Review

Martin Williams enjoys this unusual introduction to vibration analysis and structural dynamics, but is left uncertain of its intended readership. Some sections may be of use to undergraduates, and others to researchers or developers of structural analysis software.

Vibration Analysis and Structural Dynamics for Civil Engineers: Essentials and Group-Theoretic Formulations

Author: Alphose Zingoni
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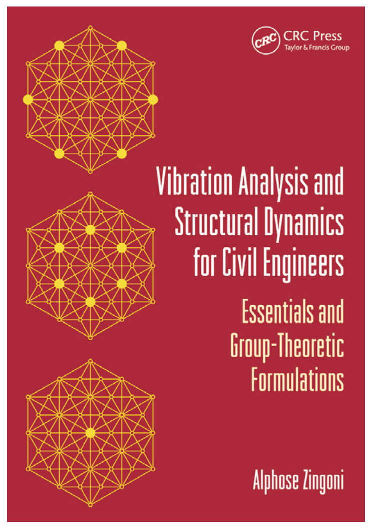

This is really two books in one – Part I covers, at a fairly brisk pace, the essential theory of structural dynamics, while Part II presents a radically different way of setting up and solving dynamics problems for certain types of structure using a mathematical approach known as group theory. Considering each of these in turn...

Part I: Essentials begins by briefly introducing the key components of dynamic systems – mass, stiffness and damping. Subsequent chapters then present the basic linear vibration theory for: single-degree-of-freedom (SDOF) systems (ones that can be modelled in terms of a single time-varying displacement variable); lumped multi-degree-of-freedom (MDOF) systems, in which the many displacement variables necessitate a matrix formulation; and continuous systems such as strings and beams, where the motion varies continuously with position in the structure, requiring the solution of partial differential equations. A fifth chapter then introduces the finite-element approach, in which the use of appropriate shape functions enables continuum structures to be converted to lumped MDOF form for solution.

The presentation here is quite concise and theoretical. It provides the basic mathematical theory in a fairly accessible form, but the reader will need to look elsewhere for advice on, for example, structural idealisation, model reduction and practical applications.

Part II: Group-theoretic formulations reads much more like a research monograph. It describes the solution of a range of linear dynamic systems through the application of group theory, a branch of algebra with which most readers will be unfamiliar. Built from foundations laid by the 19th-century mathematicians, Gauss and Galois, group theory is a powerful method of analysis which is particularly useful for systems involving symmetry.

Zingoni applies this theory to MDOF systems by breaking them down into subsystems based on symmetric and antisymmetric displacement sets. To understand the idea behind the method, consider a symmetrically arranged system of four lumped masses connected by springs. Its four degrees of freedom are the displacements of masses 1, 2, 3 and 4, and any deformed shape of the structure can be expressed simply as a linear combination of those four DOFs. Alternatively, one could imagine a symmetric displaced shape comprising equal displacements of masses 1 and 4, and another for masses 2 and 3. Similarly, an antisymmetric displaced shape can be achieved by taking equal and opposite displacements of masses 1 and 4, or of masses 2 and 3. It is fairly easy to see that any deformed shape can be achieved by appropriate combination of these two symmetric and two antisymmetric shapes. Using this approach (in mathematical language, a change of basis) our 4DOF problem can be reduced to two 2DOF sub-problems which are much easier to solve – and of course the saving in computational effort becomes much more significant as we move towards more realistic problems with many more degrees of freedom.

Having introduced this idea, in later chapters the author then shows how group theory can be used to simplify more complex structural dynamics problems in a rigorous, systematic way. The idea is an interesting one, though its use is limited to symmetric structures – examples in the book include planar grids, cable nets and rectangular plates.

In conclusion, I found this an interesting and somewhat unusual book, but its split nature left me uncertain of the identity of the intended readership. I imagine it will find a home in many university libraries, where different sections of it may be dipped into by undergraduates wanting a concise summary of basic theory, and by researchers and developers of structural analysis software in search of efficient numerical tools.

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Martin Williams is Professor of Structural Engineering in the Department of Engineering Science, University of Oxford, specialising in structural dynamics and earthquake engineering.