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Book Review

Theory of Vortex Sound, M.S. Howe. Cambridge University Press, UK (2002). xiv + 216pp., price £50, US$90, ISBN:052181281 (hardback), price £22.99, US$37.99, ISBN:0521012236X (paperback)

Theory of Vortex Sound is 32nd in a series of monographs published by Cambridge University Press under the category of Cambridge Texts in Applied Mathematics. The book is intended to be an introduction to the theory of sound generated by subsonic (hydrodynamic) flows. The author of this book, Michael S. Howe, is a very highly respected researcher and teacher in several applied mathematics disciplines. He is especially known for his numerous contributions to the mathematical theory of fluid mechanics, acoustics, flow-induced noise, and flow–structure interactions. *Theory of Vortex Sound* is concerned with the flow noise generated by rotational kinetic energy, i.e. vorticity. As such, the subject may be considered a subset of the general theory of hydrodynamic sound. The book is divided into 8 chapters with many subsections in each.

The first chapter introduces the reader to the fundamental equations of fluid motion and linear acoustics. Specific attention is given to the free-space Green's function and the sound produced by monopoles, dipoles, quadrupoles, and impulsive sources. Chapter 2 deals with the basics of flow-induced noise including the Lighthill and Curle theories, with explanations of sound produced by turbulence close to compact and non-compact surfaces. Chapter 3 provides a particularly thorough treatment of the compact Green's function and its application to the solving of acoustic radiation problems. The fourth chapter derives many important relationships and concepts involving vorticity. These include: vorticity and kinetic energy, vorticity and fluid velocity (Biot-Savart Law), bound vorticity, line vortices, added mass, and vortex-induced surface forces. Howe revisits the theory of blowing out a candle, proving that vorticity must be present in the jet in order for the flame to be extinguished. The complex velocity potential is required for proper use of the compact Green's function: it is reviewed in this chapter. Chapter 5 is concerned solely with vortex sound, the major topic of the book. The equation of vortex sound is derived in terms of enthalpy fluctuations. Its solution for free turbulence is compared to the Lighthill solution—which is in terms of the Lighthill quadrupole stress tensor. The author proves then that it is the vorticity fluctuations within the Lighthill stress tensor that produces the sound. Several low-Mach number problems are solved including the sound generated by a spinning vortex pair and the far-field radiation from vortex–surface interactions. For surfaces small compared to the acoustic wavelength, the compact Green's function is applied in developing these solutions. Chapter 6 concentrates on vortex–surface interaction noise in two dimensions. Explicit details are given for a line vortex interacting with a cylindrical body, and for vortex shedding from a half-plane. The developments are extended to three-dimensional problems in Chapters 7 and 8. The noise resulting from the interaction of vortices with airfoils, turbomachinery blades, spoilers on wings, spheres, cylinders, bluff bodies, apertures, and ducts are all treated in detail. The latter problem is related to the pressure wave generated when a train enters a tunnel. All of the chapters end with a set of problems for self-study.

According to the author, this book is designed for a one-semester introductory course at the advanced undergraduate or graduate level. Professor Howe carefully explains the underlying physical processes, fluid mechanics, and acoustics of the numerous examples presented. In each case he develops the mathematical modelling required to reach a solution that can, in most cases, be programmed easily on a computer. In some of these problems, fluid mechanical results from other analysis or computation must be used for input. Because of the extensive use of the compact Green's function in the problems presented, the reader is advised to become familiar with potential flow theory and the use of conformal transformations. A good review of this technique is provided in Chapter 4, Section 5. I find the development of the compact Green's function in

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Chapter 3 to be very well done; actually, in my opinion, better than the presentation in Howe's earlier book: *Acoustics of Fluid– Structure Interactions* (Cambridge University Press, 1998).

Theory of Vortex Sound is not easy reading for those unskilled in mathematics in that the derivations are concise with some steps left to the reader. As pointed out in the Preface, the student using this book must be skilled in vector differential and integral calculus, Cartesian tensors, and analytical functions. The worked out examples in this book are of considerable practical importance to those working in the field of hydrodynamically generated sound. Thus, one can use the solutions directly without necessarily understanding all of the details of the derivation to solve practical problems of engineering interest. The problems at the end of each chapter are challenging, and the author suggests that some of these may be used for group projects. This book meets the objectives set down by the author completely. I recommend it without reservation to those working in the complex field of flow-induced noise.

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