of the art view of experimental techniques, results and observations centred about the themes: random behaviour of liquid free surface, random behaviour of elastic columns and systems with autoparametric interaction.

Summarizing, the author has written a monograph that is unique in its field. The fundamental theorems on response and stability of systems subjected to random parametric vibration are presented together with numerous non-trivial engineering examples to illustrate its effectiveness. The large number of references enables the reader to explore further. The book is claimed to be self-contained and suitable for beginners. However, as already mentioned above, these beginners should have a reasonable background in probability theory and stochastic processes.

References

Mortensen, R. E. (1969). Mathematical problems of modeling stochastic non-linear dynamic systems. *J. Statist. Phys.* **1**, 271–296.

About the reviewer

BARTELE DE JONG studied applied mathematics at the Delft University of Technology, where he received his engineering and doctoral degree. His thesis was on the parametric stability of ships in random seas. He joined the Department of Applied Mathematics of the Twente University of Technology in 1971. His present research interests are the prediction of water levels in estuaries and coastal seas during storm surge periods and the generation of dunes and ripples in channel flows.

Control of Electrical Drives

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THE CONTROL of electrical drives has usually been included in books on electrical machines, electrical drives, feedback control systems and power electronics in the past. Special aspects of the control of drives turn up in books published in various other fields, such as traction, machine tools, computer peripheries, robots etc. Books devoted to the control of drives have been published mainly in the last 10–15 years, but most of them are not in English.

The field is a composition of various disciplines, i.e. there are quite a number of supporting disciplines. The reader has to be more or less familiar with electrical machines, drives, theory of feedback control, power electronics and, to a certain degree, with analogue and digital electronics, and more recently, with microprocessors. In certain cases, as in robots, the drive is an inseparable part of the system and the control must be designed taking into account the properties of the controlled object. Hence the difficulty of writing a book in this field—what should be included and how thoroughly should it be discussed? This book selects topics successfully and properly proportions them within the frame of limited space.

The book was originally published in German in 1974. The updated English version includes important subjects from the present state of the art.

The topics included in the first ten chapters can be found in other books. The remaining chapters are concerned with a.c.

motor drives. Here very up to date knowledge, compiled mainly from the author's own publications, can be read. By editing the material into book form and by providing certain additions, the book contributes to the enrichment of the relevant technical literature.

The book under review is nicely written. In general, the author has displayed good judgment by avoiding lengthy derivations and proofs. It can be enjoyable reading even for persons experienced in the field. Newcomers will find it, in general, an easily understandable presentation.

From the field of electrical machines only the significant control properties of d.c. and three phase induction machines are briefly discussed in Chapter 5, 6 and 10. The synchronous motors are not treated separately. The results presented in connection with the induction motors are applied to them with slight modifications.

The fundamental problems of electrical drives are included in the first four chapters. Apart from some remarks the theory of feedback, control, analogue and digital electronics, and microprocessors are omitted. Some important aspects of power electronics, namely converters and inverters, are covered in Chapters 8 and 11. The chapters mentioned so far lay the foundation for the main message, namely the various control methods of d.c. (Chapters 7, 9) and a.c. (Chapters 12–14) motors.

The book uses the block diagram technique on a broad scale. By giving quantitative and causal relations among principal variables, it supports the mathematical calculations and offers an insight into the mode of action of the system. However, it should be noted that the particular step response drawn into the blocks is rather unusual in English technical literature.

Digital computer simulation or laboratory test results are presented with almost all the control solutions discussed. This is one of the strong points of the book. On the other hand, it could give some explanation for the lack of interesting control

* *Control of Electrical Drives*, by W. Leonhard. Published by Springer, Berlin (1985), 346pp., DM 128.00.