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Book Review

Dynamic Stability of Structures, Wei-Chau Xie. Cambridge University Press, Cambridge (2006). 435pp., £65, ISBN: 0521852668

Dynamic Stability of Structures deals with the stability of mechanical structures whose behaviour is governed by equations with time-varying or random parameters. Deterministic time-varying coefficients lead to parametric equations whereas the stability of equations involving random coefficients can be studied using stochastic differential calculus such as Ito or Stratonovich's theories. In the deterministic case the study of stability leads to definite stability regions in the parameter space. In the stochastic case, the ultimate objective is to obtain useful probabilistic statements about the stability of the structure from some statistical knowledge of the input parameters. The overall structure of the book follows this fundamental distinction.

Chapter 1 introduces the concepts of stability for conservative, non-conservative and gyroscopic systems. The presentation is clear and follows that found in many books on chaos and dynamical systems published over the last twenty years. These concepts are illustrated by several examples taken from traditional structural mechanics (buckling of beams, vibration of rotating shafts, etc.). The next three chapters (Chapters 2–4) deal with deterministic parametric equations. Chapter 2 treats the general problem of linear differential equations with periodic coefficients. The presentation is neat, thorough and does not require any mathematics beyond the engineering undergraduate level. In this chapter, Mathieu's equation is solved for damped and undamped systems and the stability of the solutions is studied. Chapter 3 presents a number of approximate methods to achieve the same ends. In Chapter 4, some examples of nonlinear parametric systems are treated on a case by case basis.

The second and last part of the book (Chapters 5–9) deals with the dynamic stability of structures under stochastic loadings or coefficients. Chapter 5 is a general introduction to random processes and stochastic differential calculus associated with Brownian or Diffusion processes. Although the presentation is logical and progressive in complexity, it could appear as a rather dense introduction to novice readers, who would probably benefit from a complementary reading of dedicated monographs such as Papoulis and Pillai's [1] or Karlin and Taylor's [2,3]. Chapter 6 is more applied. Using some of the material introduced in Chapter 5, it offers a thorough study of the stability of first and second order linear stochastic systems. Various levels of almost-sure stability conclusions are derived from different kinds of statistical knowledge of the random parameters (ergodicity, knowledge of the probability density etc.). This is followed by a clearly presented application of these concepts to the study of the stability of shallow arches. Chapter 7 is on moment stability of stochastic systems, that is the study of the evolution of the system's averages, standard deviations, etc. Matthieu-Hill's equation is first used as a single degree-of-freedom example. The method is then generalised to coupled linear systems. Chapters 8 and 9 conclude with results on Lyapunov exponents. Lyapunov exponents for deterministic systems are well known. When a system involves stochastic coefficients, the generalised Lyaponov exponents are characteristic numbers that represent the average exponential rate of growth or decay of the system in the long term. Chapter 8 focuses on obtaining almost-sure stability statements using Lyapunov exponents. Chapter 9 introduces the concept of moment Lyapunov exponents. These characterise the exponential rate of growth or decay of moments and can therefore be useful indicators of the moment stability of a system. The book ends with the application of these moment Lyapunov exponents to the study of the stability of a stochastic version of Matthieu-Hill's equation thereby closing the loop with the deterministic case covered in Chapter 2.

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In addition to being very clearly written throughout, the book can boast an impeccable overall visual presentation, with numerous diagrams and charts illustrating graphically the mathematical treatments. It also contains an extensive list of references for those needing more background material or wishing to pursue a particular area further. Maple programs for some of the practical cases treated in the book are also included in an appendix.

Writing a monograph intended for engineers on advanced applications of stochastic modelling is a difficult challenge: the subject is extremely mathematical and one runs the risk of either writing for a very small target audience of experts or one has to include entire chapters of background material. Prof. Wei-Chau Xie—the latest heir of H. Leipholz at Waterloo—has managed to strike a difficult balance between these two extremes. The exposition is rigorous but it never delves unnecessarily into mathematical points. However, the intrinsic difficulty of the second part of the book means that it would be most useful to advanced postgraduates and researchers experienced in this area or willing to invest a serious effort in it. Advanced stochastic modelling has been a hot topic in statistics and mathematical finance for some time. It was first introduced to engineers through electronics [4], then in a less advanced form with the study of random vibration [5]. This book is a useful contribution to widening the dissemination of this important theory to the study of dynamic structural stability.

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