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Book Review

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Waves and Compressible Flow

Hilary Ockendon and John R. Ockendon, Springer-Verlag, New York, 2004, 188 pp., $59.95

This quaint monograph covers topics in a convenient package that would interest specialists who may find the more mathematical rather than physical coverage appealing. The authors' introduction succinctly brings to the readers' attention three "revolutions" that have affected the study of compressible flow and, more generally, wave motion: the computer revolution, the communications revolution, and the environmental revolution.

The authors suggest that fluid mechanics is the best vehicle for anyone working to learn applied mathematical methodology. Moreover, the reviewer would like to suggest that the first revolution has changed the way that we solve fluid mechanics problems. The formal elegance that has dominated much of fluid mechanics from the days of Euler and Laplace to even the latter part of the past century has been rapidly eroded by numerical solutions. Although one may lament the passing of the elegance that gives fluid mechanics a certain beauty in applied mathematics, one should also be impressed by our modern capability to tackle problems of immense complexity. What then is the role of "classical" mechanics? In the reviewer's mind, the major role is to provide the underpinning to the numerical methodology, which, unfortunately, has sometimes skipped serious attention of late. Thus, this monograph is a useful addition to the repertoire of a practitioner's tool kit, serving as a "sanity check."

As for the other two revolutions, there is fertile room for speculation on how they affect mankind and existence on this fragile planet. To these revolutions, one may add many more such as in biological and nanoscale phenomena, which will pose interesting challenges in the development of our understanding of compressible flow and wave motion.

The main contents of the book fit within five chapters, beginning with Chapter 2. For someone who is familiar with the material and just needs a refresher, this book can well be read over a weekend! However, due to the page limit, the topics can be covered only somewhat superficially and a more curious reader may have to delve deeper into the reference list. To make the monograph compact, much material that would be covered in a lengthier text is left as exercises.

The equations of inviscid compressible flow are first introduced in Chapter 2 in integral and differential form. The authors primarily used vector notation for this development and caution that the incompressible limit is nontrivial mathematically but do not enter into the details. In Chapter 3, the authors introduce several types of wave phenomena, based on the assumption of small amplitude disturbances. These phenomena are sound propagation in a gas, surface gravity waves in incompressible flow, inertial waves, waves in rotating incompressible flows, and isotropic electromagnetic and elastic waves. The authors nicely show the common underlying mathematical methodology among these seemingly disparate topics.

Much of the mathematical details for tackling the problems described in the preceding are left to Chapter 4, which is the longest chapter at over 40 pages. The types of linear, second-order partial differential equations are highlighted. Emphasis is placed here on Fourier transforms and the method of stationary phase. Certain sections, which appeal to a more specialized audience, such as wave dispersion and group velocity, can be omitted at first reading. The mathematics is applied to specific topics, within the framework of linear waves. For example, wave scattering in a homogeneous medium is described. The authors clearly point out that diffraction, unlike reflection and refraction, cannot be simply described. The authors follow with a discussion of one-dimensional wave propagation in periodic media. Stationary waves are developed using examples of stationary surface waves in a running stream, compressible flow in a Laval nozzle, and compressible flow past thin wings and slender bodies.

In the next two chapters, the authors shift attention to nonlinear waves, informing the reader of where some of the limitations of linear theory were already encountered, for example, in the transonic regime. Nonlinearity is appropriately introduced, as is usual, with the nonlinear, one-dimensional wave equation

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} = 0$$

The concept of characteristics is reinforced from its introduction in Chapter 4. Examples are drawn from the flow of a compressible perfect gas and shallow surface gravity waves. The authors also devote some attention to the Korteweg–de Vries and the nonlinear Schrödinger equations.

The problem of intersecting characteristics that result in jump discontinuities is taken up in Chapter 6. The physically important Rankine–Hugoniot conditions are well discussed. Indeed, some of the discussion here proceeds along more physical lines, such as in the case of the bow shock past a blunt body. A rich variety of shock phenomena is presented by the authors, for example, the shock tube, oblique shock interactions, the Laval nozzle, and the Chapman–Jouguet detonation. Nonlinear effects due to thermodynamic nonequilibrium in gases and in hypersonic flows are also highlighted.

This monograph makes a laudable attempt to combine a discourse on waves and another on compressible flow. Such a combination can make the book demanding, requiring either some maturity on the part of the reader or else a reader who is resourceful. The text is well written, with the authors clearly having put thought into economy of words. There is also included a reasonably comprehensive list of references to assist the reader in exploring the richness of the topics covered. A minor criticism is that there can be a broader coverage, for example, of hydrodynamic stability and of wave phenomena in plasmas. Nonetheless, in summary, this is a text that the curious reader may find interesting.

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